INVESTIGATING THE EFFECTS OF USING A SCIENCE WRITING HEURISTIC APPROACH IN FIRST YEAR MECHANICAL ENGINEERING LABORATORY REPORT WRITING AT THE NELSON MANDELA METROPOLITAN UNIVERSITY

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By

Kholisa Zizipho Papu

Submitted in fulfilment of the requirements for the degree of Master of Education in the Faculty of Education at the Nelson Mandela Metropolitan University

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Supervisor: Prof P Webb

Co-supervisor: Dr E Scheckle

DECLARATION

I, *Kholisa Zizipho Papu (student number 206005288)*, hereby declare that this *dissertation*, for Students qualification to be awarded is my own work and that it has not previously been submitted for assessment or completion of any postgraduate qualification to another university or for another qualification.

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Kholisa Zizipho Papu

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ABSTRACT

The extent to which writing can be used to promote learning from laboratory activities has received limited attention in engineering contexts in South Africa. In this study the Science Writing Heuristic (SWH) approach and aspects of academic literacies approach were used to develop laboratory report writing among first year mechanical engineering students. The intervention utilised a modified report writing template for engineering practical sessions which focused on argumentation, conceptual understanding, critical thinking and language literacies.

Quantitative and qualitative data were generated via pre-post-analysis of the modified practical report template, Cornell Critical Thinking Test, questionnaires, as well as focus group interviews with students; and individual interviews with staff, on their perceptions of the SWH. The sample (n=56 matched pairs) was divided into three groups through convenience sampling. Group 1 (n=15) utilised an online intervention, Group 2 (n=20) utilised a paper-based intervention and Group 3 (n=21) utilised a standard paper-based laboratory report template.

Statistically significant differences with large effect sizes were obtained between group scores from pre- to post-tests in terms of argumentation and language. No differences between the pre-post-test changes in terms of group conceptual scores (n= 91) were found and there was a drop in scores from pre- to post-test in terms of critical thinking (n= 56). Overall, the data indicates that the SWH approach improved students' argumentation and language literacies with large effect sizes.

Focus group interviews revealed that students believed that the SWH approach made them "think deeper" and that they preferred the intervention (SWH) over the traditional approach. The apparent unawareness of the academics concerned in terms of argument-based inquiry provides a possible answer for their use of assessment strategies focused only on concepts.

Key words: argumentation, critical thinking, engineering, laboratory report, language, learning, Science Writing Heuristic, South Africa

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INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

There is general consensus nationally and internationally that writing laboratory reports in science and engineering is problematic (Whitehead & Murphy, 2014; Harran, 2011; Knott, Lombard, & McGrath, 2011; Wallace, Hand, & Prain, 2007; Hand, Wallace, & Yang, 2004; Walker, 2000). These authors also reveal that problems associated with writing laboratory reports encompass an array of challenges that face the 'student as an author' of specific disciplinary text types (Lea, 1998). These text types or genres of writing form part of written assessment and academic success in science and engineering; and are inextricably linked to the acquisition of literacy practices such as conducting laboratory investigations, doing observations, recording data, calculating, reading disciplinary sources of information, writing and presenting findings in recognisable disciplinary genres such as laboratory reports (Lombard & McGrath, 2014; Whitehead & Murphy, 2014; Harran, 2011; Hodson, 2009; Wallace et al., 2007).

There are four main problems associated with writing laboratory reports in science and engineering. The first challenge seems to be the students' struggle to relate laboratory work to disciplinary concepts (Rudd II, Greenbowe, Hand, & Legg, 2001). The other three challenges include wrestling with content and rhetoric, lack of familiarity with the genre, and limited learning by students from laboratory work (Department of Mechanical Engineering Survey, 2013; Wallace et al., 2007; Greenbowe & Hand, 2005; Rudd II et al., 2001; Keys, Hand, Prain, & Collins, 1999). While most science and engineering students in higher education are affected by these challenges, incoming first year students are even more vulnerable. In spite of such challenges, these students are expected to demonstrate proficiency in the discourses of their discipline. In South Africa, graduate and undergraduate engineering students are expected to show proficiency in the ten Exit Level Outcomes (ELOs) outlined by the Engineering Council of South Africa (ECSA) (2012) and there have been calls to 'scaffold' these expected literacy practices throughout undergraduate level (Harran, 2011; Simpson & van Ryneveld, 2010).

In an attempt to make explicit the ten ELOs in relation to engineering literacy and instruction, Simpson and van Ryneveld (2010) have analysed the documents, processes and policies pertinent to the professional registration process of engineers. As a result, they have identified nine central literacy practices which they sub-divide into three reading, three writing and three critical thinking literacy practices. Firstly, these ‘reading practices’ include i) reading an array of text types, ii) discerning relevant information from irrelevant information, and iii) comprehending, summarising, paraphrasing, synthesising and referencing sources. Secondly, ‘writing practices’ are identified as i) language competence, ii) audience awareness, and iii) awareness of purpose/text-type. Thirdly, ‘critical thinking practices’ consist of i) argument, evaluation and reasoning, ii) reflection and independent thinking, and iii) relational and analytical thinking (application).

While the focus of this study is on writing laboratory reports, the act of writing engineering laboratory reports requires a convergence of the nine central literacy practices. Writing laboratory reports in higher education is therefore, a case of being proficient in multiple literacy practices in order to prepare the engineering student for the complexity of real work situations (Harran, 2011; Simpson & van Ryneveld, 2010). According to Engineering Council UK (2003, p.3) the ability to use “judgement and experience to solve problems” is paramount. Yet, current laboratory instruction in South Africa seems to lack sustained opportunities for the development of hybrid literacy practices that may nurture the development of judgement, argumentation, critical thinking and the articulation of conclusions (Harran, 2011; Simpson & van Ryneveld, 2010; Paul, 1995). As such, this study aims to investigate whether a Science Writing Heuristic (SWH) approach will have any effect on engineering students’ laboratory report writing, especially in relation to the development of argument, critical thinking and language literacies. The second aim is whether the use of the SWH as a laboratory report writing intervention will have any effect on students’ conceptual scores.

1.2 THE APPROACH TAKEN

The approach used in this study included the use of a customised science writing heuristic for students and aspects of an academic literacies approach. The former seeks to promote conceptual understanding and critical thinking by making explicit the notion of argumentation while the latter takes the view of academic writing and communication as 'social practices' (Lillis & Scott, 2008). Elaboration on this matter will follow in section 2.3 of this dissertation.

1.2.1 Science writing heuristics

It has long been established from research that writing promotes learning in science (see Galbriath & Torrance, 1999; Keys et. al., 1999; Klein, 1999; Gianello, 1988; Bereiter & Scadamalia, 1986, 1987; Langer & Applebee, 1987; Flower & Hayes, 1980; Emig, 1977). The particular Science Writing Heuristic (SWH) used in this study aims at utilising the "transformational potential of writing" (Whitehead & Murphy, 2014, p.492), specifically to "enhance learning from laboratory activities through writing to learn" (Wallace & Hand, 2007, p.67) and consists of "activities and metacognitive support that promote reasoning about laboratory data and concepts" (p.67). According to Wallace & Hand (2007, p.67), the purpose of the heuristic is to provide student writers with a "template for thinking, doing, and writing", in a fashion similar to Gowin's Vee heuristic. Gowin's Vee deals with conceptual and theoretical issues and methodical operations that facilitate the making of supported claims from the findings of investigations (Fox, 2007). Essentially, the 'activities and metacognitive scaffolds' of the SWH can be used in talk and in writing to foster 'authentic' meaning making opportunities on the part of the student (Wallace & Hand, 2007, p.67).

Previous research has made use of the SWH in its generic form that is, by concurrently using the student and teacher templates as initially conceived by Wallace and Hand, who were pioneers of this writing project, or as adapted versions to suit specific activities and contexts (Wallace & Hand, 2007; Keys et al., 1999). While the student and teacher templates (see table 1.1) can be used together to support 'hands-on' laboratory work, they can be used mutually exclusively to support "incremental change" with "gradual incorporation" to existing laboratory instruction (Rudd II et al., 2001, p.1680). This study investigates the effect of such a student template which aims to promote incremental change to a standard laboratory report template used at the research site, namely a mechanical engineering laboratory at the Nelson Mandela Metropolitan University (NMMU).

Table 1.1: The generic form of the Science Writing Heuristic approach with a teacher template and a student template (Keys et al., 1999)

A template for teacher-designed activities to promote laboratory understanding	A template for student thinking
1. Exploration of pre-instruction understanding through individual or group concept mapping.	1. Beginning ideas -- What are my questions?
2. Pre-laboratory activities, including informal writing, making observations, brainstorming, and posing questions.	2. Tests -- What did I do?
3. Participation in laboratory activity	3. Observations -- What did I see?
4. Negotiation phase I- writing personal meanings for laboratory activity (For example, writing journals).	4. Claims -- What can I claim?
5. Negotiation phase II- sharing and comparing data interpretations in small groups (For example, making a group chart).	5. Evidence -- How do I know? Why am I making these claims?
6. Negotiation Phase III-comparing science ideas to textbooks or other printed resources (For example, writing group notes in response to focus questions).	6. Reading -- How do my ideas compare with other ideas?
7. Negotiation phase IV-individual reflection and writing (For example, writing a report or textbook explanation).	7. Reflection – How have my ideas changed?
8. Exploration of post instruction understanding through concept mapping.	

1.2.2 Argumentation

The contention is that writing in science classes may be 'most useful' when it reflects the processes undertaken by real scientists in producing new knowledge and when students form a sense of themselves as science writers (Osborne, 2010; Wallace & Hand, 2007; Yore, Hand, Prain, 2002). Both approaches are seen as providing an 'authentic' view of science in which students are afforded an opportunity to engage in disciplinary ways of constructing knowledge. Osborne (2010, p.463) identifies argument and critique as the two practices essential in achieving the main goal of science which is to "produce new knowledge of the natural world". Greenbowe and Hand (2005) posit that science writing genres such as the laboratory report should be shaped as 'pedagogical tools' to assist students in "unpacking scientific meaning and reasoning". The use of argumentation in laboratory investigations and laboratory report writing serves this purpose.

Furthermore, Osborne (2010) maintains that argumentation is the means that scientists use to advance new ideas against the critical and 'rational scepticism' of their peers. Despite these clear aims there appears to be a marked lack of opportunities to develop scientific reasoning and argumentation in contemporary science education. This international neglect of argumentation in science curricula foreshadows the lack of clarity in the processes of constructing and communicating knowledge in science. As a result, Osborne (2004) cited in Hodson (2009) argues that science ends up relying on "authoritative discourse… that leaves students with naïve images of science… and little justification for the knowledge they have acquired" (p.259). Accordingly, the SWH was conceptualized as a "bridge between informal, expressive, writing modes that foster personally constructed science understandings with more formal, public modes that focus on canonical forms of reasoning in science" (Wallace & Hand, 2007, p.67). This means the heuristic scaffolds both students' learning from laboratory work, and the articulation of that learning through an argumentation pattern consisting of evidence-based claims.

Through the recent incorporation of argumentation and critique in school and university science syllabi, students are to be made aware that writing and reporting in science is not simply a restatement of knowledge already known to the writer (Wallace & Hand, 2007). That is, students begin to learn that knowledge is negotiated and renegotiated personally and through social interaction, and that, given the rationalist kind of thought permeating science, it is the duty of the scientist or writer to justify and validate the claims they make through persuasion (Hodson, 2009; Wallace & Hand, 2007; Shakespeare, 2003). Hodson (2009) and Osborne (2010) point out that real science is saturated with claims, counter claims, argument and dispute, and that socialising students in such disciplinary ways of thought may enhance not only 'conceptual understanding' but also 'scientific reasoning' and 'critical thinking'.

1.2.3 Critical thinking

The rationale for engaging students in argumentation extends beyond authenticating science learning and improving students' conceptual understanding. The belief is that argumentation develops students' critical thinking, communicative competency and capacity for careful and systematic reflection (Hodson, 2009). Ennis (1991, p.6) defines critical thinking as "reasonable reflective thinking that is focused on deciding what to believe or do". Moreover, reflective practice underlies the prompts and metacognitive scaffolds found in the student template of the SWH as the simultaneous engagement in reasoning, argumentation; and reflection fosters an awareness of the student's own thought processes and how they come to know (Wallace & Hand, 2007). These authors reason that "because the SWH capitalised on canonical forms of scientific thinking, such as the coordination between claim and evidence, [the heuristic] has potential to build nature of science understandings" (Wallace & Hand, p.69). There is a belief that as students engage in 'creative acts' such as questioning, formulating claims, presenting evidence, analysing, synthesising and evaluating alternatives, they also gain a heightened awareness of disciplinary discourse (Pearson, Moje, & Greenleaf, 2010; Webb, 2010, 2009; Mayaba, 2008; Osborne, 2002; Wellington & Osborne, 2001; Ennis, 1999). The use of critical thinking is often associated with the ability to deal with 'higher order conceptual questions' or the ability to use judgement in decision making or problem solving (ECSA 2012; Wallace & Hand, 2007; Engineering Council UK, 2003; Ennis 1999).

1.2.4 Language/literacy

The role of language in teaching and learning science has not always been recognised by science educators since science was understood to be an empirical subject that can be adequately learned through a hands-on approach (Webb, 2010; Pearson et al. 2010; Hodson, 2009; Osborne, 2002; Wellington & Osborne, 2001; Rowell, 1997). Webb (2010) points out that "this is a necessary, but not sufficient, approach" (p.448). Wellington and Osborne (2001, p.3) attribute the difficulty of learning science to learning the language of science. Hodson (2009) concurs that the distinctive features of scientific language might pose both, as a potential barrier to effective science learning, and a factor controlling access to science.

Therefore, numerous research-based initiatives have been conducted locally and internationally to 'integrate language and science studies' (Webb, 2010) or to 'embed literacy learning in science inquiry' (Pearson et al., 2010) in order to improve the quality of science learning (Wellington & Osborne, 2001).

The quality of science learning cannot be improved through the 'delivery model' of learning, nor through hands-on inquiry alone, but by recognising the centrality of language and by undertaking sustained attempts to make the tacit knowledge of the discipline explicit and by exposing students to authentic disciplinary inquiry (Pearson et al., 2010; Hodson, 2009; Osborne, 2002; Wellington & Osborne, 2001; Rowell, 1997). A similar stance has been noted nationally in developments in engineering education where calls have been made for language and disciplinary experts to 'collaborate' in order to make explicit the knowledge of the discipline to students who are often novices (Harran, 2011; Jacobs, 2007). Constructivist views to science learning often make a case for the importance of both, individual and public meaning-making processes where knowledge is negotiated in multiple stages (Hand, 2007). Thus this understanding of language or literacy as a 'social practice' is central to both the science writing heuristic and the academic literacies' approaches which form the theoretical framing of this study. Conceptualised as a 'social practice', language is linked with what individuals do "both at the level of the 'context of the situation' and at the level of the 'context of culture'" (Lillis & Scott, 2008, 11).

1.3 STATEMENT OF THE RESEARCH PROBLEM

Although incoming first year engineering students have to meet the minimum entry requirements for engineering studies, the majority are still underprepared for the literacy demands in higher education and disciplinary literacy practices such as writing laboratory reports. The problem is pointed out by science education researchers in that 'learning science is essentially, learning a language' and clear calls have been made to focus on the language and literacy aspects of scientific literacy (Pearson et al., 2010; Webb, 2010, 2009; Mayaba, 2008; Yore & Treagust, 2006; Norris & Phillips, 2003; Osborne, 2002; Wellington & Osborne, 2001). In South Africa, the focus on the 'literacy' aspects of Scientific Literacy is also motivated by what Webb (2007, p.2) refers to as the "three-language problem" (and "four-language problem" when students learn in a second language), or what Liebowitz (2000, p.20) refers to as "triple disadvantages".

In essence, these authors refer to three significant factors that constrain science learning in developing countries, namely; a history of a poor schooling system, learning science in a language that is not the student's home language and the burden of learning disciplinary ways of doing, thinking, believing, and talking. Various newspapers have lamented the poor state of South African education and the need for Higher Education to bridge education gaps has been well documented. Professor Theuns Eloff, Higher Education South Africa Chairman, bemoaned the fact that most of South Africa's first year university students could not 'read, write or comprehend – nor could they spell' (*Business Day*, 13 August 2009). The fact that students often struggle with these aspects, that is, the development in the fundamental sense of scientific literacy, means that there is little chance that they will develop scientific literacy in its derived sense, i.e. how science interacts with the physical, social, cultural, and economic world (Norris & Phillips, 2003; Hand, Prain, & Yore, 2001). It is against this backdrop, and recent NMMU first year mechanical engineering survey results (semester 1 of 2013) revealing unfamiliarity with the genre of laboratory reports, that the use of a modified science writing heuristic was used as an intervention in this study. The purpose of this intervention was to determine the cognitive and linguistic literacy practices that are revealed in first-year mechanical engineering students' laboratory reports, before and after their academic socialization using a science writing heuristic.

1.4 RESEARCH QUESTIONS

The main question that will be investigated in this study is:

What cognitive and linguistic literacy practices are revealed in first-year mechanical engineering students' laboratory reports before and after academic socialization using a science writing heuristic?

To address the main research question, the following research sub-questions need to be answered:

(i) What are the literacy practices that first year mechanical engineering students bring with them at entry level?

(ii) Are there any changes to the literacy practices of this cohort after being socialised into laboratory report writing?

(iii) Are there any measurable differences between first year mechanical engineering students' conceptual, argumentation, critical thinking and language abilities before and after using the science writing heuristic?

(iv) To what extent do students' writing and interview data match a priori themes developed from the literature?

(v) What are the lecturers' expectations and perceptions of both the conventional template and the modified templates (using the science writing heuristic)?

1.5 RESEARCH DESIGN AND METHODOLOGY

In the following section the research design is described, as are the methodological aspects of sampling, data generation and analysis, and related ethical issues.

1.5.1 Research Design

A quasi-experimental, mixed-methods research design with pre- and post-tests was utilized to determine the effects of a science writing heuristic approach in first year mechanical engineering laboratory report writing. Three groups of first-year engineering students, who had been allocated to the groups alphabetically as per tradition in the Mechanical Engineering Department at the NMMU, formed the sample. Two groups were designated as experimental groups while the largest of the three groups was used as a comparison group.

The two experimental groups were socialised into the science writing heuristic intervention by the researcher. One group completed laboratory report writing and peer evaluation online with the aid of a tailor-made marking rubric for argumentation and language use while the other group used a paper-based approach. The lecturer's marking rubric was used to determine content/conceptual understanding for both the experimental and comparison groups. While the students in both experimental groups worked in pairs in the laboratory, they wrote their laboratory reports individually. Thereafter they were expected to share their work with a partner for peer review. Review partners were allocated alphabetically and were different to the partners with whom they worked in the laboratory. This review partner allocation was done to encourage criticism and defence of the peer's work from an 'outside' perspective. In the comparison group, students wrote their reports individually (even though they also generated data in the laboratory with partners) on the standard report template as is conventionally done for mechanical engineering laboratory reports at the

NMMU and no online writing platform or peer review process for laboratory report writing was provided or used by this group.

1.5.2 Methodology

The methodological aspects below include a description of the sample and setting; the data generation instruments and data collection processes; how the data were analysed; the referencing system used in this dissertation, and ethical issues pertaining to the study.

1.5.2.1 Sample and Setting

The study was conducted with first year mechanical engineering students registered for the module 'Mechanics and Machines (MEC 1111)' offered at Level 1 in the first semester of 2014 in the Department of Mechanical Engineering at the NMMU. A few students who had registered prior to 2014 and who were repeating the module were also included. The participants were both female and male from diverse racial, socio-educational backgrounds and age-groups. The majority were male and second language speakers of English, usually mother tongue speakers of isiXhosa and Afrikaans. The type of sampling that was used was convenience sampling since participants were students already enrolled for MEC 1111. Participants were divided alphabetically as a standing practice in the Department of Mechanical Engineering at the NMMU. From these two groups, two experimental groups with approximately 20 students in each and one comparison group of approximately 60 students, were chosen simply on the basis that the first group on the timetable would take part in the online intervention process. The second group would constitute the paper-based intervention groups while the third and largest group would act as a comparison group.

1.5.2.2 Data generating tools

Data generation occurred at two levels, namely at student and staff/lecturer member levels. Student data generating tools that were used in this study were the Cornell Conditional Reasoning Test, Form X (1964) (for critical thinking), questionnaires, semi-structured focus group interviews, student laboratory reports using modified templates for the experimental groups, and tailor-made assessment rubrics. Individual semi-structured interviews were used to generate data with the two lecturers and laboratory technician participating in the study. Sometimes, email correspondence was used to initiate feedback on modified templates and rubrics between engineering staff and the SWH tutor who was also the researcher. Students' laboratory reports were marked by a marking assistant who was a PhD candidate in mechanical engineering.

Questionnaires and semi-structured interviews were used to generate preliminary data about the students' previous laboratory and laboratory report writing experiences, and to evaluate the effects of the traditional laboratory report and the intervention from the students' perspective. The Cornell Conditional Reasoning Test, Form X (1964), was used to determine their critical thinking abilities before any laboratory work or laboratory reports were written again and after the intervention. All of the students wrote their first laboratory report using the conventional laboratory report template used in the Mechanical Engineering department at the NMMU while experimental groups used modified writing templates based on Keys et al.'s (1999) Science Writing Heuristic (SWH) approach and aspects of Toulmin's (1958/2003) argumentation framework for their remaining two semester 1 laboratory reports. A corresponding assessment rubric was designed to test for students' argumentation and language literacy while the existing module rubric for laboratory report, which was developed by the lecturer, was used to determine conceptual understanding. The modified templates were validated and modified via semi-structured interviews and email correspondence with engineering lecturers and changes were made based on their perceptions of the modified template and assessment rubric. The modified templates were used by two experimental groups while a comparison group continued to use the unmodified laboratory report writing templates. Tailor-made assessment rubrics for argumentation and language were developed for laboratory report marking.

1.5.2.3 Data generating process

The Cornell Conditional Reasoning Test, Form X (1969) was administered according to the Cornell Critical Thinking Test Manual. Instructions on how to complete the test were followed including the six sample questions that were done in class before participants attempted to respond to the test questions individually. There were no formal interviews done to find out about students' perceptions of the Cornell Conditional Reasoning Test, Form X, but the researcher had an informal discussion with some of the students as they handed in their scripts after writing the test.

The questionnaires and semi-structured interviews that were used to generate preliminary data about the students' previous laboratory and laboratory report writing experiences were administered prior to the intervention. Students completed three laboratory experiments and thee laboratory reports during the first semester of 2014. They submitted hard copies of their laboratory reports to the lecturers for a conceptual score grading while they emailed electronic versions of the same laboratory report to the SWH tutor. The SWH tutor analysed the laboratory reports further using the custom designed writing practices and argumentation rubrics, without seeing the lecturer's grading for conceptual scores in order to avoid being influenced by the lecturers' conceptual score.

Semi-structured focus group interviews with both experimental and comparison groups were held post the intervention in order to ascertain participants' attitudes towards the expected 'social practices' in their respective groups. The participants were socialised differently into laboratory report writing depending on whether they were part of the experimental or comparison groups. One experimental group (Group 1) used an online intervention that incorporated an online peer review process on *Moodle* before the final submission was done. The next group (Group 2) used a paper-based intervention on a basic Microsoft Word document – as it is traditionally done in the Mechanical Engineering Department at the NMMU. The peer review process for this group was also paper-based. The peer review process for both groups was done using a tailor-made argumentation and language rubric. The comparison group (Group 3) used the conventional laboratory report template that is paper-based and a basic Microsoft Word document. This group was not required to perform a peer review process as was the norm in the Mechanical Engineering Department at the NMMU.

Individual semi-structured interviews and consultations with the two lectures and the tutor responsible for the laboratory exercises were carried out regularly before each laboratory investigation in order to validate the modified laboratory report templates and marking rubrics that were to be used, and to inform the questions used in the student semi-structured interviews. A final individual interview with these academic staff members and the practical session tutors was also carried out. During these interviews the academics and tutors were asked to reflect on their perceptions of the effect of the intervention in terms of its implementation, its effect on student performance and student attitudes, and its potential as a pedagogical tool. The data generated from these interviews are examined and interrogated in chapters four and five.

1.5.2.4 Data analysis

Qualitative and quantitative analyses of laboratory reports, critical thinking tests, questionnaires and interviews were carried out. Thematic analysis was used to analyse the qualitative data. Descriptive and inferential statistics were generated from the quantitative data. Inferential statistical techniques included the use Analysis of Variance (ANOVA) and Analysis of Co-variance (ANCOVA).

1.5.2.5 Referencing style

In this study report the referencing style that is used is the American Psychology Association, Sixth (APA 6^{th}) edition (APA, 2010), with the exception that *etc.* rather than *et cetera* is used and the main headings are in upper case bold, as is the tradition at the NMMU.

1.5.2.6 Ethical issues

This research study formed part of a larger research project on developing writing skills in the Faculty of Engineering at the Nelson Mandela Metropolitan University. Informed consent from the participants was requested and obtained. The purpose of the research project was made clear, as was the fact that participation was voluntary. Both students and the staff/lecturers participating were assured of confidentiality and that all data generated would be used for the purposes of the research study only. Participants were also informed that they could withdraw from the study at any time.

1.6 RELEVANCE OF THE STUDY

Primarily, this study aims at providing first year mechanical engineering students with the opportunity to engage in disciplinary ways of doing, thinking, believing and writing that are different to conventional laboratory report writing. The use of the metacognitive scaffolds that prompt students to draw connections among claims, evidence and warrants, provides an opportunity for students to relate theoretical concepts to laboratory practices through the use of written argumentation. Osborne (2010, p. 463) maintains that “argumentation is the means that scientists use to make case for their new ideas” and the use of an argument-based laboratory report template such as the SWH template, introduces students to disciplinary ways of constructing knowledge. As these literacy practices, namely demonstrating conceptual understanding, critical thinking, argumentation and communicative competency, form part of the ECSA Exit Level Outcomes (for which there have been calls to scaffold from first year through to graduate level), they are clearly important issues in engineering at higher education level. As such, this study aimed at investigating the effects of a SWH approach in scaffolding such literacy practices at a first year university level in engineering report writing.

Although a SWH approach has been used to "promote learning from laboratory" (Wallace & Hand, 2007, p.67), previous research that has been carried out in the United States of America, United Kingdom, Korea and Australia has focused on science subjects such as biology, chemistry and physics; with limited research having been done in either an African context or in engineering. Thus, this study aims to contribute to the body of knowledge on writing in the disciplines and how students from developing countries, such as South Africa, make use of a science writing intervention that has been successful in more developed nations.

1.7 OUTLINE OF THE STUDY

This research study report consists of five chapters. Chapter one provides an introduction and a concise background and overview of the context and research problems. The primary and secondary research problems are presented before the research design and methodology is outlined. The data generating tools used, the data generation process and the data analysis are presented, as are the ethical considerations, the relevance of the study, and a brief outline of the chapters presented in the manuscript.

Chapter two discusses the theoretical framework of the study. Specifically, chapter two reviews current debates on writing in the disciplines, the use of different approaches to writing and how science writing heuristics differs from those approaches. Chapter three foregrounds the philosophical orientations of the study in terms of the nature of knowledge and elaborates on the research design and methodologies used. Attention is given to the use of mixed-methods research as this approach captures the essence of this research project.

Chapter four reports on the findings of the investigation with quantitative and qualitative data used to illustrate the effects the writing intervention. In chapter five the results presented in chapter four are discussed in relation to the data generated in the study and the literature provided in chapter two. This chapter also demonstrates how the research questions posed have been answered; conclusions are drawn based on the main findings of the study; and recommendations for future research are based on the findings, the data generated and the literature reviewed.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The purpose of this chapter is to provide a review of research on writing in science and engineering. The key theoretical framework informing this study is the Science Writing Heuristic approach which has its roots in interactive-constructivism (Wallace, Hand, & Prain, 2007; Keys, Hand, Prain, & Collins, 1999), as well as aspects of Academic Literacies approach which focuses on the nature of student writing in higher education and views literacy as a social practice (Lillis & Scott, 2007; Lea, 1998; Lea & Street, 1998). The chapter begins by reviewing the problem of writing in both disciplines in general, before focusing on the specific problem of writing the laboratory report as a disciplinary sub-genre. Owing to the epistemic and ontological locus of writing in such disciplines, issues of the nature of science understandings, language of science, nature of science learning and teaching (Driver, Leach, Millar, Scott, 1996) as well as ‘discourses on writing pedagogy’ (Ivanic, 2004), will be explored in light of laboratory report writing in a first year mechanical engineering course at Nelson Mandela Metropolitan University.

This chapter is divided into four sections, the first section reviews literature on the general problem of writing in science focusing on school and university science writing, as well as writing in the professional science community. The second section reviews literature on the general problem of writing in higher education and in engineering. The third section identifies the specific problem with writing reports both in science and engineering. Reference to the Science Writing Heuristic will be made in the literature review in terms of the key theoretical constructs introduced in the preceding chapter, namely, argumentation, conceptual understanding, critical thinking and language literacy.

2.2 WRITING IN SCIENCE

It is now accepted that writing promotes learning in science (Wallace et al., 2007). However, this has not always been the case in the field of science education, especially, at school level, where the foundation of learning science is built.

2.2.1 Interest in writing in science

Writing and its potential to influence teaching and learning has not always been realised in the field of science education. Instead, in the 1980s, writing was seen as ‘interfering’ with ‘genuine’ science learning (Nesbit, 2008). At the time, there was a strong advocacy for ‘hands-on’ strategies when teaching science and writing was used mainly for note-taking, assessment and evaluation (Nesbit, 2008; Yore, Bisanz, & Hand, 2003; Rowell, 1997). The belief that science can only be learned through the manipulation of objects in the science laboratory permeated science pedagogy, (Greenbowe & Hand, 2005; Yore et al., 2003; Osborne, 2002; Rudd II et al., 2001; Rowell, 1997) until students’ academic performance suggested that the hands-on approach did not contribute much to learning (Rudd II et al., 2001). While Osborne (2002) agrees that “one of the major engagements with science is practical work” and that there may be “good educational and epistemic reasons” for engaging students in empirical enquiry, Osborne also highlights the limits of the laboratory (p.205), arguing that “science is more than empirical work in the laboratory” (p.205).

The renewed interest on the use of writing in science was brought about by the ‘writing across the curriculum’ and ‘writing to learn’ movements which are well recognised internationally and locally (Webb, 2009; Hand, 2007; Yore et. al., 2003). The writing to learn movement recognised the potential contribution writing has on learning (Rowell, 1997). Rowell contested that when writing is “advocated for learning in disciplines such as science, further assumptions and goals envelope the writing activity” (1997, p.20). It may be argued that Rowell’s contestation was fuelled by the role writing was expected to play in scientific domain subjects. Significantly, one of those roles was whether writing could be used to promote thinking about laboratory work. As such, the ‘writing to learn science’ movement integrated writing with hands-on inquiry with the idea that writing can be used as a process for constructing and transforming science understandings (Nesbit, 2008; Yore et al., 2003). The process approach to writing was developed as a corresponding writing approach that was concerned about students learning from writing, as opposed to previous product-oriented writing approaches.

Based on the process approach, numerous models developed on writing as a potential resource for learning, often focusing on the cognitive process of writing. Hand (2007) presents an historical development of the current models of writing as a learning tool from the late 1970s to late 1990s. From this analysis, writing has been conceptualised as a ‘mode of learning' (Emig, 1977); as a 'problem solving activity' (Flower & Hayes, 1980); as 'shaping learning' (Langer & Applebee, 1987); as 'a learning tool' as well as a 'knowledge telling and knowledge transforming model' (Bereiter & Scardamalia, 1987); as 'text production' (Galbraith & Torrance, 1999) and as a 'knowledge constituting process' (Galbraith, 1999). The conceptualisation of writing as a resource for learning increased in complexity with each conceptualisation. A common thread of these cognitive models of writing seems to be the centrality of 'content knowledge' and 'rhetorical knowledge'. While the former refers to subject-matter knowledge, the latter refers to issues of genre and textual forms (Grimberg & Hand, 2009). Another common thread seems to be "the interaction between an individual's prior content knowledge […] and their discourse knowledge" (Hand, 2007, p.31).

These cognitive theories of writing were applauded for two aspects. The first was an attempt to unearth the mental processes involved in composing texts and also, for spearheading the move from a product-centred approach to a process centred writing approach. However, social psychologists and socio-linguists influenced by the work of Lev Vygotsky and Mikhail Bakhtin (Rowell, 1997) criticised 'cognitively oriented research on writing' based on the grounds that this kind of research neglected the role of language and other external factors, such as the social environment, that might influence the act of composing (Rowell, 1997; Best, 1995).

The rise of constructivist approaches to learning emphasised the importance of considering the role of language and the social environment as far as learning was concerned (Rowell, 1997; Driver et al., 1994). Subsequently, a socio-cultural dimension to learning and writing in science was and is still seen as beneficial in tapping into students' epistemologies. However, this is not meant to compromise scientific knowledge but to enrich and authenticate the scientific experience (Yore et al., 2002; Driver et al., 1996; Driver et al., 1994). According to Yore et al. (2002) this current view of considering the social nature of writing moves beyond the individual writer to the interaction between the writer and the reader. Writing is conceptualised as a communal and a collaborative effort between the writer and members of a particular discourse community and for this characteristic, writing is referred to as a 'social practice' (Ivanic, 2004).

2.3 THE GENERAL PROBLEM OF WRITING IN SCIENCE

From a review of related literature it can be said that the over-all challenge with writing in science is inextricably linked to teachers' understandings of the nature of scientific knowledge or nature of science, the nature of science learning and beliefs about the role of language and writing in the practices of science (Prain, 2006; Rowell, 1997; Driver et al., 1996).

2.3.1 Nature of science understandings

There is a contention that "any account of teaching and learning science needs to consider the nature of the knowledge being taught" (Driver et al., 1996, p.5). The reasons are that the knowledge and practices of Science are committed to particular knowledge claims which ought to be translated in science writing practices (Driver et al., 1996, p.5). In support of this view, writing in science is seen as being influenced by teachers' understandings of the nature of scientific knowledge (Yore et al., 2002; Driver et al., 1996). Scwartz, Lederman and Crawford (2004, p.611) refer to nature of science (NOS) as "the values and underlying assumptions that are intrinsic to scientific knowledge, including the influences and limitations that result from science as a human endeavour". Furthermore, the term 'scientific knowledge' denotes "knowledge about the natural world" and this knowledge differs from knowing about science (Driver et al., 1996, p.3). These understandings of NOS affect the content, genre and even the target audience of scientific writings. One understanding streams from the belief that there is more than one understanding of NOS (Millar, Driver, Leach & Scott, 1993 cited in Driver et al., 1996). From a review of related literature, this thesis has identified three prominent perspectives on NOS and one fairly recent understanding. The first three are an empiricist, social and relativist perspective while the forth is an evaluativist understanding.

The empiricist understanding is grounded on the conception of science as being purely empiricist, relying on observations and hands-on inquiry. According to Yore et al. (2002), the nature of scientific knowledge is based on empirical standards of truth, logical arguments, objectivity and reputable method. However, this perspective is criticized for presenting a rigid, monolithic view of scientific knowledge (Osborne, 2004 cited in Hodson, 2009). Cultural relativists criticize this perspective for seeing science as adhering to 'durable standards of truth' as opposed to embracing a more pluralistic view of science (Hodson, 2009; Rowell, 1997; Driver, 1994). Further contestation against this perspective is presented by Rogers (2007), Osborne (2002) and Rudd II et al. (2001).

Rogers (2007) points to the inadequacy of the hands-on approach and asserts that "lessons that were 'hands-on' focused were not necessarily 'minds on' activities and were found to have resulted in learners' limited understandings of science concepts" (p.119). Osborne (2002) presents a case against the limits of the laboratory by arguing that while empirical work might have important scientific learnings, using it as the only approach to teach science embodies narrow conceptions of the nature of scientific knowledge. Rudd II et al. (2001) call for a less emphasis on science activities that seek to "demonstrate and verify" science (2001, p.1680). All three authors agree that science is not adequately learned from a purely empiricist, hands-on conception of NOS.

Secondly, the understanding the nature of science as having a 'social' dimension extends beyond the empiricist view of NOS. The social understanding of NOS acknowledges the 'social enterprise' of scientific writing and advocates for the teaching of writing activities that are authentic to professional and real world science writing (Driver et al., 1996). Writing laboratory reports is authentic to professional science writing and writing laboratory reports to learn science is one way of introducing students to scientific ways of knowing. Furthermore, writing in science is seen as recursive, collaborative and extending beyond members of discourse communities. This perspective encourages 'border crossings' and the use of diversified writing practices (Prain, 2006). It can be argued that students who are exposed to collaborative and diversified writing practices will be more inclined to understand audience differences, text purpose, and different genres of writing (Prain, 2006). Being exposed to rewriting the same content in different writing formats consolidates learning and helps improve students' ways of articulating their ideas and what was learnt (Prain, 2006).

The relativist understanding is rather pessimistic and questions the very foundations of scientific inquiry. For instance, this understanding asserts that the notion of scientific progress is problematic because "there is no way of knowing whether such knowledge is a true reflection of the world" (Driver et al., 1994, p.6). At the same time, this understanding of nature of scientific knowledge is criticized by Driver et al. (1994) as presenting an "apparent irrationalism" (p.6). Instead, Harre's (1986) realist ontology to science is preferred. Harre (1986) cited in Driver et al. (1994, p.6) rebuts by suggesting that "scientific knowledge is constrained by how the world is and that scientific progress has an empirical basis, even though it is socially constructed and validated". Therefore, a relativist understanding of NOS can be seen as incompatible and foreign to what is fundamentally scientific.

The evaluativist understanding posits that over and above empiricism, “science is generally tentative, procedural and declarative” (Yore et al., 2002, p.677). Owing to the tentative and declarative nature of science, these authors also acknowledge that there may be multiple interpretations of a data set. Leading researchers in the field of science education agree that in the scientific practice, competing interpretations of data are often subject to public scrutiny using the available evidence and that current ideas, are checked against canonical science knowledge (Osborne, 2010; Hodson, 2009; Yore et al., 2002; Kuhn, 1993). These authors also agree that scientific knowledge is constructed through patterns of argumentation that “attempt to establish clear connections among claims, warrants, and evidence” (Yore et al., 2002, p.677). This perspective uses argumentation to persuade others about the validity of their/such claims and this is seen as an authentic scientific practice that has been absent from school science and science education research until fairly recently. The Science Writing Heuristic as an argument-based writing scaffold, is based on the evaluativist view of science, where meaning is negotiated and renegotiated in multiple stages with peers and against canonical knowledge thought (Hand, 2007).

2.3.2 Nature of science learning

Driver et al. (1996) believe that a consideration of how science might be learned influences students’ writing about and in science. How science is learned is affected by how science is taught and the teaching of science depends on teachers’ understandings of NOS, as discussed in section 3.1. Since this thesis focuses on student writing, focus will be on learning rather than teaching even though the two are interlinked. Based on the review of related literature, this thesis argues that the learning of science, and later, the learning of how to write in science depends on whether teachers predominantly adopt an empiricist, social, relativist or an evaluative perspective to science teaching, as elaborated in section 3.1.

Corresponding to an empiricist understanding of NOS, science can be learned individually through discovery-type of activities where writing plays a functionalist role and is undervalued. Hodson (2009, p.269) employs Bloome, Puro & Theodoru (1989) notion of “procedural display” to argue that hands-on work alone does not engage students intellectually. This claim corroborates Rogers’s (2007) report that hands-on work alone does not necessitate learning, as highlighted earlier. The negative effect of focusing on empiricism only is that some students may develop “passive resistance techniques” such as “silence, accommodation, ingratiation, evasiveness, and manipulation” (Atwater, 1996, p.823 in

Hodson, 2009, p.269). Such passive resistance techniques can be attributes to the limited learning by students from laboratory activities.

Science can also be learned through constructivist theories of learning such as the cognitive, social and inter-active constructivist theories of learning. Cognitive constructivism uses what Piaget calls 'mental schemata' that is, the use of previous knowledge as a foundation for new knowledge, to scaffold students' learning of scientific concepts. As alluded to in section 2.1 cognitive constructivism was criticised for being individualistic and for neglecting the social environment in which learning occurs.

Social constructivism corresponds with the social understanding of NOS. Learning is identified by social constructivists as collaborative and it considers the social environment in which learning occurs. Social constructivism talks of the need to introduce learners to their social environments of learning and induct them in their cultural ways of doing, thinking and understanding (Hand, 2007). In turn, the novice is seen as appropriating the cultural tools through their involvement in the activities of this culture. Meaning-making is a dialogic practice involving people in conversation and learning is seen as a process by which individuals are cultured by more skilled members. Process of knowledge construction must go beyond personal empirical enquiry (Driver et al., 1994).

The cultural relativist perspective may be important for highlighting that there may be competing views but it may be dangerous for students who still need to learn the fundamentals of their disciplines such as canonical knowledge and how to engage in scientific thinking and doing. Norris and Phillips (2003) as well as Hand, Prain, and Yore (2001) argue that students need to be proficient in the fundamental sense of science before they can engage meaningfully in the derived sense of science. The *fundamental sense* of science refers to the 'big ideas' of science (canonical knowledge), science language, thinking and the emotional dispositions that set science apart from other disciplines. The *derived sense* of science refers to the relevance and the ways in which science interacts with society, technology, the environment, ethics and so forth. Both the fundamental and derived senses of science are used as measures for scientific literacy (Webb, 2007; Norris & Phillips, 2003; Hand et al., 2001).

Lastly, science can also be learned through interactive-constructivism. Inter-active constructivism corresponds with the evaluativist understanding of NOS and it incorporates elements of both radical/cognitive constructivism and social constructivism. Knowledge is perceived to be constructed both individually and socially (Driver, 1990 in Hand, 2007) such that there is both, a private and public form of knowledge (Hand, 2007). Learning is described as involving "negotiating meaning of the knowledge both within the public forum and within the individual's own conceptual framework" (Hand, 2007, p.22). The interactive-constructivist view of learning encourages border crossings and the use of diversified writing tasks that involve the translation of disciplinary knowledge into simpler forms by the student. Persuasion, and argumentation are employed in various genres of writing such as essays, laboratory reports, letters to the editor or even tourist guidebooks (Prain, 2006; Prain & Hand, 2002; Hodson, 1998). Thus, both the empirical and social aspects of science as well as the fundamental and the derived senses of science converge in students' written work. The science writing heuristic is based on inter-active constructivism and uses this kind of knowledge structure to cultivate disciplinary ways of knowing and doing.

2.3.3 The Language of science

As discussed above, the problem with writing in science is inextricably linked to teachers' beliefs about the nature of science and how science is to be taught and learned. The third aspect that influences writing in science is the language of science itself.

2.3.3.1 Characteristics of the language of science

A number of science education researchers agree that the nature of scientific language is complex and may pose as a barrier to effective science learning if left unaddressed (Hodson, 2009; Webb, 2007; Gee, 2005; Lemke, 1998; Driver et al, 1994). Gee (2005) believes that no learning area represents academic language better than science because it requires students to use language orally and in print, making use of such symbolical representations as diagrams, equations, analogies, chemical formulae, and computer generated images. These kinds of representation influence the presentation of scientific knowledge at the level of form (genre). It is standard practice in science to convey ideas using two or more symbolical representations and as such, the language of science is referred to as "multi-modal communication" (Lemke, 1998).

This multi-modality of scientific communication gives birth to what is referred to as the "*languages* of science" (Hodson, 2009, p.249). That means, the language of science is conceived to be a hybrid representation of ideas or findings in more than one 'language', or in more than one semiotic representation. This poses as a threat to science learning since students cannot easily navigate such multi-modalities without aid. Hodson (2009) refers to research by Peacock and Weedon (2002) and other authors which reveal that the visual elements of scientific texts are a major source of comprehension difficulty for students and even more so, for lower achieving students. Another factor that causes difficulty when learning science is an early insistence of representing observational data in symbolic form, such as chemical equations or algebraic equations (Hodson, 2009). Instead, Hand et al., (2009) point out that, to avoid confusion, students need to understand the link between mathematical and textual representation of knowledge before proceeding to graphical representation (Hand et al., 2009 cited in Hodson, 2009).

The hybridity of scientific texts adds to an already abstract kind of language. While Hodson (2009) gives a detailed account of scientific lexicography and how it may pose as a barrier to novice students, this study makes reference to some of the characteristics of scientific words. First of all, the language of science is expressed in specialised terms that often do not resemble the colloquial terms used in everyday speech (Hodson, 2009; Webb, 2007; Wellington & Osborne, 2001). These specialised words are "purpose-built for specific contexts often using Latin and Greek roots" (Hodson, 2009, p.244). Secondly, the language of science also uses 'common' words that are used in specialised and restricted ways such as the physical science and chemistry terms, "element", "conductor" and "compound" (Hodson, 2009, p245). For effective science learning, students need to know how and why the specialised terms differ from an everyday kind of language.

Thirdly, logical connectives form yet another group of words that are difficult to understand or to use appropriately in science writing. Logical connectives are perceived to be "modes of [scientific] thinking" (Hodson, 2009, p.245) and they include words such as "conversely, essentially, in practice, moreover, respective, hence", to mention but a few. These words, as Wellington and Osborne (2001) point out, are used in comparing and contrasting, formulating hypotheses, making inferences and attributing cause and effect. In writing and in speech, students need to know how to present ideas coherently and how logical connectives can be used to support and advance particular arguments. Logical connectives such as 'because', 'but', 'if', are seen as indicating reasoning on the part of the student (Webb, 2007), and the ability to reason and discriminate among ideas is a crucial scientific literacy practice that needs nurturing.

Fourthly, scientific language has a higher informational density than everyday language. Fang (2005) explains this phenomenon by saying that science has more needed content words per sentence than everyday language, which often contains non-content words. The implication is that students need to be fluent in the language of their discipline, that is, know which scientific words can be used to describe or to refer to phenomena. Students also need to know the conditions for which certain statements are true.

The fifth characteristic of scientific language is that it is filled with theoretical assumptions and that the knowledge reaches higher levels of abstraction as students progress to the next level. These levels of abstraction are achieved through nominalization, that is, the tendency to replace active verbs and adjectives with nouns. For example, active verbs such as "evaporate" become "evaporation"; "diverge" becomes "divergence"; "emits energy" becomes "energy emission" (Hodson, 2009, p.247). According to Veel (1997) cited in Hodson (2009), "[n]ominalization creates new terms and new concepts to systematise knowledge, synthesize seemingly disparate ideas and impute cause and effect relationships" (p.247). Lastly, the nature of scientific reporting as well, is noted for making little or no reference to authors through the use of past tense, passive voice. These characteristics of scientific language do not only problematize learning science but also, they restrict access to the scientific discourse at large. Lemke (1990) emphasizes, contrary to teachers' popular belief, that students cannot simply learn the nuances and subtleties of the scientific discourse without help.

2.3.3.2 Border crossings

In order to access the language of science, traverse the differences between scientific language and every day, colloquial language, students need to engage effectively in what Yore & Treagust (2006) call 'border crossing'. Owing to the multi-modal nature of scientific language and scientific writing, it is appropriate to talk of 'border crossings'. To understand any scientific concept and to make meaning of any scientific encounter, students have to be aware of the differences between their home language which is often filled with colloquialism and non-content words, as alluded to earlier. Thereafter, students have to switch between an often informal home language, to a formal language of instruction and later, to subject-specific language. Webb (2007) observes that there is a general acceptance of the fact that the words used in domestic social conversations may have a negative effect on understanding the language of science and later, on achieving scientific literacy. For this reason, Webb (2007) points out that this "enculturation into the language of science is best facilitated by someone who understands this language and thinks like a scientist" (p.2).

Mayaba (2008) and Webb (2007) use the notion, 'three-language problem' to refer to the differences between home, instructional and science language. When the language of instruction is not the students' or the teachers' home language, Mayaba (2008) refers to this as the four-language problem. In most developing nations including South Africa, science subjects are taught in English, a foreign language that is often a second or an additional language. Leibowitz (2000, p.20) uses the term "triple disadvantage" to refer to the fact that most South African students have to switch between the language of learning and teaching (LoLT) which is often not their mother tongue and the academic language of higher education institutions. The ability to traverse such linguistic and conceptual borders; and to switch between mathematical, verbal and graphical representations of scientific knowledge, may facilitate proficiency in the languages of science and later, proficiency in scientific literacy. Webb (2007) points out that students must read science and read to learn science, just as they must learn to write and write to learn science.

2.3.3.3 The scientific literacy strategy

Much of the writing that takes place in science is centred on scientific observations, or theoretical assumptions which, can be best expressed in the genres of science and in the language of science. By extension, understanding the language of science has promise for attaining scientific literacy. Postman and Weigartner (1971, p.102) posit that "the key to understanding a "subject" is to understand its language, [and] what we call a subject is its language." Therefore, this intricate relationship between the 'subject' and the 'language' could potentially lead to students being able to access the discourses of science if the two are not viewed as separate.

According to Yore and Treagust (2006), scientific literacy refers to proficiency in the discourses of science that is, talking, reading, writing and thinking. The ability to switch willingly and comfortably between discourses indicates that the students is ready to engage in a repertoire of scientific activities such as "shar[ing] scientific experiences with others, address[ing] problems, formulat[ing] and evaluat[ing] solutions, giving and receiv[ing] criticism, and mak[ing] important decisions on socio-economic issues" (Hodson, 2009, p.241).

Additionally, for Hodson (2009), proficiency in the discourses of science is like being proficient in a 'culture' of science. The prerequisite for knowing or understanding this particular culture is a substantial working knowledge of its language. Ignorance of the language, its subtleties and idiomatic deployment renders the culture unknowable beyond the merely superficial level because many cultural assumptions, values, and attitudes are implicit in the way language is structured and used (Hodson, p.241). Similarly, scientific literacy requires students to be proficient in what Norris and Phillips (2003) call the '*fundamental sense* of science', that is, proficiency in the languages of science, thinking, emotional dispositions, as well as understanding the big ideas of science. Additionally, scientific literacy recognises what is called the '*derived sense* of science' that is, the ability to understand the relevance and interactions between science, technology, society and the environment (Norris & Phillips, 2003; Hand et al., 2001). Science is committed to specific epistemic and ontological ideas that often differ from everyday common sense understanding and the personal language of everyday discussion; and the transition from one to the next needs to be scaffolded with care (Hodson, 2009). The scientific literacy strategy advocates for a content-based language instruction in order to facilitate both content and disciplinary language learning.

2.3.4 Drawing things together

The two fundamental pillars of the Science Writing Heuristic can be said to be the evaluativist view of the nature of science and interactive constructivism (Hand, 2007). The evaluativist view of the nature of science which holds that science is generally tentative, procedural and declarative and holds multiple interpretations of a data set. The use of argument and critique (Osborne, 2010) in verifying and advancing knowledge is paramount. One of the key features of inter-active constructivism is the perception that knowledge can be constructed both individually and socially, and that both the empirical and social nature of science are necessary for constructing meaningful scientific understandings (Hand, 2007). Through the multi-stage process of clarifying information privately and publicly and through the "appropriation of language, culture, practice and the dispositions of science", students have generally improved their critical thinking and standardised test scores (Villanueva & Hand, 2011). The use of the Academic Literacies approach in conjunction with the SWH has illuminated the contested nature of not only academic writing but also, writing in the discipline of science, and it has assisted to provide a South African context to science writing.

2.4 WRITING IN ENGINEERING

Over the past two decades there has been a gradual incorporation of writing instruction in engineering curricula both nationally and internationally (Winsor, 1990; Petroski, 1993; Walker, 2000; Butler & van Dyk, 2004; Jacobs, 2005, 2007a, 2007b; Harran, 2011; Lombard & McGrath, 2014; Mgqwashu & Bengesai, 2014). However, the pedagogical and epistemic value of writing has not always been recognised in the field of engineering education.

2.4.1 Interest in writing in engineering

Although the educational value of writing has been recognised to a greater extent in other fields of study such as science education, social sciences, humanities and even mathematics education, this value has only recently been realised in the field of engineering (Yalvac, Smith, Troy & Hirsch, 2007). One of the key reasons can be attributed to the understanding of engineering as being a 'technical' field, concerned with the 'production of useful objects' and the 'practical application' of empirical knowledge to solve problems (Feisel & Rosa, 2005; Walker, 2000), something which was pointed out by Winsor as early as 1990, namely that engineers tend to see their own knowledge as "coming directly from physical reality without textual mediation" (1990, p.58).

The engineer's relationship with language, writing and communication has often been viewed in a negative light. For example, Heylen and Vander Sloten (2013, p.596) note that engineers are not "communication specialists", while Petroski pointed out two decades earlier that conventionally, engineers "eschew writing, reading and speaking" (1993, p.419). Despite these negative feelings towards reading, writing and speaking, the practice of professional engineering upholds them as paramount (ECSA, 2012; Simpson & van Ryneveld, 2010; ABET, 2006; ABET, 1996).

In the United States of America, the Accreditation Board for Engineering and Technology (ABET EC2000) mandates that mastery of written communication, teamwork and design be acquired progressively throughout the undergraduate curriculum (Yalvac et al., 2007, Walker 2000). In addition, in the United Kingdom (UK), the Engineering Council UK (2013, p.3) asserts that engineers use "judgement and experience to solve problems when science or mathematics alone could be inadequate". Yet again, the Engineering Council of South Africa (ECSA) requires engineering programmes to include a cohort of literacy practices that are broadly defined as reading, writing and critical thinking (Simpson & van Ryneveld, 2010).

Specifically, ECSA's (2012) generic Exit Level Outcome 6 for professional and technical communication requires engineering graduates to "communicate effectively, both orally and in writing, with engineering audiences and other affected parties," while engaging with different kinds of texts such as technical reports, proposals and presentations (ECSA, 2012, p.9; Lombard & McGrath, 2014). The common thread is that internationally engineering departments are expected to incorporate the teaching of literacy practices such as reading, writing, critical thinking and teamwork, in engineering curricula in order to prepare engineering graduates for the demands of professional work. In response, various approaches to incorporating writing instruction into the curriculum were adopted by engineering departments (Mgqwashu & Bengesai, 2014; Heylen & Vander Sloten, 2013; Gimenez & Thondhlana, 2012; Harran, 2011; Jacobs, 2005, 2007a, 2007b; Butler & van Dyk, 2004; Walker, 2000).

The key question of these debates centred on the responsibility for teaching writing and how it should be taught. Engineering lecturers believe that their role is teaching discipline specific content subjects such as mathematics and engineering sciences, while the role of teaching language, writing and communication should be relegated to language and communication departments (Harran, 2011; Skinner & Mort, 2009; Jacobs, 2005, 2007a, 2007b, Yalvac et al., 2007). A justification for this approach was that (i) the engineering curriculum is packed, (ii) there is no time for discipline lecturers to incorporate writing or language instruction during their own contact time (iii) some engineering lecturers perceived the integration of literacy support within classroom time as "diluting the engineering syllabus and not being in the interest of the entire student cohort (Harran, 2011; Skinner & Mort, 2009, p.547). For example, in the USA, one of the key approaches to incorporating writing, language or communication instruction in mainstream engineering curricula included freshman composition classes which were the responsibility of English teachers. However, as more attention began to be paid to the relationship between language and learning, writing and communication 'skills' have became accepted as an important part of the curriculum and approaches such as 'Writing Across the Curriculum (WAC)' or 'Writing in the Disciplines (WID)', the Writing Centre model, and collaboration between engineering and language or academic literacies departments, were adopted (Skinner & Mort, 2009; Yalvac et al., 2007; Jacobs 2005, 2007a, 2007b; Walker, 2000).

The WAC or WID approach surfaced in the 1960s and 1970s and it sought to promote the idea that writing can be taught as a way of learning and not only, as "a means to remediate deficiencies in learners writing skills" (Yalvac et al., 2007, p.117). Galbraith and Rijlaarsdam (1995) accounts for how the traditional approach, centred on grammatical features, spelling and principles of good writing style were replaced by cognitive theories of writing which included planning, translating and reviewing written texts in light of audience, purpose and register. Sometimes, the WAC or WID approach included "cross-disciplinary team teaching" (Walker, 2000, p. 369). To expose students to writing and teamwork, some universities have opted for a strong implementation of real workplace communication scenarios or internships that involve writing, and integrated work place engineering content in class assignment (Pierson, 1997; Sullivan & Baren, 1997; Hendrics & Pappas, 1996; Katz, 1993).

Some tertiary institutions chose to work collaboratively with Writing Centres (Walker, 2000) where first year engineering students would receive individual or group consultation with trained writing centre consultants. The writing centre model focused more on making genres (types of texts) of writing explicit by tailoring their instruction into audience, purpose and register (Harran, 2011; Walker 2000). According to Skinner & Mort (2009), in New South Wales, Australia, first year engineering students with lower literacy proficiency than expected are often supported academically in two ways. The first (more common) is to provide "out-of-class help" from learning consultants, who are not engineering professionals but specialist literacy teachers or trained peer writing assistants. The second (less common) is to identify and explicitly assess academic literacy requirements formally within a particular engineering programme.

South African higher education institutions have also participated in the above mentioned approaches when teaching writing and communication studies in engineering studies but the approaches adopted have relied on partnerships with language or communication practioners outside of the engineering department (Harran, 2011; Jacobs, 2007a, 2007b). More recently researchers in engineering education in South Africa and in the United Kingdom have attempted to promote an academic literacies approach where literacy is viewed as a social practice (Harran, 2011; Knott *et al*., 2011; Jacobs, 2007a, 2007b; Boughey, 2002). While all of the above approaches to engineering literacy learning seem to have been elaborate and collaborative, they have not enjoyed much success due to a number of constraints, not least because of a lack of support or "resistance" by engineering lecturers (Harran, 2011; Skinner & Mort, 2009, p.547).

2.5 THE GENERAL PROBLEM OF WRITING IN ENGINEERING

From a review of related literature it can be argued that the problem of writing in engineering can be understood better, and addressed better, through an understanding of the nature of knowledge in engineering, the nature of teaching and learning in engineering, as well as a re-conceptualisation of the use of writing especially at institutions of higher learning.

2.5.1 The nature of knowledge in engineering

The Engineering Council of South Africa (ECSA, 2015, para 1) defines engineering as "the practice of science, engineering science and technology concerned with the solution of problems of economic importance and those essential to the progress of society." The solution of problems relies on the basic knowledge of science, mathematics, and engineering knowledge, while also paying consideration to the needs of society, protection of the natural environment and ensuring sustainability. In addition, at the pinnacle of engineering work, engineers still need to manage and minimise health, safety, environmental, economic and sustainability risks (ECSA, para 1). The Engineering Council UK describes engineering work as being bound-up in constant complexity and that the most successful engineering creations recognise the fallibility of humans (2003, p.3). Thus, the solution of problems requires knowledge of diverse educational fields such as mathematics and natural science, while the practice of engineering requires knowledge and compliance with legislation, a code of ethics, and the ability to manage and communicate effectively with stakeholders within and outside of the engineering domain.

So far, the nature of engineering knowledge has been described in relation to professional practice and a number of local and international authors in engineering education tend to agree that the goal of engineering education is to prepare or to ready engineering students for professional work (Grobler, 2015; Kloot, 2015; Gwynne-Evans, & English, 2014; Harran, 2011; Simpson & van Ryneveld, 2010; Walker, 2000). The terms 'graduateness' or 'graduate attributes' are used by some South African universities offering engineering programmes as applying to what students require in preparation for the challenges of professional work (Gwyenne-Evans & English, 2014; Conradie, Paxton & Skelly, 2010; NMMU, 2010). These requirements at graduate level often present significant overlaps between the universities' conceptualisation of graduateness and what industry expects of engineering graduates (Gwyenne-Evans & English, 2014).

For example, first, the University of Cape Town's (UCT) policy on graduateness includes six international graduate attributes, three of which are:

(i) preparing graduates for a global workplace
(ii) ensuring graduates are critical thinkers and interested in post-graduate research
(iii) embracing the concept of graduateness is seen to incorporate the 'skills, demeanour and values' that UCT hopes its' students will acquire by the time they graduate (CHED, 2010 cited in Gwyenne-Evans & English, 2014).

Secondly, the Nelson Mandela Metropolitan University's (NMMU) Vision 2020 Strategic Plan boasts of a 'distinct knowledge paradigm' characterised by "an open-ended, discursive paradigm based on critical thinking"; and "an advancement of strong disciplinary knowledge whilst aspiring to foster trans-disciplinary thinking in our scholars and students" (2010, p.20). The seven desired graduate attributes at NMMU include:

(i) in-depth disciplinary/ interdisciplinary knowledge
(ii) social awareness and responsible citizenry
(iii) adaptive expertise
(iv) creativity and innovation
(v) critical thinking
(vi) intra and interpersonal skills
(vii) communication skills

Both examples from UCT and NMMU's desired graduate attributes emphasise the need to groom engineering graduates who are not only proficient in the discourses of their discipline, but who are also able to apply critical thinking and critical reflection in an attempt to solve an engineering problem.

The engineering curriculum, therefore, is expected to meet both, institutional and professional work requirements. As such, the engineering qualification is designed, as stipulated by ECSA, such that students complete *fundamental modules* (natural or basic sciences), *core modules* (engineering practice, computing and information technology, engineering sciences), and *electives* (complementary studies such as Communication or Language classes and discretionary studies involving the teaching of ethics and moral codes) (ECSA, 2012; SAQA 60071, 2008). The diversity of content in undergraduate engineering qualifications signals the need for engineering students to acquire diverse literacy practices in order to graduate and be certified as professional engineers (Simpson & van Ryneveld, 2010). These literacy practices involve high cognitive demands in such literacy practices as written, verbal, and technical communication; the use of the latest technological inventions; conducting investigations; problem solving, critical and creative thinking as well as working according to ethics and best practice (SAQA 60071, 2008; ECSA 2012; Simpson and van Ryneveld, 2010).

2.5.2 The nature of teaching and learning in engineering

Academic literacy practitioners in South African universities, together with their colleagues in the United Kingdom, have theorised about the nature of disciplinary discourses and about the nature of their teaching and learning (Harran, 2011; Knott et al., 2011; Gee, 2003; Jacobs, 2005, 2007a, 2007b; Lillis & Scott, 2008). From a synthesis of literature emanating from New Literacy Studies and Rhetorical Studies, Jacobs (2007, p.869) concludes that "the knowledge of disciplinary discourses has a tacit dimension, which makes it difficult for experts to articulate, and therefore difficult for students to learn." Academic literacy practitioners have been concerned with how the 'tacit dimension' can be made explicit to students, especially first year university students who still need to learn the discourses of their discipline.

The unfamiliar and inexperienced incoming student is often viewed as a 'novice' to the discipline while the disciplinary lecturer is often viewed as an 'expert' (Jacobs, 2007a). In an ideal learning situation, a symbiotic relationship between the expert and the novice is expected. However, the conundrum of the tacit disciplinary discourses and the expert/novice divides has been exacerbated by disciplinary, in this case, engineering lecturers who often construe problems with discourses as 'language problems' for which language lecturers are responsible (Harran, 2011; Jacobs, 2005; Gee, 1990). Reducing literacy learning to generic communication or language courses, and relegating language or academic literacy learning to language or communication, or academic literacy departments, single-handedly, is criticised for decontextualizing academic literacy teaching (Jacobs, 2005).

To solve this conundrum, Gee (2001) implied that disciplinary experts or disciplinary specialists at tertiary institutions are to carry the task of inducting novice students into their disciplines. Gee's implication was founded on his earlier definition of discourse as "a socially accepted association among ways of using language, of thinking, feeling, believing, valuing, and of acting that can be used to identify oneself as a member of a socially meaningful group" (Gee, 1990, p.143). However, Jacobs (2005) problematized the view that discourses, or academic literacies are best taught by experts who have mastered the discourse of that particular discourse community. In problematizing this view, Jacobs (2005) uses the metaphor of an 'insider' and an 'outsider' to a particular discourse community to illustrate the respective positions of the 'expert' and the 'novice' in terms of accessing disciplinary discourses. She points out that "such 'insiders' or experts have a tacit knowledge and understanding of the workings of discourse within their discipline which *remains unarticulated* [my emphasis] as they model appropriate disciplinary practices and discourse patterns for their apprentice students in the classroom" (Jacobs, 2005, p.477). In addition, Jacobs (2005) points out the contradictory position of engineering lecturers as one where engineering lecturers may have expertise and experience from industry and not a knowledge of how to teach and how to make explicit their discipline knowledge since most of them do not have a background on education and teaching philosophy.

A potential solution pointed out by Jacobs (2005, 2007a, 2007b) and seconded by a number of South African academic literacy researchers and elsewhere in the world, calls for a collaboration between disciplinary specialist and language/academic literacy specialists. To re-contextualise engineering teaching in respect of discourse and academic literacies, disciplinary boundaries between engineering and language/academic literacy specialists must be crossed in a bid to make explicit the tacit knowledge of the discipline and thus, facilitate better acquisition of disciplinary discourses by novice students (Harran, 2011; Knott et al., 2011; Jacobs, 2005, 2007a, 2007b, 2010). Both Harran (2011) and Jacobs (2005, 2007a) believe that language specialists, who are also 'novices' and 'outsiders' to the engineering discipline, can assist engineering lecturers to make their engineering discourses clearer to novice and outsider students. Language specialists are better suited because in their understanding of discourse and language, they are able to see language as 'opaque'.

However, academic literacy research is aware of both the intricacies of disciplinary knowledge and that language/academic literacy specialists do not know the content knowledge of the discipline and that is why collaboration is suggested.

The conceptualisation of collaboration as a way of teaching and learning has added benefits in that, through the mutual work of the discipline and language specialist, students are in a better position to gain a meta-knowledge and a meta-understanding of their discipline (Jacobs, 2005, 2007a). Thus, students are taught for 'learning'. Moreover, collaboration presents a move from the deficit conceptualisation of literacy are an "add-on" or optional extra or as a set of 'discrete skills' which are technically transferable across socio-cultural contexts (Harran, 2011; Knott et al., 2011; Jacobs, 2005, 2007a, 2007b). Instead, Harran (2011) argues that literacy in the sense of ability to use written language is a constellation of practices which differs from one social setting or from one discourse community. The understanding of literacy as situated in a particular discourse community (Lave & Wenger, 1991), supports the move towards understanding literacy as a social practice that is both negotiated internally within one individual, and also, externally through collaborative partnerships with others. Therefore, embedding academic literacies in mainstream curricular, in order to build engineering communities of practice though a literacy as a social practice understanding, is seen by academic literacy researchers, nationally and internationally, as bearing hope for better learning in engineering (Harran, 2011; Knott et al., 2011; Lillis & Scott, 2008; Jacobs, 2005, 2007a, 2007b; Lea & Street, 1998).

2.6 THE SPECIFIC PROBLEM OF WRITING LABORATORY REPORTS

Writing laboratory reports in science and engineering is a practice fraught with problems. This study has identified four main problems associated with writing laboratory reports in science and engineering, based on a review of related literature. As mentioned briefly in the first chapter, these specific problems face the student as an author of these disciplinary text-types. Failure to address such problems affects the students' ability to write in discipline-specific ways or in recognisable genres; it interferes with learning and the students' chances of attaining academic success.

The first specific problem seems to be the challenge of *relating laboratory work to disciplinary concepts* (Rudd II et al., 2001). These authors note the apparent disjuncture between laboratory activities and the understanding of disciplinary concepts on the part of the student. Reportedly, this was often the case when hands-on inquiry was at the centre of science education and when the value of writing as constituting learning was not yet realised (Nesbit, 2008; Yore, Bisanz & Hand, 2003). The use of the conventional laboratory report template often consisting of a "purpose, methods, results and conclusion" seemed to contribute less toward learners' understanding of scientific concepts, and as students often 'verified and demonstrated' what was already known (Wallace & Hand, 2007; Rudd II et al., 2001). The argument against this laboratory report template is that it "tends to obscure rather than teach science learners how knowledge is developed and communicated in science" (Wallace & Hand, 2007, p.68). As a move away from the regurgitation of content when writing laboratory reports, the Science Writing Heuristic (SWH) was developed in 1997 by Wallace (formerly Keys) and Hand in order to promote learning from laboratory work through writing to learn (Wallace & Hand, 2007; Keys et al., 1999).

As highlighted earlier in chapter one, the SWH is a semi-structured writing template consisting of meta-cognitive prompts that guide the student in establishing the relationships amongst questions, observations, data, claims and evidence (Wallace & Hand, 2007). In addition, the SWH is different from the conventional template in that it consists of pre-laboratory, laboratory and post-laboratory writing activities that suggest that knowledge of the investigation is to be generated throughout. The last two ways in which the SWH is different from the traditional template is that: the latter encourages the collaborative nature of scientific work in that students are purposefully driven to engage in discussion with their peers; and lastly, the SWH enhances students' metacognition by requiring them to reflect on their own knowledge growth (Wallace & Hand, 2007). Through these activities, the SWH has achieved significant gains in promoting conceptual understanding from laboratory generated lessons (see Wallace et al., 2007; Greenbowe & Hand, 2005; Hand et al., 2004; Rudd II et al., 2001).

The second specific challenge with writing laboratory reports is associated with *limited learning from laboratory activities*. Hand, Wallace and Yang (2004) argue that traditionally, secondary science laboratory activities have often followed "prescriptive outlines in structure and reporting of the activity" (p.131). As a result, students' writing of laboratory reports came across as "recipes" (Webb, 2010, p.448), following the same structure with a general lack of understanding of the procedures followed; and presenting a poor quality of discussion (Rudd et al., 2001).

The standard laboratory report template is criticised for not promoting the development of connections among elements of the laboratory experiment as well as the development of meaning, especially in the case of chemistry concepts (Rudd II et al., 2001). These authors explain that in the standard report format students attempt to fill-in isolated pieces of information and spend less time making connections and drawing meaningful inferences. To add, Keys (1999) found that in the absence of explicit writing instruction, the majority of middle school students often write lists of observations when reporting on scientific investigation, rather than writing interpretive statements.

In support of the view that 'learning should be an inquiry-based process', Rudd et al. (2001) advocate for a process whereby students are encouraged to construct explanations by establishing connections between their current knowledge and their new knowledge. For Webb (2010), the Science Writing Heuristic approach presents a move away from prescriptive and "simple report writing to meaningful writing towards sense making by integrating understandings of the nature of science, science inquiry, and issues of argumentation" (p.448). The prompts, forming part of the SWH act as metacognitive scaffolds that require students to draw relationships among claims and evidence, and to consider difference of opinion (counter-arguments) and how they may rebut to such counter-arguments (Wallace & Hand, 2007; Hand et al., 2004). Previous research has indicated that the use of the SWH by students has resulted in improved understanding of science concepts, metacognition and the nature of science (Hand et al., (2004). To foster learning from laboratory activities, the SWH requires science teachers to adopt a more student-centred approach to teach and use writing to learn to ensure that students take ownership of the learning process.

The third specific problem seems to be *wrestling with content and rhetoric* (Yore, Hand & Prain, 2000; Keys, 1999). There are various genres of writing and each one responds to a specific purpose. Writing in science is committed to specific epistemological ideas and the laboratory report is a discipline specific genre of writing that embodies such epistemological beliefs at the level of form and content. Yore et al. (2000) describe Bereiter & Scardamalia's (1987) knowledge transformation model of writing as comprising a dynamic between the content being addressed and the rhetorical requirements of the writing task. Keys (1999) explains that the 'content' to be considered when writing often encompasses the problem or the purpose of the writing while the rhetorical aspects consists of discourse or knowledge of how to express the content considered. These authors add that this 'dynamic' between the content being addressed and the discourse often leads to a constant evaluation and transformation of an individual's knowledge (Yore et al., 2000).

Bereiter and Scardamalia (1987) concur that the intent to match the content to the rhetorical goals of writing helps to develop an individual's understanding. For Thompson (1993) cited Yore et al. (2000), focusing on the rhetorical components is a crucial element of the writing process, especially when one considers that science is based on inquiry and argumentation. The writer's ability to persuade their readers rests on the rhetorical process. Previous research indicates that in science writing, novice writers are not readily equipped to traverse the content/rhetoric problem of writing. Instead, novice writers like most science students, often retell information without alterations and struggle with the rhetorical aspects of writing (Yore et al., 2000; Keys, 1999; Bereiter & Scardamalia, 1987). Comparatively, experienced writers like science professors, actively attend to both the content and rhetorical requirements while at the same time, engaging in the transformation of knowledge. In order to facilitate learning through writing, writers in science and engineering, and especially, at first year university level, need to be provided with opportunities for knowledge transformation rather than knowledge telling.

The fourth specific problem seems to be the *lack of familiarity with the genre* (Department of Mechanical Engineering). The low literacy levels of youth entering science and engineering university programs is an international problem but an even more so, in the South African higher education sector (Skinner, & Mort, 2009; Butler & van Dyk, 2004; Zamel & Spack, 1998). Literature exploring the reasons for the under preparedness of incoming first year university students abounds but for now it suffices to note that, the majority of science and engineering students entering universities as first years have not been exposed to conducting experiments in high school; and most under-resourced schools do not have science laboratories while some do not even have science teachers (eNca, 2014; Nel, 2010; Christie, Butler, & Potterton, 2007; Mji & Makgato, 2006).

The results of a recent questionnaire completed by first year Mechanical Engineering students in semester one of 2013, at the Nelson Mandela Metropolitan University (NMMU) indicated that 35% of students have not written any laboratory reports at school and 14% of the students indicated that they have written a maximum of two laboratory reports. Therefore, 49% of incoming first year students at NMMU in 2013 either lacked experience or were underprepared for the genre of writing laboratory reports. This study argues that students need to be academically socialised not only in the discourses of higher education but also, in their disciplinary discourses and genres as well. The majority of those students, who have a history of writing reports, have not been exposed to the use of critique and argument in constructing their understandings about science (Osborne, 2010). The reasons could be linked to the long standing conceptualisation of science as an empirical activity with durable standards of truth that cannot be contested (Hodson, 2009).

Therefore, the academic literacies approach is committed to a particular epistemological position and that is the conceptualisation of literacies such as reading and writing as social practices rather than as 'discrete skills' that are transferable from one task to the next (Harran, 2011; Jacobs, 2005, 2007a, 2007b; Lillis & Scott, 2007; Lea, 1998). The conception of literacy as a social practice sees literacy as 'situated' in the discipline and that such disciplinary literacies can be learned in discipline specific communities of practice. Through systemic and sustained collaboration among discipline specialists and language/academic literacy specialists, the tacit nature of disciplinary discourses can be made explicit to benefit novice students.

2.7 CONTRIBUTION OF THE STUDY

While laboratory reports have long been written in science and engineering, the use of scientific argumentation to develop critical thinking and language literacies in engineering has not yet been explored especially in a South African context. There is limited or no research done so far on the Science Writing Heuristic in engineering contexts. Second, employing two frameworks, the SWH which focuses on writing in the discipline and the Academic Literacies approach which seeks to make explicit the tacit nature of disciplinary discourses, has given the study a unique angle in attempting to understand how first year university students navigate laboratory report writing.

2.8 CHAPTER SUMMARY

The purpose of this chapter was to review salient literature on writing in science and engineering in order to contextualise the practise of writing laboratory reports in a first year mechanical engineering course at the Nelson Mandela Metropolitan University. The Science Writing Heuristic (SWH), which has its roots in interactive-constructivism and aspects of the Academic Literacies approach which focuses on the nature of student writing in higher education and conceptualises literacies such as reading and writing as social practices, were employed as the study's theoretical framework. Firstly, the problem with writing in both science and engineering was explored generally before specific problems were identified.

The key arguments presented on the general problem with writing in these disciplines was influenced first, by the incoming first year student who is yet to be socialised in the discourses of Higher Education in terms of academic literacies and also, in the discourses of their discipline, both, at a practical and theoretical level. Secondly, the nature of disciplinary knowledge, the nature of teaching and learning that knowledge, as well as the discourses on writing to learn or learning to write were at the centre of the argument on the general problem of writing in the disciplines. The specific problems of writing in both disciplines were similar and centred on resolving the conceptual and rhetorical problem of writing. This study has attempted to make two main contributions. First, while laboratory reports have long been written in engineering, the use of scientific argumentation to develop critical thinking and language literacies has not yet been explored especially in a South African context. Second, employing two frameworks, the SWH which focuses on writing in the discipline and the Academic Literacies approach which seeks to make explicit the tacit nature of disciplinary discourses, has given the study a unique angle in attempting to understand how first year university students navigate laboratory report writing.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

The purpose of this chapter is to present the research design and the methodology employed in this study. First, the philosophical underpinnings of the study, also known as the ‘research paradigms’, are discussed, after which the use of quantitative and qualitative research approaches are examined with each approach interrogated in terms of its relevance to the study. The research design presents the ‘plan’ of the study while the ‘methodology’ section explains how the study was conducted. The context, sample, data generation instruments, data collection process, data analysis, ethical consideration, notions of quality standards such as validity and reliability, as well as the limitations of the study are elaborated under the methodology section. Finally, a chapter summary of the key ideas communicated in the chapter is provided.

3.2 RESEARCH PARADIGMS

An understanding of what is meant by the term ‘research’ is needed before the meaning of ‘research paradigms’ can be explored. Mertens (2010, p.2) describes research as “a process of systematic inquiry that is designed to collect, analyse, interpret and use data” in order to “understand, describe, predict or control” a discipline specific phenomenon, or to empower individuals in such contexts (Mertens, 2010, p.2). As a systematic inquiry, any particular research study is underpinned by specific philosophical assumptions such as the nature of reality (ontology), the type of knowledge that can be generated (epistemology) and a discipline-specific way of generating that knowledge (methodology) (Taylor & Medina, 2013). A set of these disciplined philosophical assumptions form what is known as a ‘paradigm’. According to Willis (2007, p. 8), a paradigm “is thus, a comprehensive belief system, world view, or a framework that guides research and practice in a field”. Research paradigms therefore inform the nature of inquiry and they can be seen as unique means of producing knowledge (Taylor & Medina, 2013). There is a continuum of research paradigms, ranging from the ‘traditional paradigms’ with often one view of reality, to the ‘relatively new paradigms’ with multiple understandings of reality (Taylor & Medina, 2013; Taylor, 2014).

The major research paradigms on this continuum that equip the researcher to resolve the research questions are the positivist, post-positivist, interpretive and the pragmatic paradigms.

3.2.1 Positivist paradigm

The positivist paradigm is regarded as one of the traditional paradigms and it often serves as a point of departure in most debates and discussions about paradigms (Taylor, 2014; Taylor & Medina, 2013; Creswell & Plano Clark, 2011; Mertens, 2010; Willis, 2007; Cohen, Manion & Morrison, 2000). Positivistic types of research emerged during the *Renaissance* and the *Enlightenment* eras when experiments and observations were used to discover 'truths' about the world (Willis, 2007). This was a time when belief in Greek, Roman and Christian ideologies was declining and belief in the knowledge generated scientifically through empirical evidence was on the rise (Taylor, 2014; Mertens, 2010; Willis, 2007). These authors also note that positivism predominated experiments done in the physical and biological sciences since the seventeenth century. Positivist research has also been employed in social sciences for examining human behaviour. The use of control and treatment groups, pre- and post-tests, randomised sampling and large sample sizes are the key features of positivist research (Taylor, 2014).

The fundamental assumption of positivism is that the use of the scientific method is the primary way of discovering the truth about the world (Willis, 2007). The term 'scientific method' refers to a method of procedure consisting of systematic observation, measurement, testing, speculation, modifying hypotheses, creating ideas and conceptual tools, as well as constructing theories and explanations (Lederman, Abd-El-Khalick, Bell & Schwarts, 2002). Thus, reasoning is based on empirical objectivity and mathematical certainty in order to uncover law-like properties of the material universe (Taylor, 2014). Furthermore, to maintain objectivity, the researcher controls the research process and is external to the research site. Consequently, for some, scientific knowledge is "valid, certain and accurate" (Crotty, 1998, p.29 cited in Mertens, 2010, p.11).

Positivists also believe that there is a way of studying the social world in a manner that is value-free and where causal explanations can be given (Mertens, 2010). However, positivism has been criticised by social science researchers for this very belief (Chalmers, 2013). Also, since positivism was 'exported' from the sciences, education and social science researchers do not subscribe to this approach and believe that human beings cannot be studied the same way as material matter. Mertens (2010, p.11) reasons that "there is much about the human experience that is not observable but is still important (e.g. feeling, thinking)". Additionally, post-positivist psychologists saw positivism as 'narrow' and that what could be studied was not limited to what could be observed (Mertens, 2010). Positivist research is also criticised for not being sensitive to local contexts and individuals since the focus on large sample sizes does not allow for much to be learned from the "small dots" (and especially the outliers)" that make up the big picture of statistical results (Taylor, 2014, p. 7). Attempts at objectivity and minimal interaction between the researcher and participants, have been found to be limiting in education and social science settings where the 'subjectivity' of the researcher and participants are regarded as active (Taylor & Medina, 2013; Mertens, 2010; Creswell, 2008; Willis, 2007). Finally, Lederman et al. (2002) consider the notion of a 'scientific method as a "misconception" and a "myth" that was "explicitly debunked" based on the absence of a single scientific method that would "guarantee the development of infallible knowledge" (p.501).

3.2.2 Post-positivist paradigm

Post-positivism succeeds positivism and is also regarded as part of the traditional paradigms. However, since post-positivism responded to the limitations of positivism, some researchers consider the former as a "milder" or "softer" form of positivism (Taylor & Medina, 2013; Willis, 2007, p.3). The "epistemological softening" of positivism was to "better serve the interests, structures and priorities of local communities" (Taylor, 2014). The use of quantitative methodologies was supplemented by qualitative methodologies in order to discover the participants' thoughts, actions, feelings and perceptions about a particular phenomenon (Taylor, 2014; Mertens, 2010; de Vos, Strydom & Delport, 2008; Willis, 2007). That is, what is true and what is regarded as knowledge, is not only based on empirical evidence but also on participants' affective responses (de Vos et al., 2008)). Unlike positivism, post-positivism is characterised by (i) more interaction between the researcher and the participants; (ii) sampling that is not limited to random assignment but also includes non-random sampling, convenience sampling and purposive sampling; (iii) smaller sample sizes and (iv) data collection that includes qualitative data generation tools such as interviews and participant observation. Thus, Taylor and Medina (2013, p.3) consider post-positivism as a "modified scientific method for social sciences".

While positivist research is based on 'true' experimentation i.e. random assignment and large sample sizes, post-positivism is based on 'quasi-experimentation' i.e. non-random assignment and smaller sample sizes (Taylor & Medina, 2013). The similarities between positivism and post-positivism are that both can use control and treatment groups as well as pre- and post-tests in intervention-based studies. According to Mertens (2010), post-positivists still see objectivity and generalisations as important but they suggest that researchers modify their claims to *understandings of truth* based on probability, rather than certainty. As noted before, in this study, quantitative data have been generated and have been analysed probabilistically. These different types of data, both quantitative and qualitative, have been triangulated in order to provide more meaningful understandings of the problem at hand.

3.2.3 Interpretive/constructivist paradigm

In the continuum of research paradigms, the interpretive paradigm forms part of what can be considered to be the relatively new paradigms. The key feature that distinguishes the newer paradigms (including critical, transformative and postmodern paradigms) from the older ones is acknowledging that multiple realities exist (Mertens, 2010; Willis, 2007). The newer paradigms responded to the hegemony of quantitative research methodologies which only legitimated the 'scientific method' (Arthur, Waring, Coe & Hedges, 2012). Before a comparison is done between the three paradigms, the key characteristics of the interpretive paradigm will be given.

Interpretive research grew out of the philosophy of German scholars such as Edmund Husserl and Wilhelm Dilthey who focused on the study of interpretive understanding (*hermeneutics*). Interpretivists sought to understand the lived experiences of human beings and they believed that natural reality was not the same as social reality and that different methods were required to study social reality (Willis, 2007). As a result, the need to 'understand' or to 'make meaning' of people's lived experiences placed an emphasis on the importance of 'context' and the 'situatedness of knowledge' (Willis, 2007). Most researchers use the term 'constructivist paradigm' interchangeably with interpretivist paradigm due to the quest of constructing insightful understandings of people's realities. Therefore, the fundamental belief of an interpretivist framework is that reality is socially constructed and that multiple experiences and conceptions of reality can be apprehended (Mertens, 2010).

The unique process in which knowledge is constructed within an interpretive paradigm is influenced by the field of anthropology which aims to understand other cultures from the inside (Taylor, 2014; Taylor & Medina, 2013; Willis, 2007). Given the importance of context in the research endeavour, the interpretive paradigm takes on an inter-subjective knowledge construction model where knowledge of the other is produced through a prolonged process of interaction between the researcher and the participants (Taylor, 2014; Taylor & Medina, 2013). The concept of 'objectivity' that marks both the positivist and post-positivist paradigms is replaced by 'confirmability,' a notion relating to whether the research data can be tracked back to the source or not (Taylor & Medina, 2013; Mertens, 2010).

3.2.4 Comparing the three paradigms

The interpretive/constructivist paradigm presents an epistemological shift in terms of the nature of reality, the nature of knowledge and how that knowledge is to be generated. Firstly interpretivism rejects the positivist idea that the truth or knowledge can only be devised through the scientific method, and that quantitative analyses are the only means of generating knowledge. As Mertens (2010) asserts, while the focus on empirical and objective data has some appeal, this view is seen as 'narrow' and limiting when applied to human behaviour. Secondly, the interpretive paradigm commends post-positivists for realising that multiple realities exist and that the addition of qualitative methodology within a previously quantitative paradigm enriches the nature of knowledge generated. However, some researchers observe that researchers operating in a post-positivist paradigm only use qualitative methodology in a supplementary role (Taylor, 2014; Taylor & Medina, 2013; Mertens, 2010). Taylor complains that using qualitative methodologies as a supplementary "blunts the transformative potential" of qualitative research (Taylor, 2014, p.1) as considering the human dimension to research allows for a better understanding of people's lived experiences. By combining aspects of these three paradigms, one enters the realm of what Creswell (2009, 2003) refers to as the pragmatic paradigm.

3.2.5 The pragmatic approach taken in the study

The purpose of this section is not to join the debate on 'paradigm wars' by discussing which paradigm is superior. Instead, the purpose is to make explicit where this study is positioned in the continuum of research paradigms, and to provide a rationale for such a position. It has already been established in section 2 of this chapter that "each paradigm has a specific purpose in providing a distinct means of producing unique knowledge" (Taylor & Medina, 2013, p. 1). Therefore, the 'unique' knowledge that is to be produced is that which satisfies this study's research questions. Given that the research question seeks to investigate the effects on students in terms of a laboratory report writing intervention in terms of argumentation, critical thinking, conceptual knowledge and language literacies, both quantitative and qualitative methodologies were necessary.

Informed by the work of Patton (1990) as well as Rossman and Wilson (1985), Creswell (2009) reasons that the worldview (paradigm) concerned with applications, that is, 'what works', and solutions to research problems, is known as pragmatism. These authors further concur that Pragmatists "use all approaches available to understand the research problem" (Creswell, 2009, p.10). While the epistemology of positivist/post-positivist research focuses on 'empirical observation and measurement', and that of interpretive/constructivist research focuses on 'social and historical construction', the epistemology of pragmatist research is 'pluralistic' (Creswell & Plano Clark, 2011). This means that pragmatism is underpinned by more than "one stem of philosophy and reality" (Creswell, 2009, p.10). At the same time Mertens (2010) argues that in a pragmatist worldview, it is possible to assert that there are both a 'single real world' and that individuals have their own unique interpretations of the real world. Thus, pragmatism can either adopt an objective or subjective or even an 'intersubjective' stance. As this study operates in both the post-positivist and the interpretive/constructivist paradigms in an attempt to answer the research questions and resolve the research problem, it is framed within a pragmatic worldview.

3.3 RESEARCH APPROACHES

Having established the philosophical assumptions of this piece of research, it becomes necessary to consider the research approaches. The majority of researchers seem to agree on three research approaches namely: quantitative, qualitative or mixed-methods (Creswell & Plano Clark, 2011; Mertens, 2010; Creswell, 2009; Maree, 2007; Tashakkori & Teddlie, 2003; Patton, 1990). Contrary to popular understanding, the difference between qualitative and quantitative research is not only attributed on the use of words and open-ended questions (qualitative), or the use of numbers and closed-ended questions (quantitative), but also, on the philosophical assumptions informing the study, the types of research strategies used overall in the research and the specific methods employed in conducting these strategies (Creswell, 2009). Simply put, the approach to research involves philosophical assumptions as well as corresponding methods and procedures (Creswell, 2009, 2003). Creswell (2009) provides a framework to explain the interaction between these three components (Figure 3.1). This study is informed by such a framework and each research approach can be described and traced back to the corresponding philosophical assumption.

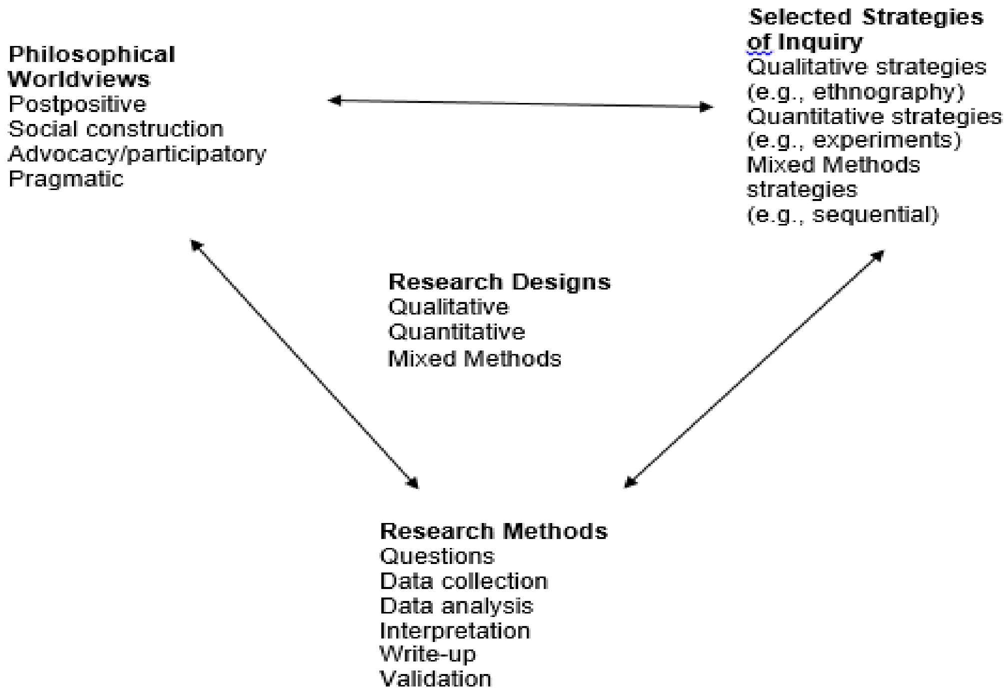

Figure 3.1: Framework for Design – The Interconnection of Worldviews, Strategies of inquiry, and Research Methods (Creswell, 2009).

3.3.1 The quantitative research approach

Maree & Pietersen (2007) define quantitative research as a systematic and objective process that uses numerical data from only a selected subgroup of a universe (or population) in order to generalise the findings to the universe that is being studied. These authors emphasise that the three most important elements in this definition are 'objectivity', 'numerical data' and 'generalisability'. From a review of literature on research methodologies, it can be argued that contemporary quantitative research either articulates assumptions consistent with the positivist or post-positivist research paradigms (Taylor, 2014; Taylor & Medina, 2013; Creswell & Plano Clark, 2011; Mertens, 2010; du Plessis & Majam, 2010; Creswell, 2009, 2003; Maree, 2007; Johnson & Onwuegbuzie, 2004).

As noted earlier, quantitative purists (positivist) believe that social observations should be treated in the same manner as scientists treat physical phenomena and that social science inquiry should be objective (Johnson & Onwuegbuzie, 2004). Since post-positivism acknowledges the limits of positivism when applied to human or social science research, quantitative research within a post-positivist paradigm "reflects a deterministic philosophy in which causes *probably* [my emphasis] determine effects or outcomes" (Creswell, 2003, p.7). That is, post-positivist research uses numerical values to establish 'probability' whereas classical or traditional positivism employs numerical values to ascertain an 'absolute truth' (Phillips & Burbules, 2000 cited in Creswell, 2003). At the same time, post-positivist quantitative research is also based on careful observation and measurement of the objective reality and the ability to generalise and replicate findings is possible (Taylor & Medina, 2013; Creswell, 2009, 2003).

3.3.2 The qualitative research approach

One description of qualitative research is offered by Nieuwenhuis (2007) who posits that qualitative research aims at collecting rich descriptive data in respect of a particular phenomenon or context in order to develop an understanding of what is being observed or studied. This description highlights three important terms that align qualitative research with the interpretive/constructivist paradigm and which seeks to understand people's lived experience and thus, acknowledges multiple realities. These terms are, 'description', 'context' and 'understanding'. The emphasis is on the quality and depth of information and not the scope or breadth of the information provided as is the case with quantitative research. Mertens (2010) concurs that qualitative research is a situated activity that locates the observer in the world. However, a fuller understanding of qualitative research can be achieved by understanding the more fundamental constructs and concepts underpinning this kind of research.

Fundamentally, the qualitative research approach was developed as an alternative to positivist philosophy which underpinned twentieth century research. While the positivist philosophy construed the world in a single objective manner, qualitative researchers argued that "the knower and the known cannot be separated because the subjective knower is the only source of reality" (Guba, 1990 cited in Johnson & Onwuegbuzie, 2004, p.14). Furthermore, these authors contend that multiple-constructed realities exist, that time- and context-free generalisations are not possible, research is value-bound, that it is impossible to differentiate fully causes and effects and that logic flows from specific to general.

3.3.3 The mixed-methods research approach

Some researchers position mixed-methods research as an approach 'whose time has come' (Johnson & Onwuegbuzie, 2004), as an approach that 'has come of age' at a time when including only quantitative and qualitative methods is inadequate for contemporary research (Creswell, 2003) and yet some advocate for mixed-methods research as a 'new' or a 'third' approach (du Plessis & Majam, 2010; Johnson & Onwuegbuzie, 2004). For the sake of clarity and consistency, I have substituted the concept of 'paradigm' as found in the cited texts with the concept of 'approach'. Moreover, various authors in the field of research methodologies tend to use terms like 'paradigm', 'approaches' or 'methods' differently and each concept is to be understood within that particular context. For instance, I have reserved the concept of 'paradigm' for 'philosophical assumptions' or 'worldviews' only. Contrary to this, Johnson and Onwuegbuzie (2004) as well as du Plessis and Majam (2010), use 'paradigm' to refer to what is called research 'approaches' in this study. That is, instead of positioning mixed-methods research as an approach, they position it as a paradigm. While these researchers hail mixed-methods research as an alternative to quantitative and qualitative research, other researchers argue against mixed-methods research (Nieuwenhuis, 2007; Lee, 1991) as they believe the different paradigms are not reconcilable.

Creswell (2009) refers to a mixed-methods research as an approach to inquiry that combines both qualitative and quantitative forms; and that it also involves philosophical assumptions and the mixing of both qualitative and quantitative approaches. The mixing of both qualitative and quantitative research approaches is seen as strengthening the study, more than either qualitative or quantitative research (Creswell, 2009). Owing to the limitations of all research methods, Creswell (2003) reports that some researchers felt that biases inherent in any single method could neutralise or cancel the bias of other methods. Johnson and Onwuegbuzie (2004) argue that the aim of mixing the methods is not to replace either one but to draw from the strengths and minimize the weaknesses of both in single research studies or cross studies. In a continuum of research approaches, mixed-methods research would be positioned in the middle of both qualitative and quantitative research (Johnson & Onwuegbuzie, 2004), much like the pragmatic paradigm would rest somewhere in between post-positivism and interpretivism/constructivism. Similar to pragmatism, the mixed-methods research approach is problem-centred and may employ multiple research approaches (Creswell, 2009).

The dispute surrounding mixed-methods research centres around the different philosophical assumptions regarding the nature of reality (ontology), the nature of knowledge (epistemology), the processes of generating knowledge (methodology) and the purpose of the knowledge generated (axiology) (Lee, 1991 cited in Nieuwenhuis, 2007). Three responses to this dispute exist (Nieuwenhuis, 2007). The first is a 'functionalist' role whereby mixed-methods research is employed a pragmatically. The second response complicates the first by arguing that if research questions were to be answered using the 'best-fit' means of gathering the data, a series of binaries such as 'objective and subjective', 'linear and mutual causality', 'prediction and understanding' would present themselves (Nieuwenhuis, 2007). Furthermore, the argument is that such binarisation is not easily smoothed over in the functionalist approach. The third response approaches the problem from a research methodological perspective where such binaries are reduced or eliminated and the focus is on the underlying philosophical assumptions. For instance, Nieuwenhuis (2007) explains that attention is to be paid to the underlying ontology and epistemology, thus eliminating thinking that focuses on method rather than methodology. The functionalist and the methodological stance is consistent with the discussion about the philosophical assumptions underpinning research.

3.3.4 The research approach taken

The research approach taken in this study is mixed-methods. The motivation for using a mixed-methods approach was the need to gain a deeper understanding of the research problem. Since the study is centred around testing the effects of a laboratory report writing intervention, the research problem could be understood better (i) if the effects of the laboratory report writing intervention could be measured and compared against those of existing literature, (ii) if the students' writing could be compared to *a priori* themes and (iii) if perceptions of the participants about the intervention could be learned.

Concurrently, the research questions also fell along what would be seen as multiple research paradigms and multiple research approaches. For instance, in order to resolve the research questions, measurement and generalization were required and at the same time, understanding and the participants' sense-making strategies are also required. Therefore, the conceptualisation of the research problem traversed the borders of singular paradigms and therefore, "a plurality of philosophical paradigms, theoretical assumptions, methodological traditions, data gathering and analysis techniques, personalised understandings and value commitments" were required (Schwandt, 2007, p.196). In this sense, the mixed method approach may be seen as falling under the notion of the pragmatic paradigm. Creswell & Plano Clark (2011) concur that the pragmatic paradigm is typically associated with mixed-methods research as it is also pluralistic and centred around the research problem. The mixed-methods approach has assisted me to generate data and explain my findings in a pluralistic manner.

3.4 RESEARCH DESIGN AND METHODOLOGY

The research design employed in this study is elaborated below in both narrative and pictorial format. The sample and setting is described, as well as the data generating instruments, the data analysis procedures and the validity and reliability of the design and results. The limitations of the study and the ethical considerations that were taken into account are also discussed.

3.4.1 Research Design

Research design is often explained as a 'plan', a 'proposal', a 'procedure', a 'framework' or a 'scheme' of how the researcher intends to investigate the research problem (Maxwell, 2013; Creswell, 2009; Maree, 2007; Denzin & Lincoln, 2006). As explained earlier, in section 3, the research design involves the intersection of the philosophy, strategies of inquiry and specific methods for data collection (Creswell, 2009). In this study, a quasi-experimental, mixed-methods research design with pre-tests (baseline), intervention and post-tests were used to determine the effects of a laboratory report writing intervention in a first year mechanical engineering class. As mentioned earlier, a quasi-experiment resembles a true experiment but differs on the grounds that the former may use a variety of sampling techniques (such as convenience sampling) other than random assignment; and may also use smaller sample sizes rather than 'large scale' samples (Taylor & Medina, 2013; Taylor, 2014; Mertens, 2010).

The aim of this study was to investigate whether an adapted version of the Science Writing Heuristic (SWH) could use argumentation as a metacognitive scaffold in students' laboratory report writing for Mechanics of Machines, a year 1, semester 1 module (MEC 1111). Previous research indicates that the development of argumentation through disciplinary genres such as laboratory reports bears a correlation with the development of critical thinking (Whitehead & Murphy, 2013; Hodson, 2009; Wallace, Hand & Prain, 2007). Consequently, the aim of the study was not only to investigate the use of argumentation but also the extent to which the use of argumentation may have affected participants' critical thinking. The effect of argumentation in students' laboratory report writing was also considered in terms of language and content scores. Therefore, the research design process was divided into a series of five broad steps taken chronologically (Figure 3.2).

Step 1 was the 'pre-test and preparation' stage and it involved two initial questionnaires (Appendices A and B), a pre-test of critical thinking (Appendix C) and testing and modifying the intervention (the Science Writing Heuristic) with mechanical engineering lecturers. This step was conducted before the 28th February 2014 and before any laboratory investigations were done by participants. I introduced myself and the research project to the participants and the students solicited their informed consent to participate in the study. The purpose of the initial questionnaires were to specifically find out the students' prior knowledge and practices on conducting laboratory investigations, writing disciplinary texts such as laboratory reports, as well as their perceptions on writing in general. Perceptions included beliefs and attitudes towards writing and 'discourses of writing and learning to write' (Ivanic, 2004). The study on students' perceptions on writing followed a survey conducted by the Department of Mechanical Engineering in conjunction with the NMMU Writing Centre in 2013 on first year mechanical engineering students' familiarity with writing laboratory reports (see Appendix D; Lombard, & Knott, 2013). The Cornell Critical Thinking pre-test was administered at this stage in order to determine students' critical thinking abilities before the intervention was implemented.

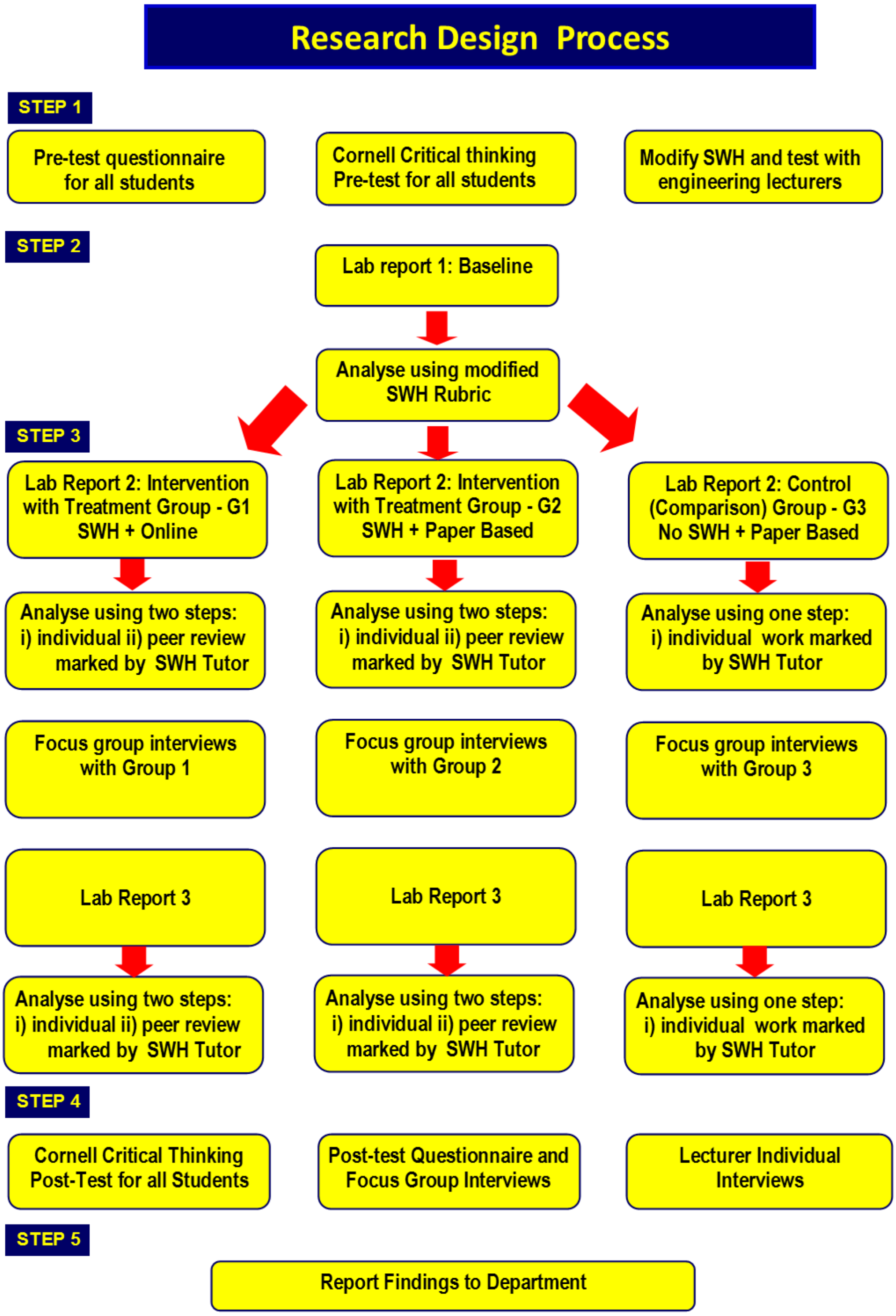

Figure 3.2: Pictorial representation of the research design of the study.

Step 2 determined the students' 'baseline' abilities in terms of writing the first laboratory report for MEC 1111 after completing a laboratory investigation on 'the triangle of forces'. All participants were provided with the standard departmental template for writing laboratory reports and were required to submit the final copy of their individual reports two weeks after conducting the laboratory investigation. This original template was modified to provide the intervention template for the experimental groups. The original and modified templates are shown in appendices E and F. Traditionally, laboratory reports are assessed to determine students' disciplinary knowledge (content score) (Appendix G) only but, since the interest of this study was in investigating the use of argumentation in first year mechanical engineering laboratory report writing, a tailor-made Science Writing Heuristic rubric (Appendix H) was used to analyse the students' first laboratory report in terms of argumentation. Owing to the importance of linguistic and communicative competency in both verbal and written engineering communication, a tailor-made language rubric, assessing writing, was also developed (Appendix I).

Step 3 represents the 'intervention' stage and provides an outline of when and how the intervention was implemented. The intervention, the modified version of the Science Writing Heuristic approach template, was introduced before the second laboratory session. Participants were provided with support in terms of how to use the template when writing up the second laboratory report which was on a 'centre of gravity' practical investigation. The class was divided into three groups where Group 1 used an online version of the template, Group 2 used a paper-based template and Group 3 used the original paper-based traditional template as described in Step 2. In other words, both Group 1 and 2 used the intervention template (online and paper-based, respectively) while Group 3 used the traditional template in paper-based form. Participants in Group 1 and 2 were paired alphabetically in order to provide peer review on their partner's draft laboratory report before final submission. Group 1 students conducted the peer review process online while Group 2 students conducted a paper-based peer review process.

The peer review process included giving feedback on a partner's laboratory report using the tailor-made Science Writing Heuristic (modified) marking rubric for argumentation and language. Group 3 students carried on traditionally, without the peer review process. As a data analysis measure, students' laboratory reports in all three groups were analysed by the Science Writing Heuristic tutor using the same SWH marking rubric for argumentation and language. A week after the laboratory reports were submitted by all three groups, focus group interviews were conducted with selected students from each group in order to ascertain their experiences on writing laboratory reports and find out the report template they preferred, that is, the traditional and intervention versions (see appendix J). The same protocol was followed for the third laboratory report which was based on the theoretical construct 'friction'. Again focus group interviews were held with selected students from each group to find out students' experiences and to evaluate the effect of both the traditional report template and the intervention.

Step 4 represents the 'post-test and evaluation' stage. The same Cornell Critical Thinking test was administered as a post-test to all participants to ascertain any effects of the intervention on critical thinking. A post-intervention questionnaire was given to all participants to find out their experiences in their respective groups (Appendix K). Semi-structured interviews were also held with the two mechanical engineering lecturers offering the MEC 1111 module and the module's laboratory technician to find out their views on the use of the intervention (Appendix L). In step 5 the findings of this study were presented to the Department of Mechanical Engineering to inform and assist in improving the teaching and learning of laboratory reports as socially situated genres.

3.4.2 Sample and setting

In an attempt to address the research question a researcher must engage in a 'sampling procedure' that involves determining (i) the location or the site for research, (ii) the sample of participants who will provide data in the study (iii) the number of participants needed to answer research questions and the (iv) recruitment procedures (Creswell & Plano Clark, 2011). Gibson and Brown (2009) refer to the notion of 'sampling' in broad terms as, the points of data collection or *cases* to be included within a research project. These points of data collection may be a person or persons, a document, an institution, a setting or any instance of information or data gathering.

According to Walker (2010, p.23), a "good sample" is representative of the population being studied and notion of 'representation' include certain characteristics, roles, knowledge, opinions or experiences that may be particularly relevant to the research (Gibson & Brown, 2009). Initially, the sample consisted of 99 first year mechanical engineering students (n=99) who were already registered for the mechanics of machines module in semester 1 of 2014. Thus, the sample in this study was selected 'conveniently' or 'purposefully' and group sampling was done alphabetically (Creswell & Plano Clark, 2011).

In the course of the study, the numbers dropped due to students cancelling the module, de-registering their engineering studies, dropping out of the study, non-submission of lab reports and due to the inadequate use of the online platform. Initially, 20 students (n=20) from surnames A-KE formed part of Group 1 (online intervention); 20 students (n=20) from surnames KF-MSO formed part of Group 2 (paper-based intervention); and 30 students (n=30), surnames MP-Z were part of Group 3 (paper-based, no intervention – comparison group).

3.4.3 Data generating instruments and data analysis

The data generating instruments that were used in an attempt to address both the primary and the secondary research questions are represented in Figure 3.3. Quantitative data were gathered through the critical thinking tests, questionnaires and laboratory reports (Appendices A, B, C, D and E). Laboratory reports and focus group interviews were also used to gather qualitative data. Table 3.3 presents a summary of the interface between the key elements investigated per research question, the data sources, the data types and the mode of analysis.

3.4.3.1 Cornell Critical Thinking test

As mentioned previously, the Cornell Critical thinking test was administered as a pre- and post-test to all participants. As a pre-test, the test was used to evaluate participants' critical thinking abilities at their point of entry as first year engineering students. These preliminary critical thinking results were compared to the participants' post-test results at the end of the first semester once the module syllabus and all writing tasks were completed. In the Cornell Conditional Reasoning Test (Form X) (1964) administered, students are presented with 72 conditional reasoning questions where statement 1 is the antecedent (if) and statement 2 is the either a confirmation or denial of the antecedent and statement 3 is the consequent (then). That means students have to use statements 1 and 2 to make a reasoned decision about whether statement 3 is 'true' or 'false'. In addition to 'true' or 'false', students are presented with a third option for an answer, 'maybe', which is used when the consequent could either be true or false, i.e. when the information provided to make a decision about the statements (data) is insufficient and could result in ambiguous claims.

Table 3.1: Summary of the key elements investigated per research question, the data sources, the data types and the mode of analysis.

Key element	Data source	Type	Method of analyses
Literacy practices at entry level	Pre-test Questionnaires	Quantitative Qualitative	Descriptive statistics Thematic analysis
Literacy practices at entry level	Focus group interviews	Qualitative	*a priori* thematic analysis
Critical thinking	Cornell pre- and post-tests	Quantitative	Memorandum Analysis of variance techniques (ANOVA)
Conceptual understanding	Laboratory reports	Quantitative	Marking rubric ANOVA
Argumentation	Laboratory reports	Quantitative	ANOVA
Language (discourse)	Laboratory reports	Quantitative	ANOVA
Experiences on lab report writing	Focus Group interviews	Qualitative	*a priori* thematic analysis
Argumentation	Laboratory reports	Qualitative	*a priori* thematic analysis
Language (academic literacies)	Laboratory reports	Qualitative	*a priori* thematic analysis
Literacy practices post intervention	Post-test questionnaire	Quantitative Qualitative	Descriptive statistics Thematic analysis

For each of the 72 questions in the test, each student has to decide whether the consequent is true (option A), or false (option B) or maybe (option C). See Appendix C for a sample answer sheet for the Cornell Conditional Reasoning Test Form X pre-post-test. This test was administered manually according to the ethics and protocol described in the Cornell Critical Thinking Tests Level X & Level Z Manual (1985/2004). It is suitable for both high school and entry level university students.

3.4.3.2 Questionnaires

A pre-test questionnaire investigating the literacy practices of participants was administered on the same day, after administering the Cornell Critical Thinking Test. It was important to establish what competences these first year students already possessed at entry level before any formal writing or laboratory work was required. The participants' responses provided baseline knowledge about their previous (high school) experience with conducting scientific investigations, writing scientific reports based on laboratory investigations, working individually, in pairs or in groups, the nature of their disciplinary writing, exposure to reading and writing different kinds of texts, their beliefs about writing and learning to write (Ivanic, 2004).

This questionnaire was adapted from an existing pre-test questionnaire that was developed in a collaborative literacy project between the Department of Mechanical engineering and the NMMU Writing Centre known as the HEADS-Teaching and Learning language project (Knott, Lombard, & McGrath, 2011). The Acronym HEADS stands for Higher Education Access and Development Services, a structure that includes the Centre for Teaching Learning and Media (CTLM) within which writing centres are situated, the Faculty of Engineering, Built Environment and Information Technology as well as the Department of Applied Language Studies which forms part of the Faculty of Arts. This questionnaire was also informed by a previous survey conducted by, as alluded to earlier, the Department of Mechanical engineering about incoming first year's familiarity with writing laboratory reports. In turn, this baseline knowledge informed the designing and contextualising of the Science Writing Heuristic as a laboratory report writing intervention for first year mechanical engineering students at a South African university.

The post-test questionnaire was administered to participants at the end of the semester once all laboratory tasks, including writing, were completed. The purpose of this questionnaire was to investigate the effects of the laboratory report writing intervention from a student perspective. Again, the participants' experience with conducting scientific investigations, writing scientific reports based on laboratory investigations, working in pairs or groups, the nature of their disciplinary writing, exposure to reading and writing different kinds of texts as well as beliefs about writing and learning to write were ascertained. This post-test data, when compared to the baseline data, was to ascertain whether the SWH had any effects on students' disciplinary and linguistic literacy practices or what Fairclough (2003, p.17) refers to as "socially situated" literacies.

3.4.3.3 Laboratory reports and marking rubrics

The participants were required to conduct three laboratory investigations on which to base the three laboratory reports written. There was a gap of about two weeks between laboratory investigations/experiments and two weeks before the final submission of each report. The first laboratory report on the ‘triangle of forces’ was used as a baseline while the intervention was introduced to the experimental groups during second and third laboratory reports on ‘the centre of gravity’ and ‘friction’. Details on how data was generated using laboratory reports and the tailor-made argumentation and language assessment rubrics are presented in Steps 2 and 3 of the Research Design section, and an example of the SWH student template with prompts that function as metacognitive scaffolds is shown in Chapter 1, section 2 of this dissertation. The structure of the traditional laboratory report template, the modified template (intervention) and the areas that were assessed for argumentation (Toulmin, 2003) are indicated in Table 3.2.

The SWH intervention is a semi-structured writing guide that uses prompts to scaffold students’ thinking. As an addition, examples of good writing when responding to prompts, using full sentences and writing coherently was modelled to the students. There were three key elements investigated from the laboratory report as a data source, in an attempt to address the primary and the secondary research questions. These three elements were i) argumentation, ii) language usage (discourse) and iii) conceptual knowledge (content). Each key element was assessed with a tailor-made rubric in order to ascertain the score – these documents are attached as appendices G, H and I. The argumentation rubric matched the laboratory report sub-sections with ‘arguments’ and it used a nominal scale of 1 to 5 where one indicated lack of or poor use of argumentation while 5 indicated explicit and appropriate use of argumentation.

The language rubric focused more on language usage and coherent writing and it used a nominal scale of 1 to 5 where one indicated lack of or poor language usage while 5 indicated mastery of language use. The content rubric was assessed out of 100 marks by the lecturer concerned and focused on conceptual and procedural knowledge by assessing the general quality of the report (10) ; articulation of aim/objective and apparatus (5); method (5); theory (10); presentation of results, tables, graphs and sketches (30); discussion/conclusion (30) and bibliography (10).

Table 3.2: The structure of the traditional laboratory report template, the modified (intervention) and the areas that were assessed for argumentation.

Traditional template lab report sections	SWH intervention additions	Areas used for assessment of argumentation
Aim/objective	Aim/objective	
	Introduction (exploration of beginning ideas)	Exploration of beginning ideas, Warrants
Apparatus	Methods and Materials	Backings – in terms of rigour of the investigation
Method	Observations	Data and backings
Theory (definition of terms)	Theory (use of theory and key terms to advance argument)	Backings
Results	Results	Data/evidence and backings
	Claim	Claim and qualifier based on evidence, warrants and backings
Discussion/Conclusion (Includes explicit instruction to address trends, anomalies and possible improvements)	Discussion (Includes explicit instruction to base discussion on preceding laboratory report sub-sections and to address trends, anomalies and possible improvements)	Rebuttals
	Reflection	Understanding of the validity of the claim and how beginning ideas might have changed.
Bibliography	References/ Bibliography	

3.4.3.4 Focus Group Interviews

Focus group interviews were held twice with representatives from each of the three groups. The first set of interviews was held in Step three of the Research Design, after the second laboratory report was written in order to understand the participants' experiences with writing laboratory reports first, using the traditional template (baseline) and second, using the intervention. Moreover, focus group interviews were used in order to elicit more nuances responses from participants and to ascertain whether participants' interview responses and experiences with disciplinary genres are the same or different from their initial responses to the pre-test questionnaire. Most importantly, these focus groups interviews provided a "collective [student] perspective" and their group opinion is as important as their individual responses (Arthur et. al., 2012, p.187). The second set of interviews was held in Step 4 of the Research Design after the third laboratory report was written. These interviews sought to understand the students' experiences and to understand what effects both the intervention and the traditional template had on students' laboratory report writing. A set of semi-structured interview questions were prepared for each group and permission to record each group interview was obtained beforehand. The traditional and the intervention templates were used as prompts before questions about each template were asked. Each focus group interview meeting had between four to eight participants who were selected based on the following criteria:

- Adherence to the instructions given on completing work online or not online (online steps: Upload first draft for peer review, review partner's draft using a model marking rubric and upload, do recommended changes, upload final draft and submit)
- Deviation from instructions (including those who have struggled to upload)
- Good writing using the modified writing heuristic,
- Incomplete and not so good lab reports even though a writing heuristic had been provided
- Students whose writing seems to have improved in the second lab report when compared to their first lab report

Individual interviews were also held with the two mechanical engineering lecturers involved in the teaching of MEC 1111 and the laboratory technician who was responsible for setting up laboratory practical sessions.

3.4.4 Data analysis

The Quantitative data generated from the Cornell Critical thinking test, the laboratory report using the argumentation and language rubric as well as the content scores allocated by the engineering lecturers were captured on an Excel spread sheet with coding for all the variables of interest were sent to the NMMU Statistical Services Unit. Descriptive statistics were generated as well as inferential statistics using Analysis of Variance techniques

(ANOVA) and Analysis of Co-variance (ANCOVA). The qualitative data were considered against the *a priori* coding categories gleaned from the literature. The *a priori* codes used focused on disciplinary content and disciplinary learning, genre, reading and writing.

The codes used were:

(i) The nature of disciplinary writing (Hodson, 2009; England et al., 2008; Prain, 2006; Jacobs, 2005; 2007a; 2007b; Schwartz et al., 2004; Yore et al., 2002; Osborne, 2002; Driver et al., 1996; 1994).

(ii) Relating laboratory work to disciplinary concepts (Wallace et al., 2007; Greenbowe & Hand, 2005; Rudd II et al., 2001).

(iii) Limited learning by students from laboratory practices (Nesbit, 2008; Greenbowe & Hand, 2005; Osborne, 2002; Rudd II et al., 2001; Keys et al., 1999).

(iv) Wrestling with content and rhetoric (Prain, 2006; Yore et al., 2002).

(v) Lack of familiarity with the genre (Whitehead & Murphy, 2014; Department of Mechanical Engineering Survey, 2013).

(vi) Exposure to reading and writing (Knott et al., 2011; Webb, 2010; Pearson & Moje, 2010; Lillis & Scott, 2008; Mayaba, 2008; Ivanic, 2004; Yore et al., 2002; Wellington & Osborne, 2001; Lea & Street, 1998).

(vii) Beliefs about writing (Knott et al., 2011; Ivanic, 2004; Rowell, 1997).

(viii) Beliefs about learning to write (Lombard & Knott, 2013; Knott et al., 2011; Lillis & Scott, 2008; Ivanic, 2004; Rowell, 1997).

3.4.5 Validity and reliability

The Cornell Critical Thinking test is a well-established standardised test. The validity of the argumentation rubric was based in literature and argumentation and the reliability was considered as a factor of the match between students' responses and what could be expected of them as suggested by literature on argumentation. Moreover, argumentation is inherent in the SWH as while not explicitly stated, students are expected to consider the relationships among claims and evidence. The language rubric was developed using an Academic Literacies approach which views language and writing as social practices. The validity of the language instrument was checked with a language and literacy expert. Content data were marked by disciplinary experts. Regarding thematic analysis, the *a priori* themes were developed from the literature produced by experts in the field.

3.4.6 Ethical considerations

This research study forms part of a larger research project on developing writing literacy in the Department of Mechanical Engineering at Nelson Mandela Metropolitan University. The ethic clearance number is HUM12.84.8 [H12-ENG-PGS-001]. Informed consent from the participants was requested and obtained. The purpose of the research project was made clear, as was the fact that participation was voluntary and that participants could withdraw from the study any time. Both students and the staff/lecturers participating were assured of confidentiality and that all data generated would be used for the purposes of the research study only.

3.4.7 Methodological limitations

Firstly, the Cornell Conditional Reasoning Test (Form X) used was first published in 1964 and it can be argued that the test is very old. Secondly, the test was printed in American English and the setting of certain questions was American while the participants were South African. After careful consideration, the test was administered since more recent versions were not easily available and because the content of the test was still valid as the same deductive reasoning structures were used in recent tests. Differences in wordings or terminology were addressed if participants came across unfamiliar wordings and asked for clarity. Additionally, the Cornell Critical Thinking tests have been used elsewhere in settings beyond the United States of America.

McLellan's 2009 United Arab Emirates University study sought to "determine the efficacy of the Cornell Conditional Reasoning Test Form X in measuring the deductive abilities of students living in a culture different than the culture for which the test was designed, and for whom the English language is not their mother tongue" (p.1). McLellan (2009, p.12) concluded that the Cornell Conditional Reasoning Test, Form X, as originally developed in 1964, "can be considered an effective tool for measuring the deductive reasoning abilities of students in the UAE [United Arab Emirates], after having compared the findings of his study with results of students in the USA and Jamaican studies.

Another limitation is that the duration of the study was relatively (six months). Previous intervention studies in educational settings report that an intervention needs to be used over a minimum of 9 -12 months to stand a better chance of noticing changes (Mayaba, 2013; Wallace et al., 2007). Owing to the participants' tight time table and a number of national public holidays during the first semester of 2014, the SWH tutor (who is also the researcher), could not provide feedback to the online and paper-based intervention groups before the third laboratory report was submitted.

Other limitations pertain to the Moodle online platform used in this study. While all students were familiar with this online platform (all of their module codes have a Moodle account) they still struggled to upload and engage on the online platform because their documents were larger than the allowed 5MB as they also inserted pictures of the set-up during their practical sessions. The majority of the students' struggled with formatting pictures and other graphics so that the size of the documents could be reduced. Another challenge was the scarcity of resources; engineering students do not have computer laboratories of their own, they have to use general computer laboratories as all the students and these are often filled to capacity. The majority of the students were unable to use the general laboratories afterhours and neither did they have internet access in their places of residence off campus.

The number of participating students dropped significantly from pre-tests to post-tests for a number of treasons. There were difficulties with internet connectivity at the time of the post-test questionnaire and it was administered at the end of the semester close to exam time when there was poor class attendance. Other factors include drop-outs from the course, deferring the course due to time-table clashes, and some students not submitting their lab reports to the SWH tutor (researcher). A limitation when using *a priori* thematic analysis is that themes are pre-generated from literature which might limit the diversity of the findings and emerging themes were not considered.

3.5 CHAPTER SUMMARY

In this chapter I have presented, with reasons, why a quasi-experimental research design with pre-tests, baseline, intervention and post-tests was employed. The philosophical underpinnings or the paradigmatic approach taken in the study is pragmatic, as this method appeared to be the best fit for answering the complex research questions raised. The methodological issues that were discussed were sample and setting, data generation instruments, data collection, data analysis, ethical consideration, notions of validity and reliability. I have presented a table summarising the key elements investigated that is, critical thinking, argumentation, conceptual knowledge and language literacy, from each instrument as well as the method of analysis, is presented. Another table has been included that indicates the similarities and differences between the traditional template and the intervention as well as their comparison against the tailor-made argumentation marking rubric. Finally, methodological limitations were also discussed.

CHAPTER FOUR

RESULTS

4.1 INTRODUCTION

This chapter presents the results provided by each data generating tool. These results are analysed and discussed in the next chapter. The results reported in this chapter include, firstly, data generated from two initial questionnaires which assessed the general and discipline specific literacies practices that participants might have learned in high school before enrolling for the first year Mechanical Engineering course namely, Mechanics of Machines. Secondly, the data derived from a critical thinking test that was used both as a pre-test and as a post-test is presented. Thirdly, this chapter also reports on the results of two laboratory reports, one on the ‘triangle of forces’ (pre-test) and another on ‘friction’ (post-test). Fourthly, the findings from focus group interviews with students who have used the intervention (Group 1 and Group 2) and those who have use the conventional laboratory report writing template (Group 3) are presented, as well as a report on individual interviews with staff. Fifthly, post intervention questionnaire results and a chapter summary are provided.

4.2 OVERALL RESULTS PER INSTRUMENT

The results of the initial questionnaires, Cornell Critical Thinking test, laboratory report data, focus group interviews with students, individual interviews with staff members and the post-intervention questionnaires are presented below.

4.2.1 Initial Questionnaires

Questionnaire 1(a) was used to generate the biographical data of participants as well as their general literacy practices based on their high school experiences of reading and writing. Questionnaire 1(b) was used to generate the respondents’ disciplinary literacy practices based on their experiences of high school scientific investigations.

A variety of languages were indicated as home languages, with Xhosa as the dominant language (Figure 4.1). Despite only 25% of the students having English as their first language, three out of four students recorded that they had never consulted dictionaries when writing laboratory reports in English.

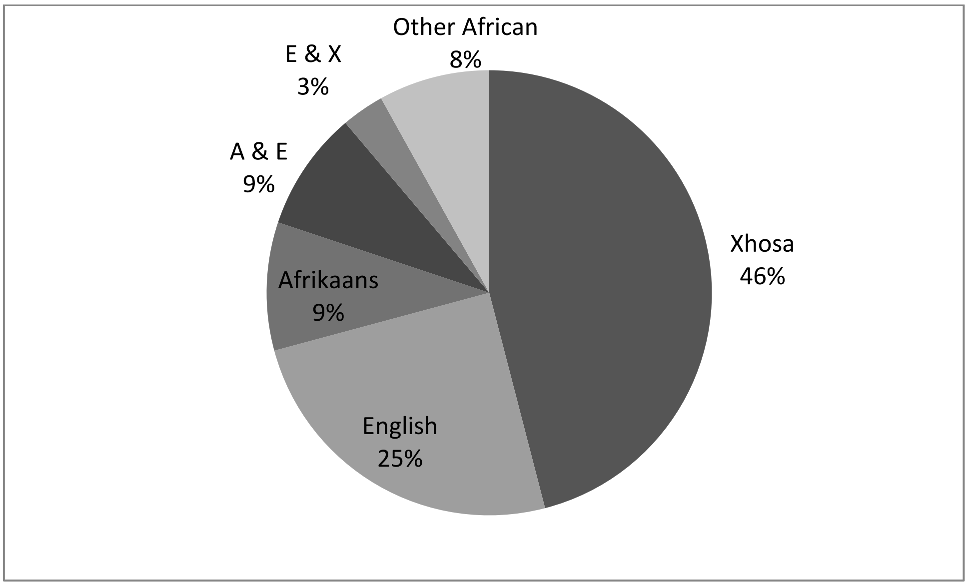

Figure 4.1: Frequency distribution of home language as a percentage (n=172)

The majority of first year mechanical engineering students participating in this study were fairly young (Figure 4.2) and almost all of the respondents (95%) had begun their tertiary education at NMMU. Of the 176 respondents, 87% were male and 92% were semester one (s1) students meaning that they were in their first semester at university. Only 11 (7%) of the respondents were either in their second or third semester at university.

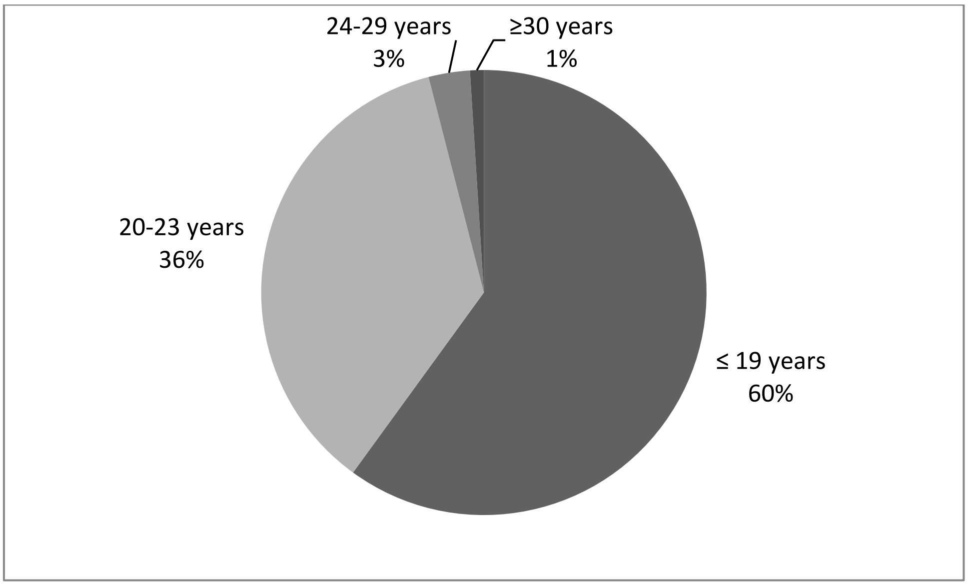

Figure 4.2: Frequency distribution by age as a percentage (n=176)

The total number of respondents repeating the module was 19 out of 159. Only 12% of the students resided on campus, 33% resided closer to campus and 56% resided at a distance of 15-40 kilometres away from campus. Thirty nine percent of the respondents did not have a personal computer device available for their use off campus.

4.2.1.1 Literacy practices at university entry level

The percentage of respondents who have never written laboratory reports in high school was 45 while those who have written between one and four laboratory reports made up 38% of the total number of responses where n=176. Eighty two percent of the students said that they knew that well-written laboratory reports are necessary in engineering while only one percent did not see the need for writing laboratory reports. Half of the students recognised that they need more than one draft to provide an acceptable laboratory report while two out of three said they enjoyed discussing their writing with someone else. More than half said that they seek help when they encounter problems when writing, while one third said that they try and work out the problem themselves.

4.2.1.2 Disciplinary literacy practices at university entry level

The data suggest that most of the students had been exposed to scientific investigations while at high school through science subjects such as biology and chemistry. An indication of how respondents perceived scientific investigations while at school is illustrated in Figure 4.3.

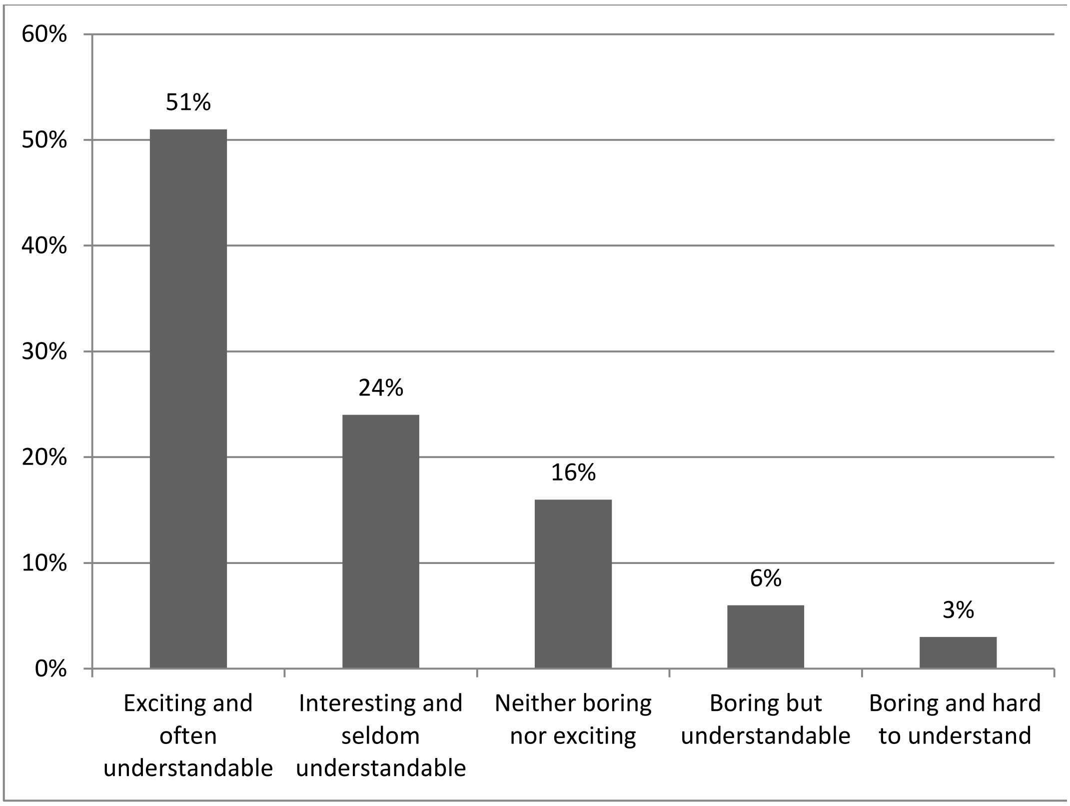

Figure 4.3: Participating students' perceptions of the scientific investigations they had done while at school

Forty six per cent of the respondents indicated that they used scientific apparatus effectively in groups or in pairs, 32% said they shared and used apparatus effectively, and the remaining 21% indicated that they either watched or not used the apparatus. When asked whether they were unfamiliar with science concepts that were taught using scientific equipment, 39% of the respondents agreed with the statement and 17% said it was difficult to follow the lesson. Lastly, 43% of the participants agreed that as part of their laboratory reporting they were required to reflect on laboratory processes and note whether their thinking had changed after the experiment while 9% disagreed with the statement and the remaining 48% said they were either unsure or only sometimes were they asked to reflect.

4.2.2 Cornell critical thinking test

The specific critical thinking test used was the Cornell Conditional Reasoning Test, Form X. Ninety six students wrote the pre-test and 69 wrote the post test. Fifty six students wrote both the pre- and post-test which allowed for matched pairs t-test analysis. As expected the frequency distribution in terms of gender was predominantly male (77%). The matched pairs comprised 48 students (86%) between ages 17-19 and 8 (14%) between ages 20-32 years. The majority of South African youth enter tertiary education at age 18 or 19 and, in this particular investigation, 57% of incoming first year students were 18 years old and 20% were 19 years old.

No statistically significant difference in was found between the ages of the students in the Online, Paper and Control groups, (Chi²[d.f. = 2, n = 56] = 0.80; p = 0.671). Moreover, there is no evidence of significant differences between the gender groups, (Chi²[d.f. = 2, n = 56] = 0.25; p = .882). Of the 72 multiple choice questions answered by the students in the test, there were certain questions that had unexpectedly low (≤ 35%) success rates such as questions 11, 18, 23, 26, 30, 34, 48, 53 in both the pre- and post-tests (see *appendix M* for detailed results of the Cornell critical thinking test).

Analysis of variance (ANOVA) techniques were applied to the pre-test data and reveal no statistically significant differences between and within groups (F=0.396; p = .675). ANOVA post-test by group also bore no difference between and within groups (F=1.140; p =.328). ANOVA for the changes in mean scores of the groups indicated no statistically significant difference in change in mean scores (F=0.731; p = .486). Although no statistically significant differences were evident between these changes in mean scores, it can be seen that the drop in mean score for the 'paper' participants was statistically significant (see table 4.1).

Table 4.1: Pre-post change in mean scores for the three groups participating in the study

Group	Pre-test	Post-test	δx	t	p	d
Online	57.5	56.48	-1.02	-0.3	0.765	
Paper	56.39	50.14	-6.25	-2.25	0.037*	0.05 (medium)
Control	58.86	54.37	-4.50	-1.6	0.125	

n=56 *statistical significance at 95% level of confidence

While the drop in scores for the control group was fairly large, -4.50, it was not statistically significant. When considering table 4.1, inspection reveals that on the online group the number of participants whose scores fell by greater than 5%, was 27% for the online group as compared to 50% and 48% respectively for the paper and control groups respectively. In other words, the online group had the smallest percentage decrease compared with the paper and control groups. On the other hand, when we consider how many students increase their scores by greater than 5%, 40% of the students increased their scores in the online group but only 20% and 29% increase their scores in the paper and control groups. This suggests, although not statistically significant, that presenting the writing heuristic online had a more positive (less negative effect) effect on the students' writing. The drop in score was least in the online group and 40% of the scores in the group improved.

Table 4.2: Increases and decrease in the Cornell Test pre-post scores per group

Group	Down >=5%		Similar		Up >=5%		Total	
On-line	4	27%	5	33%	6	40%	15	100%
Paper	10	50%	6	30%	4	20%	20	100%
Control	10	48%	5	24%	6	29%	21	100%
Total	24	43%	16	29%	16	29%	56	100%

(Chi²[d.f. = 4, n = 56] = 2.77; p = .598).

Overall, the Cornell test data are difficult to explain but will be discussed in greater detail in chapter five.

4.2.3 Laboratory report data

There were three key elements investigated from the laboratory report as a data generation instrument, namely, *argumentation*, *content* and *language*. As mentioned earlier, for the purposes of this study, only the first laboratory report on the 'triangle of forces' and the third, on 'friction' are considered as pre- and post-tests on laboratory report writing. The argumentation and language scores (n=38) were assessed at the same time as part of the intervention while the content score (n=91) was assessed separately by engineering lecturers. The differences in numbers are accounted for in the methodology section in chapter three.

4.2.3.1 Argumentation score results

Inferential statistics using one-way analysis of variance techniques were generated in order to determine whether the differences between the pre- to post-tests were significant. A total of 38 matched pairs (n=38) were obtained for the analysis of argumentation. There were 5 matched pairs for Group 1 (online intervention); 10 matched pairs for Group 2 (paper-based intervention); and 23 matched pairs for Group 3 (comparison group which used the traditional paper-based template. The mean scores for a pre-test on argumentation were 40%, 35%, and 41% for Groups 1, 2, and 3, respectively. There were no statistically significant differences between groups in the pre-test. The *p-value* was above 0.005, which means any differences that might have occurred were probably due to chance. For the post-test the mean scores per group were 68%, 70% and 49%, respectively. Inferential statistics results suggested that there was a statistically significant difference between the groups in the post-test at the 99% level of confidence ($p \leq 0.001$). Even though all three groups were the same at the beginning, with no statistically significant results in the pre-test, their post-test results show a statistically significant difference after the intervention.

A Scheffe test was done to determine where the differences lay. Statistically significant differences occurred between Group 1 (online intervention) and Group 3 (control), where $p \leq 0.042$ and the effect size (Cohen's d) was large at 1.21. However, an even larger effect size of 1.69 occurred between the paper-based intervention group (Group 1) and the control group (Group 3). A statistically significant difference at 99% level of confidence ($p \leq 0.002$) was also observed between the two groups. There was no observable difference between the online group and the paper-based group (Table 4.3).

Table 4.3: Effect of the intervention on argumentation scores between the three groups

Groups	Scheffe' p	Cohen's d (effect size)
Online vs. paper-based	0.951	
Online vs. control	0.042*	1.21 (large)
Paper-based vs. control	0.002**	1.69 (large)

*Statistically significant difference at 95% level of confidence;

** statistically significant difference at 99% level of confidence

4.2.3.2 Content score results

The laboratory reports were submitted directly to the lecturers for grading, and not always to the researcher electronically as requested, a larger sample of 91 matched pairs of content marks were obtained (n=32 for Group 1; and n=26 for Group 2 and n=33 for Group 3). The pre-test mean scores for Groups 1, 2 and 3 were 32%, 53% and 53% respectively. The post intervention results provided mean scores per group of 62% for Groups 1 and 2 and

63% for Group 3. The post-test mean scores increased from the pre-test by a little over 10%, and there were no statistically significant differences between groups (p=0.968) despite Group 1 and Group 2 using the intervention.

4.2.3.3 Language score results

Of the 38 matched pairs attained (n=38) for the language score, five matched pairs were for Group 1 (n=5); ten matched pairs (n=10) were for Group 2 and lastly, Group 3 had 23 matched pairs. The pre-test mean scores for Groups 1, 2 and 3 were 48.6%, 40% and 38.8% respectively. Statistically, there was no significant difference between groups for the language pre-test. The post-test mean scores were 67.2%, 67.5% and 48.5% for Groups 1, 2 and 3, respectively. A Scheffe test indicated that there was (i) a statistically significant difference at the 99% confidence level between the online and the control group, and between the paper-based and the control group (Table 4.4). As was the case with the argumentation scores, the greatest positive change in score was reflected in the paper-based group data.

Table 4.4: Effect of the intervention on language scores between the three groups

Groups	Scheffe' p	Cohen's d (effect size)
Online vs. paper-based	1.000	n/a
Online vs. control	0.043*	1.19 (large)
Paper-based vs. control	0.006**	1.32 (large)

4.2.3.4 Analysis of co-variance

To further verify the results, analysis of co-variance (ANCOVA) statistical tests (see Appendix N) were performed which confirmed the previous results were confirmed, namely that there were statistically significant differences at the 99% level of confidence in terms of argumentation between the three groups (p=0.000) and the differences were revealed by means of a Scheffe test to be between the control group and both the online group (95% level of confidence) and the paper-based group (99% level of confidence) with both the latter groups improving their mean scores statistically significantly over the control group. No statistically significant difference was revealed between the online and paper-based groups (p=0.944).

Analysis of co-variance also showed a statistically significant difference between the groups in terms of language use (p=0.02) with a Scheffe test revealing the differences again being between the control group and the online group (95% level of confidence) and the paper-based group (99% level of confidence) with both the latter groups improving their mean scores statistically significantly over the control group. Again there was no statistically significant difference between the online and paper-based groups change in scores (p=1).

Analysis of co-variance in terms of content revealed no statistically significant differences between any of the groups in terms of change in scores between the pre-post-test (first and last laboratory report; p=0.899). However, when all three key elements, argumentation, content and language (ArCoLa) were combined and subjected to one-way analysis of variance techniques to determine differences a statistically significant difference was revealed between the three groups, but with the Scheffe test revealing a statistically significant difference only between the control group and the paper–based group (p=0.010).

4.2.4 Focus group interviews with students

Pre-selected students from each of the three groups, Groups 1 (online intervention using the expanded version of the Science Writing Heuristic), Group 2 (paper-based intervention also using the expanded version of the SWH) and Group 3 (conventional laboratory report template used by Department of Mechanical Engineering at NMMU), responded to focus group interview questions based on high school and first year university scientific investigations and laboratory report writing experiences. In this report the experiences and perceptions of students using the intervention, that is, Group 1 and Group 2 are represented first while those of Group 3, the comparison group are presented last. Even though students in Group 3 did not use the intervention, their experiences are still important in terms of contributing toward laboratory report writing instruction in Mechanical Engineering. Participants' high school disciplinary literacy practices are presented as 'literacy practices at university entry level' while their experiences in university are presented as 'introduction to laboratory report writing at university' and 'laboratory report writing experiences post the intervention' in sections 4.4.2 and 4.4.3, respectively. Even though emphasis seems to be on the writing of laboratory reports, it is important to note that each laboratory report written was based on a real practical scientific investigation conducted by the students in an educational laboratory at the research site. An interpretation of the participants' responses in terms of the *a priori* themes identified in chapter three follows in the next chapter.

4.2.4.1 Literacy practices at university entry level: Intervention Groups

Question 1: Have you written laboratory reports at high school?

The majority of participants in the intervention groups reported that they had written up to a maximum of three laboratory reports in biology and natural science subjects while in high school, while a few students reported that they have never written laboratory reports before. Those who have written laboratory reports before highlight that their teachers provided a "structure" for writing laboratory reports and they were taught how to write in a "step-by-step" fashion and teachers also used examples. The laboratory report structure that was used in high school by most of the participants comprised of an 'introduction', 'method', 'results', 'discussion' and 'conclusion', but that they got little guidance on writing laboratory reports beyond setting out the structure. Many of those who said that they had not written any laboratory reports before also claimed that their schools "did not even have a laboratory" and one student asserted that "this is all new to me," that is, conducting scientific investigations in a laboratory and reporting on findings using a laboratory report.

Question 2: Has the 'structure' given for writing laboratory reports helped you to understand the content of what you were learning in class, whether it was science or biology?

Many of the students who had experience with writing laboratory reports in high school agreed that writing laboratory reports contributed to their learning because they were provided with a structure and a step-by-step guide of how to write. Some of the respondents also suggested that understanding and learning was indicated to them when they were able to 'get the answer' based on their understanding of procedures. One respondent said, "Yes it [structure of lab report] definitely helped, uhm!... While we were doing it, the ways we were doing it *uhm nca*!... We got the answer!"

Another important finding was that doing the hands-on work in the laboratory has helped the participants to "see what the teacher was saying" (Student M). Student N elaborated by making an example about periodic calculations. She said, "when you do it [investigation] practically, you will prove whether what you get practically is more or less what is reflected periodically". Student M concurred by saying that practice and what the teacher had said, was further validated by textbook formulas for calculations. This student would "go back to the textbook to check formulas for calculations." All in all, the structure of writing laboratory reports appeared to have helped students "in terms of combining practical and classwork".

4.2.4.2 Introduction to laboratory report writing at university: Intervention Groups

Students' experiences and perceptions using the traditional and intervention templates were established by comparing the two templates.

Question 3: How did you find the second lab report template (intervention) compared to the first lab report template (conventional)? Did it help you in any way to understand the practical and what you were taught in class?

Students' views on this matter were conflicting. Some students did not think the intervention helped them to understand practical work any better than the conventional template. However, the same students believed that the intervention helped to formulate answers more effectively. One of the respondents, student O, reasoned that the intervention was "broader…the previous one [conventional] was… ja this one [intervention] was more uh… accurate, drawing, giving you answers". Another student asserted that the intervention helped because it broadened his level of thinking, by not simply understanding the terminology but by understanding the concepts more clearly. An extract from student M's response to illustrate this point is given below:

> I think it broadened my level of thinking like not only understand what centre of gravity is but to understand clearly the concept what is centre of gravity… so it broadened my level of thinking. (Respondent 4/Student M, Group 1)

Again, compared to the conventional template, one student reported that the intervention made him "more aware of what to write, how to write, [and] what you needed to write". Conducting the second laboratory practical on the 'centre of gravity' was even better for another student (K), compared to undertaking the first practical on the 'triangle of forces' since the student was doing a practical investigation for the second time. For this first practical investigation, this student pointed out that she "did not even understand the theory"

(Student K, Group 2). Therefore, for Student K, the intervention assisted her when writing only because she was writing a laboratory report for the second time.

When asked what made the students feel more confident with writing using the intervention template, the students highlighted the following points:

(i) being provided with a semi-structured guide with examples of how to write
(ii) the presence of a marking rubric
(iii) clear instruction in terms of what to cover when writing and how much writing is required
(iv) presence of prompts instead of instructions

To illustrate the latter point, Student N said, for example, under 'discussion' it was easier to respond to "a simple question like [prompt] 'what did you understand?'". This student says it was difficult to respond to an instruction like "write anomalies".

Question 4: How did you feel when you saw examples that were guiding you in your writing - in the second lab report whereas they were not there in the first one?

The students' feelings towards the use of modelled writing were mixed: the majority responded positively while a few shared negative feelings. Some of the negative feelings were that the examples of how to write made them to "think less" as they almost felt obliged to use the same wording as the example. Most of the students found the examples helpful as they could get an idea of what was expected from their writing.

Question 5(a): How did you find the use of the online writing platform? (Silence) How was your experience of it?

This question was directed to Group1 (online intervention) only and the respondents' perceptions were positive but they were also burdened by a concern about an "unresponsive" partner. Student O asserted that "if the partner you were working with was more receptive to your feedback, I think it would have made it a pleasant experience". Other participants nodded their heads and shared that their partners either "ignored" them or they did not upload their own laboratory reports online for peer review. Some of the partners did not effect the suggested changes from peer review. One pair that worked well together reported that they both benefited from the exercise. Some of the unresponsive partners did not seem to take the feedback exercise seriously as another partner said to his peer he was not worried about writing laboratory reports. Generally, there seems to have been a one-way exchange of laboratory reports during the peer review process.

Question 5(b): How did you find the use of an email system when sharing your work with your partner? (Silence) How was your experience of it?

This question was directed to Group 2 (paper-based intervention) only and the participants' responses were positive for those who had previous emailing experience and in-between for those with no experience with emails. The former highlighted that it was easy to access emails.

Question 6: What were your feelings towards peer assessment and the use of the marking rubric?

Almost all of the respondents shared the feeling that the peer review process using the tailor-made assessment rubric for argumentation and language could have been a valuable tool if both partners were receptive to it. One student believed that if her partner was open to the feedback he received, he could have achieved better marks. Reportedly, this student lost marks because of "incorrect equations, language and layout". In agreement, some of the students added that the marking rubrics made them aware of what they would not have been aware of while another student added that the rubrics improved the general quality of his laboratory report.

Other important findings regarding peer assessment and the use of a tailor-made argumentation and language rubric was the "shock and feelings of intimidation" on the part of the peer reviewer. One student shared that seeing her partner's work she got scared as she realised that her partner's report had pieces of information that hers did not have. This student (Student K) and others also felt that their work might have been inadequate compared to their peers, and they often felt uneasy about improving their reports after marking a partner's report in case they are accused of copying. An extract from Student K's interview transcript reads as follows:

> Not good actually, not good because when you see your partner's work and you realise that yho! he did this and I didn't do it, he did this and I didn't do it. Yho! 'Cause

> obviously when you are reading you are going to see all of his lab report and you will see his calculations and maybe you did not do this one. Yho! You start feeling like maybe he's gonna get more marks than me and you start feeling like your work is not what the lecturer wants. Now you think of doing it again [improving] but then you feel like you will be copying. You don't feel free. (Student K)

One of the students mentioned that using the marking rubric was confusing for her as she did not know how to use it and as she was still struggling with her own laboratory report. Finally, most of the students agreed that what is most important is to have a partner who is willing to work and share their work.

Question 7(a): How can the writing template and the online writing platform be improved?

Most of the students in Group 1 (online intervention) felt that the writing template could be improved by reducing the number of prompts in order to avoid repetition when answering. Only one student did not agree with this view. Regarding improvements to the online writing platform, students had mixed views. Some felt that the online platform was user-friendly and appreciated the "how-to-guide" that was provided for ease of access. In addition, the online platform sent email alerts when documents were uploaded or if a partner edited the work. An alternative view was that the online platform should have "more flash support and that it must be more interactive". One of the students revealed that she struggled with uploading her work online as she did not know how the platform worked, and the majority of those who did not upload shared that they did not have the time to share their work online.

Question 7(b): How can the writing template and the peer review system be improved?

Respondents in Group 2 (paper-based intervention) felt that the prompts provided in the writing template were helpful: they gave them a "head start" and an idea on how to expand on what was given. This group also emphasized the need for explicit instruction on how to write the 'discussion" and "conclusion" sections of the laboratory report as these sections carried the highest marks. One student noted that he had to "Google" what "anomalies" and "trends" meant, especially when writing the first laboratory report. This group did not comment any further about peer assessment but they emphasized the need to receive feedback from the lecturer, and to have an opportunity to view their marked laboratory reports well in time before the next report is due, in order to avoid repeating errors on the next report.

Question 8: How can you be helped to write better? Do you think you need any more help to write better?

The participants shared diverse opinions regarding more assistance with writing laboratory reports. Some were more confident and they felt they did not need any more help while some felt that the "fundamentals should have been set in high schools through writing skills". While some participants agreed with the latter, they also expressed that perhaps a lot of other students might not have been exposed to such writing and that these students may not have English as a first language so they too, needed to be considered. A few of the respondents noted the apparent differences between high school and university writing and the need for guided writing even for those students who had written laboratory reports in high school.

Extra support was required by students in terms of using the computer to draw, insert equations and diagrams in their laboratory reports. Student O shared how she had to "help" a fellow student who, seemingly, was not as computer literate. In agreement, Student K said, "I also struggled with this computer what what. So I did not do the equations, the graphs, the sketches on the computer". This student also added that "it's difficult when you are doing it for the first time" and, based on her high school experience, it was helpful to have a more experienced person to help with inserting shapes and with drawing. Most of the students agreed that a consultant is required especially with using equations and drawing diagrams on the computer. Another student expressed a wish that a consultant would be available to provide feedback on the first draft of the report but another, Student O, responded that she thought "that was the reason for the peer review process". The final suggestion from the respondents was that perhaps the Communication module that is taught in the second semester should be taught in the first semester and that that module should cover certain elements of laboratory report writing based on the engineering syllabus.

Question 9: You were required to reference secondary sources in the theoretical section of your laboratory reports. Did you find relevant sources to quote in your writing?

A few of the respondents said they had consulted library sources while some said they referenced electronic books while most relied on Wikipedia for references and definition of key terms. Those who knew that referencing Wikipedia is not allowed in academic writing, opted to quote Wikipedia's reference list instead of quoting Wikipedia. Those who had consulted library books complained that the books were old and that they did not understand them. When asked to expatiate, the students said Lami's theorem was "hard" partly because they had not been taught about in class, they had to "discover new things and new calculations" by themselves. The most difficult part was knowing "how to relate Lami's theorem to this practical that you are given".

4.2.4.3 Literacy practices post intervention

The participants' literacy practices post the intervention (the expanded science writing) have been categorised according to this study's key elements that is, *argumentation, content* and *language,* with the addition of *writing* as another element. The post intervention focus group interview results are grouped into key elements, firstly, in order to assess qualitatively whether the intervention has had any effect of participants' laboratory report writing practices. Secondly, this has been done in order to avoid redundancy as most of the respondents' views and experiences seem to be similar and these were expressed elaborately in section 2.4.2. In a bid to summarise and present the central post intervention practices without presenting the focus group interview questions one by one as done in section 2.4.2, the umbrella key element of *writing* was introduced. Although all of these categories overlap as much as they exist within each other, for the sake of clarity, they will be separated. Because writing underpins or is underpinned by the other key elements, I will start by presenting post intervention findings based on writing as a literacy practice.

(i) Writing

Most of the participants from both experimental groups, that is, Group 1 and Group 2, highlighted that they have benefited from the use of a laboratory report template, which "guided" them in the practice of writing a laboratory report. Firstly, one respondent said that the template

> ... gave me a guide in terms of how to approach the report, to consider the thinking process that I will be taking the person reading my report through, write clearly, and systematically, something I would not be able to organise myself.

Secondly, the participants said they had learnt from the template how to “structure” or “layout” their own laboratory reports. Thirdly, the prompts assisted the students in terms of knowing precisely what was expected of them in a particular laboratory report section. Fourthly, the examples of how to write gave them an idea of how to go about writing their sentences in full. However, for some of the participants the examples of how to write “limited” them in terms of their own writing. One respondent noted that she struggled to rewrite the exemplars in her own words since sometimes there are not many ways of expressing a particular point. Although the prompts were helpful in helping the participants to “think more”, they were also found to be “harder”. Fifthly, almost all the participants agreed that the examples of how to write helped by demonstrating how to insert and label diagrams and graphs and how to present information graphically.

Regarding peer evaluation, most participants noted that they do not submit their first draft but rather submit a second draft. One student revealed that “when I write it [laboratory report] the first time, there are quite a few mistakes and I checked it again. I checked it about four times, made sure it was correct. I also checked my calculations”. Other participants report that they checked their own laboratory reports against the tailor-made assessment rubric “to see if we have written correctly and from where we can improve”. Again, the importance of having a responsive partner, who can participate in the peer review process, arose. In terms of the online platform, some of the students did not like the alphabetic assignment of peer review partners since these partners are different from the ones the students had during the laboratory practical. Another important factor was the inability of students to view their laboratory reports timeously. Most of the students report that since they could not receive their marked laboratory reports well in time before the next laboratory report was due; they could not see where their problems lay and thus, could not improve on the following reports because they were not made aware of what they should improve.

(ii) Argumentation

In terms of argumentation, only a few students articulated that there seemed to be differences between the laboratory reports written in high school and those written at university. One respondent, Student P articulated the difference in the following manner:

> The only difference with the investigations we did in high school and here at varsity is that there is a different approach. In previous investigations we had investigative question (so you investigate what you are looking for), aim, method, find your results and you came to a conclusion. Compared to the lab reports that we do now, it's not as simple as we did previously so you'd need a different approach because it has more information that's needed. (Student P)

While the students have already highlighted that the prompts forming part of the intervention have "broadened [their] level of thinking", most of them emphasized that some of the prompts were "hard", "challenging" and "more difficult". The respondents identified one of the challenging prompts as, "what will other people say if they are opposing what you are saying about theory?" The second prompt was "what would you say to convince other people that what you did was right?" One respondent's interpretation of the two prompts was, "to me it made me to put myself in other people's perspective and made me to see my work as incorrect so that I can improve it". Another respondent said, "I was struggling with that question about what would someone else think, so I just wrote what I thought was wrong and I was corrected by my peer". On the contrary, one student (Student Q) said the prompts;

> engraved the concepts in your head even better because one the question is asked, it forces you to think according to the question asked. It makes you to think deeper and to think about the relationships that you are supposed to think about. (Student Q)

Finally, the same student said,

> Every time I wrote the report I'd see myself in a position where I was beginning to write like the people (style, format) who write textbooks. If maybe I did a PhD someday, I'd be able to use these skills, how to reference other people's work, being part of a global network of people where knowledge is shared. It also taught me to be careful of writing something as if they are my own discoveries. Using the right tone representing the work in a very professional manner. (Student Q)

(iii) Content

Students' experiences affirm that the practice of writing, especially when writing the laboratory reports, contributed to their understanding of content knowledge in mechanics. "The parts of the laboratory report that we understood the most are those that had references to what we were learning in class," recalled one respondent. The same respondent made an example that for the practical work on "'friction' and 'centre of gravity'- we had an idea of what was going on because we had already done that part of the work in class, we had the theoretical part already". Another participant added that the theoretical knowledge gained during class time had also given them an understanding of how to do the necessary calculations. At the same time, the practical work done in the laboratory assisted the students to understand the content knowledge even better. One participant relayed that "as we got the results, we were able to compare the theoretical results we got from class with the practical results that we got as we did the experiments in the lab". This participant elaborated by saying,

> ... in terms of writing the lab report, we wouldn't have a useful link between what we learn in class because most of what we learn in class is problem solving whereas in the lab report you analyse most of the things that you have to do with the lab report. And most of the stuff we write in the lab report is not usually what we do in class. (Participant)

Lastly, some of the students also highlighted the importance of referring to their course textbooks when unsure and in order to be guided on the factors that might influence the results. One student observed that "it is pointless doing an experiment if you do not know which variables to control for". This student relayed that, "we knew what to change in the prac [practical] and what to keep constant to obtain results very close to the theory.

(iv) Language

The respondents' experiences with language pertained to the use of academic language, disciplinary discourse as well as writing laboratory reports in English. Most of the respondents had English as a first additional language and their mother tongues were Afrikaans, Xhosa and Zulu. Only two respondents were first language speakers of English. When the participants were asked whether writing laboratory reports in English was a challenge, they said "no it was not" a challenge, and neither was it difficult. Another respondent said, "that is what we are used to, even in my school we used to write in English." The challenge with writing in English was "only the big words" or "terminologies" or the "jargon" as some of the students put it. One student shared the frustration that 'lecturers seem to expect their writing as first years to be as good as theirs' and yet 'the lecturers had years of experience with the "big words" while the students only had months of experience'.

The effect of academic language on their laboratory report writing was further identified by one participant: "when writing the report, instead of writing in everyday colloquial language, we had to use a very passive tone which is very [*silence*] it is my own words but I had to change my tone". Further, the ability to write the report using mostly the students' own words depended partly on "how much English understanding or intuition a person has, especially formal writing English which is often informed by how much a person has read." This student, who has referred to himself as an avid reader, said he was confident with using the English language even though his mother tongue was Xhosa. According to this student, writing laboratory reports in English "improved my language of writing and terminology – my writing language like other terminologies that were introduced to me which I did not understand or know before."

4.2.4.4 Literacy practices at university entry level: Comparison Group

Question 1: Have you written laboratory reports at high school?

Most of the respondents indicated that they have written laboratory reports while in high school and a few indicated that they had not been exposed to laboratory report writing. Those who had been exposed mentioned that they still remembered the structure of a laboratory report and they had an idea of how to write one. One respondent shared that when one writes a laboratory report, they start with an introduction, then the method, then discussion and a conclusion at the end. These students report that their teachers showed them how to go about writing laboratory section. This group wrote laboratory reports for biological sciences and chemistry.

Question 2: Has the 'structure' given for writing laboratory reports helped you to understand the content of what you were learning in class, whether it was science or biology?

Most importantly, the majority of the respondents noted that they learned more as they completed their laboratory reports assignments since they also had to do research and give a background of the investigation they were writing about. They found the examples provided by their teachers as being helpful.

4.2.4.5 Introduction to laboratory report writing at university: Comparison Group

The comparison group comprised of Group 3 students. These students have written all three laboratory reports using the conventional laboratory report writing template provided by the Department of Mechanical Engineering at NMMU. Their experiences and perceptions using the traditional template were established in a way similar to the intervention groups.

Question 3: How was your first experience of writing laboratory reports at University? What was your experience of completing the first laboratory report on 'triangle of forces'?

The participants' experiences were diverse and generally positive. Most of the students said their experiences were "good" and associated with learning. One student noted that he learnt about the "process" of conducting investigations, reflection and seeing where one went wrong. One student shared that at first, his methodology was wrong but after consulting other students during the practical, he ended up following the correct procedure. This student claimed that "I compared my own numbers [findings] with those of my peers and I saw the mistakes I made". Another student learned how to work out problems by using summations like "some graphical solutions whatever", says the student. Student K learnt that "it's not good to cook up numbers – to make up your own numbers when you're doing an experiment". The student's reasons are that "I find it [experiment] kind of tiring so I just started making up my own numbers instead of doing the actual investigation". One respondent was disappointed to have achieved lower marks than he anticipated. This student, Student L said "I thought I was perfect but I was disappointed with the mark that I got. I got less than expected."

Question 4: You were provided with a template for writing all you laboratory reports. Was this template useful to you?

All of the respondents found the conventional laboratory report template useful in terms of structuring the report formally. Some students used the word "guideline" to describe the nature of the template. One student said "it helped me to know exactly what to write and where I should put too much effort, e.g. on discussion and conclusion section was 30 marks so I put too much effort there." The student continues to say "referencing had 10 marks so I put less effort there because you did not have to reference much". Student K also described himself as being "kind of a lazy guy" and that the mark allocation template, which is part of the conventional laboratory report writing template, "told [him] where to mainly focus" and he "focused mainly on the ones with lots of marks". In addition, another student said the template also drew her attention to important definitions and a good structural layout while another student said with the help of the structure, he "could write a report, maybe 50 pages – I knew what to do, [and] how to do it".

Question 5: Consider all the laboratory reports that you have written so far. Based on your experience, did writing the laboratory reports help you to understand the theory you were taught in class?

All the respondents agreed that writing the laboratory report assisted them with understanding the theory taught in class. Importantly, the students draw a link between the theoretical instruction that precedes laboratory investigations and the formal writing. One student's reflection is as follows:

Before you do reports, you do theory. And now you're doing it practically and then you see that this is exactly as I was studying. And now you know what to expect and what not to expect. And we were told that the theory and the practical don't always lead to the same thing so that you can compare. It's good to do the theory and the practical and then you can make a statement to say the theory is different.

Two other students elaborated based on their personal experiences. The first student said the "theory learnt in class is always static, it's not moving compared to what we are doing practically". This participant expanded by saying that "not everything is as accurate as theory" and that theoretical results come from experiments that were done in a vacuum whereas in their laboratories, they do not have expensive equipment. The second student's explanation was that "*not everything is as accurate as theory because the practical has certain things like human errors and stuff which are unavoidable. After the prac* [practical] *you begin to see how the theory works itself out*." The first student also agreed that theoretical work "can't exactly substantiate some practical things like give in-depth understanding".

The students seemed to value the writing experience as well while a few claimed that they did not enjoy writing. Those who were positive about writing laboratory reports agreed that "the more you write, the more you apply the knowledge" and "you can tell if you are writing nonsense or something correct". One student noted that writing has a positive effect on his learning if he writes reports on predominantly theoretical modules like Material Science as compared to practical modules like Mechanics of Machines. When probed, other participants responded by saying, "writing reports about practical subjects – it drains your brain cells. As a matter of fact, it transcended me to a higher level of IQ". Based on their understanding of theory and their practical experiences, some students said that they felt confident about explaining to someone who maybe, did not do the practical.

Question 6: Do you think you understood the instructions given?

All the respondents said the instructions were understandable as they were clear and straight forward. One of the two respondents who claimed that they did not enjoy reading, said that from the given instructions, he could "see the logic… I executed the practical very smoothly". The second student said he did not even read the instructions of the practical investigation. He said, "I just look at the equipment on the table and just think this is what we have to do, relating it to what I read in the [text] book. So I do not read the actual instruction to find out what it really says".

Question 7: What support do you think can be given to students in terms of writing laboratory reports?

Various possible solutions were suggested by the respondents but a pressing concern was that the students do not receive feedback well in time in order to learn from their mistakes. Other suggestions were that the students could learn from a previous year's laboratory report that was well written by another student. The need to pre-read the practical guide in advance was also seen as important. One student said that pre-reading helps one to "understand the language used". Peer evaluation, supplementary instruction and feedback practices by the lecturer were also suggested as possible support for future laboratory report writing.

4.2.5 Individual interviews with staff

Three members of staff, two lecturers and one laboratory technician were interviewed in terms of what they expect from student writing and also, their perceptions of the extended science writing heuristic intervention.

4.2.5.1 Expectations from student writing

The staff shared similar understandings of what is expected from first year laboratory report writing. Foremost was the importance of providing support and guidance with conducting laboratory investigations and with writing the actual laboratory report. As such, students were provided beforehand with a laboratory manual, which both guides laboratory work and provides a template for writing the actual laboratory report. Instructions of how and what is to be done in each practical are provided in this manual/template, together with questions that must be answered in the laboratory report. Each work station is set-up differently from the next so that the students' results can be varied. During the investigation, all students were allowed to work in pairs or in threes and they were allowed to talk and help each other but each student was expected to write their own laboratory report.

In terms of writing, the lecturers expect clear, concise and coherent writing that demonstrates a level of accuracy during investigations, appropriate application of theory and formulae, accurate interpretation of instructions, legible and unambiguous sentence and paragraph construction. The referencing style that is expected from student writing is the Vancouver referencing style, both in-text and in the reference list. Students are expected to cite in their laboratory reports a wide range of academic sources or reliable sources to support the theoretical part of the laboratory report. The members of staff also noted that the majority of first year students often struggle with summarising their data in tables. To assist the students, the conventional laboratory report writing template also presented examples of how to present laboratory data into tables and how to insert titles for tables and captions for figures. While guidance and support is to be provided for all students, the lecturers emphasize the need for a certain level of independence and originality on the part of the student. Students are not allowed to copy or to plagiarise.

The pre-reading of the laboratory manual is required before partaking in any practical investigation in order for the student to know what is to be done and how the investigation must be done. The laboratory technician who prepares the set-up of all experiments stressed the importance of pre-reading and asserted that failure to pre-read the laboratory manual results in students being confused and not knowing what to do or how to do the investigation even though they have received the written instructions beforehand, and time was taken to explain the practical orally before the investigation began. As a result, some students miss out on recording meaningful data during the investigation and for some, "writing seems… to be an afterthought". Moreover, students who do not pre-read tend to run out of time before completing the investigation or before they have had the chance to repeat the investigation a few more times. The technician concluded by saying that "if students don't read the guide then all the work we do for them is meaningless".

4.2.5.2 Perceptions of the extended science writing heuristic intervention

The overall perceptions of the extended science writing heuristic (SWH) intervention among staff were positive even though there were concerns as well. Some of the positive comments included seeing the intervention as a "much better improvement" in terms of scaffolding students' writing and thoughts about laboratory investigations. Two of the staff members shared that they would like to "incorporate" the SWH idea of laboratory report writing in other modules that require the writing of laboratory reports. One lecturer indicated that she/he (gender not specified to avoid identification) had already adapted a laboratory report writing template for second year mechanical engineering students, based on the extended SWH.

Two of the three staff members interviewed shared positive thoughts about the use of prompts to scaffold students' thinking as they write their laboratory reports. One member expressed that the SWH encouraged students to "reflect and think back" and that way, the heuristic "teaches students that conducting a practical investigation is not a once-off event". Another noted that even though the prompts might come across as requiring more effort from the students, the "probing" makes the students think. Importantly, one of the key concerns was that while the prompts are good, they might also "stifle students' creativity if they continue to use this kind of writing". While this staff member was happy to see this intervention used, she/he mentioned that she/he "would not want to see it used in more than three practical sessions for Mechanics one". This member of staff feared that students might be "given too much of a helping hand".

Other concerns raised included the fact that the majority of the students' have limited computer literacy especially when using equation editor, drawing in Microsoft Word and Excel, drawing and scanning pictures that are to be attached electronically as appendices and the inability to use text boxes. The tight academic timetable of engineering students at NMMU is 22 periods per week and this is seen as having a drastic impact in terms of engineering staff being able to provide timely feedback to students on laboratory report writing. Lastly, students come across as being shy or embarrassed to ask questions publicly during class time. They tend to ask questions aside after the lecture had already passed and this way, their questions do not receive timely response.

4.2.6 Final questionnaire results

A final questionnaire was administered to all participants to evaluate the knowledge's and practices they were engaging in after writing three laboratory reports. Their overall experience with writing laboratory reports was also ascertained. Certain questions were specific to the experimental group which used the expanded version of the Science Writing Heuristic while other questions were specific to the comparison group which used the conventional template.

4.2.6.1 Results based on writing practices

After being exposed to conducting three laboratory investigations and writing three laboratory reports, 67% (n=30) of the respondents said they knew how to structure a laboratory report. When asked what helped them to write their reports, the following three options had the highest percentages of 70%, 63% and 53% respectively:

(i) The template for writing a laboratory report
(ii) The written instructional guide on the topic
(iii) The written instructional guide on the topic with prompts

When asked whether the respondents were confident with using the marking rubric, 50% of the respondents agreed with the statement while 42% said they were not sure. The participants were also asked about who helped them to understand the assessment rubric for laboratory reports and they were allowed to choose more than one option. Their top three responses at 31%, 14% and 7%, respectively were as follows:

(i) The assessment rubric was clear enough for me to interpret by myself
(ii) The MEC 1111 (Mechanics) lab report writing tutor
(iii) A classmate.

The top three responses to the question, 'who used the marking rubric to assess your writing before you submitted your laboratory report?' revealed that:

(i) Forty seven per cent of the respondents had used the language and argumentation rubrics to evaluate themselves

(ii) Twenty seven per cent requested the Writing Centre to evaluate their reports using the rubrics

(iii) Seventeen per cent did not use any marking rubrics for self or peer evaluation

Three fifths of the respondents indicated that they knew how to use precise, formal language when writing a laboratory report, while 30% were unsure and the remaining 8% disagreed with the statement. When asked what helped the respondents to use signpost words (like however, similarly, therefore) and phrases to link sentences and paragraphs while writing their reports, the following three options were the highest selection rate of 34%, 28% and 21% respectively:

(i) I have always known how to use signpost words and phrases to link sentences and paragraphs together

(ii) The written instructional guide on the topic with prompts (questions) and examples of how to write

(iii) Knowledge gained from another lab report writing module or communication module

When asked whether writing laboratory reports has helped the respondents to understand and explain concepts relevant to investigating the triangle of forces, centre of gravity and friction, 80% of the respondents agreed with the statement while the remaining 20% was either unsure or disagreeing with the statement. Regarding the sequencing of numbers and making links to the reference list using the Vancouver system, 23% said they use the two page Department of Mechanical Engineering Vancouver referencing guide; 20% said they used examples that they found on the internet while other participants said they either used examples of previous reports or they chose the option ‘all of the above’. Based on what the respondents knew when they completed the questionnaire, 74% of them said they expected to do well in writing laboratory reports in future while 17% said they were unsure and the remaining 6% disagreed. The most challenging laboratory report section to write according to students’ experiences, where n=27, are listed below with percentages. Foreigners

(i) first place was the ‘discussion’ with 70% of the respondents agreeing

(ii) second place was the ‘reflection’ with 52% of the respondents agreeing

(iii) third place was the ‘claim’ with 19% of the respondents agreeing

(iv) fourth place was the 'theory' section with 15% of the respondents agreeing

Finally, table 4.4 presents the results of students' responses to the question: *When I write the discussion section of a laboratory report, I use the results of the investigation to…:* The five options given to the students also appear below as part of the table.

Table 4.4: Frequency distributions of students writing practises for the 'discussion section' (n=30)

	No		Yes	
Q4-6 Compare &contrast	12	44%	15	56%
Q4-6 Explain	7	26%	20	74%*
Q4-6 Argue in support of my claim	15	56%	12	44%
Q4-6 Address trends, anomalies & possible improvements.	7	26%	20	74%
Q4-6 Rebut against the aim or a certain theoretical concept (e.g. Lami's Theorem)	22	81%	5	19%**

*Most students (74%) 'explain', 'address trends, anomalies and possible improvements' when they write the discussion section of their laboratory report while few students
** (19%) rebut.

4.2.6.2 Results based on laboratory practices

Participants were also asked about what type of laboratory activities they engaged in before laboratory work (pre-laboratory activities), during the laboratory investigation (during laboratory activities) and after the laboratory activity (post-laboratory activities) in order to ascertain whether they perceived laboratory writing a stand-alone activity and also to ascertain the extent to which laboratory investigations and the writing of reports was a shared activity between one student and their peers.

Table 4.6: Frequency distributions for pre-laboratory activities

	No		Yes	
Q2-1. Downloading and pre-reading the laboratory report instructions guide	17	59%	12	41%
Q2-1. Downloading and pre-reading the laboratory report instructions guide with prompts (questions) and examples of how to write	22	76%	7	24%
Q2-1. Recalling theoretical information and calculations from previous lecturers	9	31%	20	69%*
Q2-1. Reading relevant library books to understand theoretical terms	15	52%	14	48%
Q2-1. Reading about the specific theoretical terms from the internet	16	55%	13	45%
Q2-1. Skimming through the laboratory report writing guide	24	83%	5	17%
Q2-1. Bringing a printed copy of the laboratory report writing guide to the laboratory practical	21	72%	8	28%
Q2-1. Other	26	90%	3	10%

*The majority of respondents (69%), where n=29 said they before they engaged with laboratory activities, they recalled theoretical information and calculations from previous lectures.

Table 4.7: Frequency distributions for activities during laboratory sessions

	No		Yes	
Q2-2.Referring to the printed laboratory report instructions guide when doing the investigation	11	38%	18	62%
Q2-2.Active involvement in doing the laboratory investigation	11	38%	18	62%
Q2-2.Recording data generated in the laboratory report writing template	9	31%	20	69%**
Q2-2.Working in groups of twos or threes	9	31%	20	69%**
Q2-2.Comparing our laboratory procedures with our classmates	18	62%	11	38%
Q2-2.Consulting the laboratory technician when unsure or when experiencing difficulties with the investigation	17	59%	12	41%
Q2-2.Taking pictures of the key procedures and results	5	17%	24	83%*
Q2-2.Discussing and asking questions to group mates while doing the investigation	11	38%	18	62%
Q2-2.Connecting theoretical themes with procedures and observations	14	48%	15	52%
Q2-2.Generating authentic data	22	76%	7	24%
Q2-2.Fabricate or cook-up data	26	90%	3	10%
Q2-2.Identifying my beginning ideas for the investigation	15	52%	14	48%
Q2-2.Other	26	90%	3	10%

*Most respondents (89%) where n=29 said that during laboratory investigations, they took pictures of the key procedures and results while **69% of them indicated that they recorded the data generated in the laboratory report writing template and that they worked in groups of twos or threes.

Table 4.8: Frequency distributions for post-laboratory activities

	No		Yes	
Q2-3.Writing the first draft of a laboratory report individually	5	17%	24	83%*
Q2-3.Recalling my beginning ideas about the investigation	12	41%	17	59%**
Q2-3.Comparing my beginning ideas with the aim of the investigation, observations, and results of the investigation	15	52%	14	48%
Q2-3.Re-writing the methods and materials section as it appears in the laboratory report instructions guide without making any changes	22	76%	7	24%
Q2-3.Re-writing the methods and materials section in past tense, active or passive voice mentioning how materials were used	22	76%	7	24%
Q2-3.Formulating the claim based on observations, results and the theoretical sections of the laboratory report	13	45%	16	55%
Q2-3.Including in-text references in the theoretical and discussion area of the laboratory report	20	69%	9	31%
Q2-3.Include technical graphics such as labeled graphs, tables and pie charts	17	59%	12	41%
Q2-3.Other	27	93%	2	7%

*The majority of the respondents, where n=29, said after laboratory investigations they wrote the first draft of their reports individually, while ** 59% said they recalled their beginning ideas about the investigation and

***55% indicated that they formulated a claim based on observations, results, and the theoretical sections of the laboratory report.

4.3 CHAPTER SUMMARY

In this chapter the results of the study are presented based on each data generating tool used. The key elements reported on were *critical thinking, argumentation, conceptual/content* and *language* scores. The data generating tools included questionnaires, the Cornell Critical Thinking Test, laboratory reports, focus group interviews with students and individual interviews with three mechanical engineering staff, two lecturers and one laboratory technician. All instruments were administered both as pre- and post-tests. Both quantitative and qualitative analyses were employed to ascertain the effect of laboratory report writing in a first year mechanical engineering class at a South African comprehensive university. Firstly, the participants' general and discipline-specific literacy practices were assessed at university entry level based on their high school experiences. Secondly, their disciplinary literacy practices based on conducting laboratory investigations, writing practices as well as writing the laboratory report as a discipline specific genre, were assessed using the conventional laboratory report template and the expanded Science Writing Heuristic (intervention). Thirdly, the participants were divided into three groups where Group 1 and Group 2 used the intervention and Group 3 three used the conventional laboratory report template, as consistent with the quasi-experimental, mixed-methods research methodology employed in this study. Lastly, post-intervention qualitative results were also generated based on writing practices, argumentation, content knowledge and language/discourse.

Assessment of the students' general and discipline-specific literacy practices at university entry level based on their high school experiences revealed that some students have been exposed to conducting investigations and writing laboratory reports in science subjects while some were not exposed to both. Previous experience laboratory activities and writing, as well as guidance from high school teachers on how to write reports contributed to a more positive view on the topic. There were no statistically significant changes in terms of the pre-post test scores of the Cornell Critical Thinking test or the content scores awarded by the lecturer. In contrast there were statistically significant differences between the changes in test scores of the online and paper-based groups against those of the control group. The post-intervention qualitative results revealed that students had become more aware of the intricacies of disciplinary writing and noted how writing at university was different from their previous writing in high school. The participants also revealed positive feelings towards the intervention and peer collaboration, but found that the intervention was challenging intellectually and that peer collaboration was dependant on the participation of their respective peers.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 INTRODUCTION

The purpose of this chapter is to discuss the results of the study based on each data generating tool as presented in the preceding chapter. The intent is to understand first, the participants' general and discipline specific literacy practices at university entry level based on their high school knowledge and experiences. These literacy practices were expected to give an indication of the participants' prior knowledge before being exposed to laboratory report writing at university using both the conventional template and the science writing heuristic template which was the intervention. The results of the Cornell Critical Thinking test, focus group interviews with students, individual interviews with staff as well as the post-intervention questionnaire are interpreted in light of the key arguments emanating from the literature review as well as the science writing heuristic and the academic literacies' approaches which were employed as the study's theoretical framework.

5.2 DISCUSSION OF OVERALL RESULTS PER INSTRUMENT

The results will be discussed in chronological order starting with the initial questionnaires, the Cornell Critical Thinking test, laboratory report data, focus group interviews with students, individual interviews with staff members as well as the post-intervention questionnaire.

5.2.1 Initial questionnaires

5.2.1.1 Biographical data

The cohort of first year mechanical engineering students in this study was fairly young, with two thirds of the class 19 years of age or younger. Almost all the respondents were semester one students, and there was a very low percentage of students repeating the module. This suggests that most participants were entering university for the first time and that they had a similar starting point with little or no previous exposure to tertiary education, thus providing a largely age-homogenous sample. However there were differences in terms of the distance to the university campus that students had to travel and whether they had personal computer devise or not. Access to personal devices are important as students are expected to submit laboratory reports that are computer generated using Microsoft Word, and have to be formatted according to the requirements of the department concerned. In engineering the use of equation editor, inserting tables and figures and formatting documents in a neat and professional manner is expected. 'Differential access' to personal computers, internet, computer laboratories, etc. is a variable that may compromise the quality of the work that students submit (Lombard & Knott, 2013). Students who live far from the campus, and who do not have personal computers of their own, would find it difficult to participate in online laboratory report writing initiatives once they had left the campus.

The initial questionnaire results revealed that isiXhosa was the dominant home language of participants and that a majority (63%) of first year mechanical engineering students participating in the study were not first language or home language speakers of English. This finding is similar to those of Kapp's (2004) who noted that the majority of the high school participants who were first language or home language speakers of the Xhosa language, learned English as a second additional language, and that English was also the language of learning and teaching. Learning in English might present more difficulties for these English language learners and as consistent with international research, these students tend to form part of underachievement statistics (Cummins, 2015).

The data above suggest that the cohort of students in this study are probably very similar to first-year engineering students at other South African universities to a greater or lesser degree, when consideration is paid to age, variables in terms of resources and technical support, and access to the language of teaching and learning (Mgqwashu & Bengesai, 2014; Butler & van Dyk, 2004; Kapp, 2004). While that does not mean that the findings of this study are generalizable, it does imply that the findings should be useful in terms of the expected demographics at other institutions and provide a useful exemplar.

5.2.1.2 Literacy practices at university entry level

Given that English was the second, third or even fourth additional language of most participants, one would expect them to have referred to academic support materials such as dictionaries when learning and writing in English. However, the findings from this questionnaire indicated that three out of four students did not consult dictionaries when writing texts in English. Such literacy practices form part of the academic literacies that institutions of higher learning assume to be pre-requisite literacies or competencies for entry into academic programmes (Knott et al., 2011; Skinner & Mort, 2009). At this stage, it is difficult to say exactly why the students do not consult academic support materials such as dictionaries in their high school practices of writing discipline specific texts, but the possibilities are that:

(i) they did not have such supplementary resources in their homes and schools due to low socio-economic status and under-resourcing at school (Mgqwashu & Bengesai, 2014; Kapp, 2004),

(ii) or the practice of consulting dictionaries and other resources for referencing were generally not literacy practices that these students often engaged in at school (Wells, 2011).

Results of the focus group interviews (which will be discussed in more detail later) held with students indicated that since the students have always learned in English, they did not find writing in English challenging. As reported in chapter four, another respondent said, "no it [writing in English] was not a challenge. That is what we are used to, even in school we used to write in English." This hints at the possibility that students might have felt over confident about writing English texts without consulting dictionaries.

5.2.1.3 Disciplinary literacy practices at university entry level

The percentage of students who had never written laboratory reports in high school was 45%, and this percentage is 10% higher than the findings of the Department of Mechanical engineering in semester 1 of 2013 where 35% of the respondents indicated that they had never written laboratory reports in high school. This finding is consistent *a priori* theme *v* which reports on the *lack of familiarity with the genre* (Whitehead & Murphy, 2014; Department of Mechanical Engineering Survey, 2013). Students who have never been exposed to writing laboratory reports are unlikely to be familiar with the laboratory report as a disciplinary text-type or genre. Furthermore, it has been reported in the literature and in South African national news that "a science lab is no different from any other classroom in most South African schools" and that "the closest many get to a science experiment is an illustration in a textbook" (eNCA, 2014). By inference, this news report suggests that if most South African schools do not have science laboratories one would wonder about how much science learning takes place in schools and whether students have the experience of reporting on scientific investigations.

This finding is a matter of concern as the implication is that most students who have graduated from high school, and who have qualified for the first year engineering courses, do not have some of the expected literacies. In the context of this study, it should be noted that in South Africa there is a history of poor schooling as a result of segregation and underdevelopment due to Apartheid (Mji & Makgato, 2006; Butler & van Dyke, 2004). This history provides insights into issues which are key contributors to the under preparedness of high school graduates who enter South African universities. Concomitantly, it is worth noting that international studies also indicate that the problems with academic literacies and first year university students who do not meet the demands of higher education are not restricted to South Africa (Skinner & Mort, 2009; Butler & van Dyk, 2004; Zamel & Spack, 1998).

Since the biographic and disciplinary literacy data revealed that the majority of the cohort participating in this study had not completed computer generated written tasks at school, the intervention included socialising these students in the discourses of higher education and of their discipline in order to produce the expected outcomes of their computer generated laboratory reports to meet the standards of their departments and as required by ECSA. These literacies were scaffolded gradually from the first laboratory report through to the third laboratory report, as suggested by Harran (2011) and Simpson and van Ryneveld (2010).

Despite the fact that most students have never been exposed to laboratory report writing in high school, 82% indicated that since reaching university, they now understood that writing laboratory reports was necessary in engineering. As such, they also recognised it was necessary to revise their drafts many times before final submission in order to stand a chance of scoring better marks. Based on their high school experiences, some of the students preferred to solve problems associated with writing on their own while some preferred to discuss their written work before submitting. These results imply that some of the students have already been exposed to the social aspect of writing that is, sharing and discussing ideas with peers in order to develop wider and deeper understandings of topics before submitting their final draft.

This finding is contrary to the literature which reports that writing and literacy in general are often seen as skills located in individuals (Knott et al., 2011; Lillis & Scott, 2008). The cohorts' *beliefs about writing* and *learning to write* (*a priori* themes *vii* & *viii*) seem to support the notion of literacy as being a shared social event amongst some of the students in this study (Lillis & Scott, 2008; Ivanic, 2004; Wenger, 1998). However, the framework used to base the use of the social aspect of writing is not yet clear but it can be gathered that the students have never been exposed to a Science Writing Heuristic approach.

The cohort's perceptions of conducting scientific investigations while at school were varied. As depicted in Figure 4.3, half of the cohort (51%) indicated that they found scientific investigations "exciting and often understandable" while 24% said they were "interesting and seldom understandable"; 16% felt that they were "neither boring not exciting"; 6% felt that they were "boring but understandable" while the remaining 3% said they were "boring and hard to understand". These results suggest that the cohort of students generally had positive feelings towards scientific investigations and that scientific investigations were mostly associated with understanding on the part of the student. The percentage of those who felt indifferent and who felt that scientific investigations were hard to understand was low. These results seem to differ from *a priori* theme *iii* which reports that laboratory activities are traditionally associated with limited learning by students (Nesbit, 2008; Hand et al., 2004; Rudd II et al., 2001; Keys et al., 1999).

The respondents who were exposed to scientific investigations at school shared varied experiences of working with scientific apparatus. The highest per cent of 46 claimed that they "used scientific apparatus effectively in groups or in pairs" while the lowest per cent of 21 indicated that they either "watched" or "not used the apparatus". While some of these students seemed to feel confident about laboratory work, some students seemed to feel ambivalent towards laboratory work. Moreover, the percentage of students who said they were unfamiliar with the science concepts taught using laboratory apparatus was 39% while 17% said it was difficult to follow the lesson. These findings are consistent with *a priori* theme ii and one of the specific problems with writing laboratory reports namely, the challenge of *relating laboratory work to disciplinary concepts.* Problems with relating laboratory work to disciplinary concepts are often associated with the limited learning by students from laboratory activities. When asked about whether the participants used reflection as a form of facilitating learning from laboratory activities, 43% of the participants agreed with the statement while 9% disagreed with the statement and the remaining 48% said they were unsure. These results suggest that the majority of the participants are unfamiliar with the use of reflection as a way of consolidating learning through metacognition. As such, such baseline results suggest that when socialised in to the science writing heuristic, the cohort were introduced to reflective practice and other metacognitive tasks for the first time.

Overall, these baseline data based on the initial questionnaires shed light on the cohorts' disciplinary literacy practices at university entry level in terms of previous exposure to writing reports based on scientific investigations; their perceptions of laboratory activities and the associated learning; as well as their beliefs about writing and learning to write in the disciplines. While the cohort possesses certain literacy practices at university entry level already, the pertinent disciplinary literacy practices seem to lacking or to be inadequately developed. While the social nature of writing, as well as working collaboratively with peers seems to be an existing practice, the framework on which this notion is based is not clear at this stage although one can infer that the cohort does not seem to have previously been exposed to metacognitive scaffolds such as the SWH, as generally indicated in the literature.

5.2.2 Cornell critical thinking test

As noted in chapter four, the Cornell Critical Thinking data are difficult to explain in terms of the drop in scores from the pre- to post-test. While no statistically significant differences were found in terms of age or gender, and the drops in scores of the online and control groups were not statistically significant, the drop in score for the 'paper-based' group was significant at the 95% level of confidence with a medium effect size.

It is noted in the literature (Poock, Burke, Greenbowe, & Hand, 2007) that a lengthy duration of exposure to any intervention is required before one could expect changes and this seems to have been the case in Cornell scores. As such it was more in hope than certainty that the Cornell test was used in this study. However, the decrease in scores was unexpected. A number of reasons for scores falling between pre-post testing in general are to be found in literature. These include, as identified by Mitchelle and Jolley (2010):

(i) instrumentation
(ii) regression and;
(iii) mortality/attrition

Firstly, changes in instrumentation or how the measuring tool is being administered or evaluated may affect the post-test score. Secondly, regression on post-test scores may occur due to random measurement error and thirdly, post-test scores drop due to mortality when a lesser number of participants is being measured in the post-test, than they were in the pre-test. The Cornell Conditional Reasoning Test (Form X) was administered in the same manner in the post-test as it was in the pre-test, following directions of the Cornell Critical Thinking Test manual. Therefore, the drop in scores from pre- to post-testing could not have been due to instrumentation. Moreover, neither could the drop have been due to random number assignment. As noted in the methodology chapter, this study used purposive sampling rather than random number tables. While it is possible that the scores might have dropped as a result of mortality, seeing that the number of participants (n) was noticeably higher in the pre-test (n=96) and lower in the post-test (n=69), this reason is not satisfactory in this particular case. The reasons are that, the drop in the number of participants from pre- to post-testing can be observed from other instruments as well and yet, there was no drop in scores. Perhaps other factors, such as maturation, history and testing as the key contributors to the drop in scores from pre-test to post-test (Campbell & Stanley, 1963).

According to Campbell and Stanley (1963) ‘maturation’ refers to the changes that occur as a result of the physiological and psychological growth of participants; while ‘history’ refers to the possibility that other events in the participants’ lives might have contributed to pre-test post-test changes; and lastly, ‘testing’, refers to the possibility that participants could have scored differently on the post-test due to the practice and experience they got in the pre-test. As relayed earlier, no statistically significant changes were observed in the participants’ critical thinking abilities in the six month duration of the study.

Maturation in the context of the Cornell Critical Thinking results would suggest an increase in scores and not a decrease. Since there was a decrease in post-test scores, ‘maturation’ is an unlikely explanation for the decrease in scores. The events in the participants’ lives that could have caused the drop in post-test scores are unclear, and as explained earlier, the test was administered in the same manner as the pre-test so the drop could not be due to testing administration. Perhaps other factors such as fatigue might have influenced the difference between pre-test post-test scores (Mitchelle & Jolley, 2010). An informal talk with the students as they handed in their test scripts for the Cornell Critical Thinking Test indicated that most of the students felt that the test was tiring and confusing. These possibilities provide some basis for speculation, but are far from definitive. As such, while the findings of this study are not consistent with those of Mitchelle and Jolley’s (2010) as well as those of Campbell and Stanely (1963), the reason for the drop in scores remains a puzzle.

Another issue noted in chapter four, namely around the percentages of students increasing versus decreasing their scores within groups, provide some stimulation for speculation, but are also far from definitive. For example, the suggestion that, although not statistically significant, presenting the writing heuristic online had a more positive (less negative effect) effect on the students' writing. What is clear though is that investigating the effects of the intervention used in this study over a longer period of time and with a larger sample after taking into account possible causes for a decrease in scores such as fatigue, loss of interest, etc., could provide better insights of an aspect of the ECSA requirement, namely critical thinking.

5.2.3 Laboratory report data

There were three key elements investigated from the laboratory report as a data generating instrument, namely, *argumentation, content* and *language.* The decision to investigate these three elements was informed by the fact that particular genres of writing tend to advance particular arguments, sometimes implicitly and sometimes explicitly, as noted in the literature review in chapter two. For example, Yore et al. (2002), Keys (1999) and a few seminal writers such as Bereiter and Scardamalia (1987) and Thompson (1993), consider the act of composing scientific texts such as laboratory reports as juxtaposing the content and the rhetorical goals of writing in order to advance a particular argument and to persuade others. According to Kelly, Regev, & Prothero (2008, p.138), written argument requires students to draw on a variety of diverse knowledge and practices, including:

(i) conceptual knowledge specific to the scientific [or engineering] discipline
(ii) rhetorical knowledge specific to the genre conventions of the discipline and task
(iii) linguistic knowledge of lexicon and grammar (Halliday & Martin, 1993)

Thus, the evidence from the literature encouraged me to focus on argumentation, content and language.

While all three key elements were intricately interwoven in the rhetorical task of composing a laboratory report, each key element was investigated individually before all three elements were investigated collectively. As noted earlier, all students in the cohort had the opportunity to use the conventional laboratory report provided by the Department of Mechanical Engineering at the research site. This template was used as an instruction manual and a tool for recording data generated in the first laboratory investigation on the 'triangle of forces'. The second template, which was the adapted version of the Science Writing Heuristic (SWH) and Toulmin's Argumentation Pattern (1957/2003) was used by the experimental groups as a laboratory report intervention for the remaining two tasks, i.e., in the 'centre of gravity' and 'friction' practical sessions. However, as indicated earlier, for the purposes of this study, only the first and the third laboratory reports were used as the pre-test and post-test for laboratory report writing.

The intervention was available online for one group and on paper for the second experimental group, while the conventional laboratory report template was also paper-based. Traditionally, at the research site, laboratory report writing has always been paper-based. As such, the intervention provided an opportunity to explore the interface between online and paper-based writing practices, the preliminary findings of which could inform future research on online laboratory report writing at the research site.

5.2.3.1 Argumentation score results

Importantly, the argumentation score results revealed that the intervention had statistically significantly different results between groups in the post-test at 99% level of confidence ($p \leq 0.001$). Comparatively, when the conventional template was used for the first laboratory report there were no statistically significant results observed, suggesting that any changes that had occurred for instance in terms of mean scores, were due to chance. The implication is that the SWH had positive effects on the students' laboratory report writing practices in terms of argumentation. Based on the theoretical framework and a synthesis of literature, a number of reasons can be provided for why the intervention improved the student's argumentation practices better than the conventional laboratory report template.

The first reason is that the SWH template might have been a better facilitator of argumentation compared to the traditional template because the former has an inherently argument-based structure whereas the former does not explicitly scaffold argumentation. The scientific argument structure of posing investigable questions (or aims), formulating claims based on evidence and considering explicit justification for the claim (warrants), is embedded in the SWH template. On the contrary, traditional templates of writing laboratory reports are often not based on such scientific argumentation structures and as a result, tend to "obscure rather than teach science learners [or engineering students] how knowledge is developed and communicated in science" (Wallace & Hand, 2007, p. 68). Using scientific argumentation through oral speech or writing is a deliberate effort, as stipulated by the National Research Council (1996) to engage students in the 'habits of mind' and the 'emotional dispositions' of their disciplines (Villanueva & Hand, 2011). Similarly, the Engineering Council UK stipulates that the standard for professional engineering competence includes the use of "a sound evidence-based approach to problem solving" (2003, p.12), a practice that seems to be missing from / implicit in current laboratory report writing instruction in the Department of Mechanical Engineering at NMMU.

This conventional template, consisting of the traditional sections of 'aim/purpose, methods and materials, results and discussion/conclusions' is similar to the traditional template described by Wallace & Hand (2007) who were pioneers of the SWH approach, and who felt that such traditional templates are "poor tools for the construction of scientific knowledge" p.68). Moreover, the conventional template tends to focus on reporting the procedures, results and their discussion, without explicitly paying attention to the rhetorical practice of argumentation. The rhetorical practice of argumentation includes establishing connections among data and claims, claims and evidence, claims and warrants as well as claims and rebuttals. As such, for Rudd II et al. (2001), "the standard laboratory template does not particularly promote and may actually discourage both the development of connections among elements of the laboratory experiment and the development of meaning" (p.1680) regarding disciplinary concepts.

Secondly, the intervention template included a sub-section on formulating a claim based on evidence whereas the traditional template did not require the formulation of a claim nor did it guide students on how to formulate them. As Osborne (2010) pointed out and as highlighted in the literature review, there seemed to be an 'absence' of argumentation in the conventional template provided by the Department of Mechanical Engineering at the research site hence students using the conventional template scored significantly lesser on argumentation compared to the intervention groups. The ability to formulate claims based on evidence is an authentic scientific practice and provides "experiential meanings" to the student (Wallace et al., 1999, p.68). While students using the conventional template might have learned something in the process of writing their laboratory reports, evidently, these students have not learned how to formulate claims, a practice that is authentic to the development of scientific knowledge (Wallace et al., 1999). Moreover, the statistically significant differences between the intervention and comparison groups is important to note given that the numbers of participants (n), or the matched pairs was low for the intervention groups (n=15), compared to the 23 matched pairs in the comparison group. This suggests that the intervention registered statistical significance despite the low number of participants.

Thirdly, the intervention groups might have performed statistically significantly better than students using the traditional template because the intervention also provided writing prompts that enhance metacognition. The term 'metacognition' refers to the ability to "monitor the quality of one's thoughts and the products of one's [thinking] efforts" (White & Fredereksen, 2009, p.79). Metacognition is also described as the ability to "bracket one's own prior theory and view alternatives" (Garcia-Mila & Andersen, 2008, p.40). In addition to facilitating argumentation as discussed above, the modified template also explicitly required students to reflect on how their thinking might have changed. Practices that promote explicit reflection are considered to explicitly develop metacognition as well (Garcia-Mila & Andersen, 2008).

On the contrary the conventional template did not explicitly require students in the comparison group to reflect. This situation is similar to that espoused by Felton (2004) who found that an experimental group of participants that used reflection showed greater improvements in argumentive discourse than students in a control group did. His conclusion was that practice and reflection was more effective than practice alone. Students in the comparison group were only exposed to the 'practice' of conducting scientific investigations and writing laboratory reports (reflection implicit) without being explicitly encouraged to 'reflect' on what the practice might mean and how their thinking might have changed during the course of the investigation as well as when they were writing the report. The ability to trace one's thinking and reason about the implications of certain events is considered to make a contribution to reasoning and meta-awareness.

The fourth reason why the intervention groups may have performed statistically significantly better than the comparison group could be attributed to the explicit scaffolding of counter-argumentation. Counter-arguments are also known as rebuttals and they are often presented to challenge the claim or the main argument. In the context of this study, the cohort was presented with an "aim" or "purpose" of the investigation which was the same for all participants. However, data sets were different and each individual student had to argue whether the given aim or purpose of the investigation was “verifiable” or whether the theoretical results were comparable to practical results. Depending on the thoroughness of the student’s investigation, their understanding and application of theory and the ability to articulate in the discussion of their results, students were expected to either concur or refute the given aim which is often based on theoretical assumptions such as the ‘triangle of forces’ or the ‘coefficient of friction’.

Evidently, students in the intervention groups seemed to be more aware of what was expected of them in terms of accepting or refuting the given aims and in terms of envisaging what a critic would say if the critic believed that the investigator (student) was wrong. The prompts and the examples of how to write might have contributed to the intervention groups’ ability to articulate their standpoints and possible rebuttals to a critic, in addition to discussing the “trends, anomalies and possible improvements”. While most students in the comparison group discussed the trends, anomalies and possible improvements fairly well, they were not always clear on their standpoint, i.e. whether they concurred or refuted the aim/purpose of the investigation and neither did they consider potential criticism and how they would counter that criticism. This was an important and unexpected finding considering that the nature of engineering work requires the use of judgement, evaluation and reflective reasoning, in an attempt to solve *well-defined* engineering problems (ECSA, 2013). These results are similar to those of Simpson & van Ryneveld (2010, p.809) who posit that the three central literacy practices that support critical thinking in engineering are, as noted in chapter one:

- “argument, evaluation and reasoning;
- reflection and independent learning;
- and relational and analytical thinking (or the ability to apply knowledge)”

This implies that while these central literacy practices are required by ECSA in the form of the ten exit level outcomes, writing instruction in terms of laboratory reports at NMMU, still needs to be made explicit in order for these central literacy practises to be scaffolded from first year level through to graduation.

The fifth and last reason why the intervention groups performed statistically significantly better than the comparison group could be attributed to the explicit instruction to make use of a peer review process. As described in the methodology chapter, the use of a peer review process with a tailor made argumentation and language rubric could have facilitated the intervention groups' ability to evaluate their laboratory reports in terms of argumentation, before a final submission was made to the lecturer. The rubrics could have functioned as a checklist and reminded students of the sections to address as they completed their laboratory reports. The opportunity to receive feedback from a peer, may have had positive contribution as well. In a similar study where high school students were socialised into writing laboratory reports, Whitehead and Murphy (2014) concluded similarly, that the use of exemplars and rubrics can support students' understanding of content, ability to write, confidence, and examination success.

While examinations were not part of this study, it can be said that the use of exemplars, i.e. examples of how to write and a tailor-made rubric may have contributed to the intervention groups' understanding of content whereas, without the explicit guidance of what was expected from their writing, the comparison group may not have been readily aware of what to write and how to write. Essentially, the use of rubrics and peer feedback practices, illustrated what was meant by literacy, or writing being a social practice. Concurrently, through the dialectical application of the notion of literacy being a social practice, argumentation was being developed as a social practice! In contrast, students in the comparison group who did not have the benefit of explicit instruction and scaffolding, did not have this additional opportunity to make sense of their writing and negotiate meaning on multiple levels.

While it has already been established through inferential statistics that the intervention groups performed statistically significantly better than the comparison groups, it must be established more specifically where the differences lay. When the three groups were compared in terms of the effects of the modified SWH template (intervention) and the conventional lab report writing template provided by the Department of Mechanical Engineering, statistically significant differences occurred at 95% level of confidence between Group 1 (online intervention) and Group 3 (comparison group); and at 99% level of confidence between Group 2 (paper-based intervention) and the comparison group. The effect sizes were measured using Cohen's d and a large (1.21) effect size was recorded for comparison between the online intervention and the control group while the effect size between paper-based intervention was even larger at 1.69. Significantly, there were no differences observed between both intervention groups and a discussion of what this might mean follows after the discussion of the first two groups described.

As it can be noted, the intervention had a greater effect size when provided on paper than online. This is an important and unexpected finding since the expectation was in favour of the online intervention. The reasons are that I believed the online environment could combat issues of time and space and that the peer feedback practice would be supported better, considering timetable clashes and the heavy timetables of participants. Thus, it was envisaged that the online environment would provide more freedom in terms of time and space, multiple opportunities to revise laboratory report drafts and converse with peers, as well as being connected to multiple online resources that they could use as references, for explanation and for guidance.

For example, most of the practical investigations for Mechanics I are available on YouTube, and students could have multiple opportunities to watch and learn more about the theoretical concepts of their practical investigations and what they have learned in class, and this could have contributed better to their understanding. However, since visiting YouTube was not mentioned to the students, none of them seemed to have been aware or taken advantage of the online environment to that extent. The other possibilities could be that the online group had an even smaller sample size and there was lack of response in practice.

This situation suggests that using online writing environments requires awareness of other online knowledges and practices that could benefit individuals if they were more aware of the benefits. Comparatively and to my surprise, the paper-based intervention had an even greater effect size and the possibilities could be attributed to a larger sample size and a greater response rate. The fact that there was no difference between the online and paper-based intervention groups is favourable because it suggests that the medium in which the intervention is presented does not seem to be factor, as per the findings of this study.

5.2.3.2 Content score results

The most important finding regarding content score results was that the post-test results were rather uniform between the three groups and the intervention did not affect the participants' content score results. While some researchers, for example Quitadamo and Kurtz (2007) and Stephenson and Sadler-McKnight (2015) revealed similar results in studies in biology and chemistry respectively found no increase in content knowledge between treatment and control groups, the results were unexpected and contrary to broader literature. For instance, Choi, Hand and Greenbowe (2013) whose study examined the written arguments of college first year students using the SWH in inquiry-based general chemistry laboratory classrooms and its relationship with students' achievement, found that students' scores were positively correlated with their achievement as measured by the final grade received for the general chemistry laboratory work and the general chemistry lecture course. Similarly, Poock, Burke, Greenbowe and Hand (2007) found that using a SWH laboratory notebook format that includes a component of reflective writing can positively contribute to students' overall learning of chemistry while overall, the SWH approach had a positive impact on student performance over an entire academic year and a greater impact was observed in the first semester. Lastly, the findings of Anderson and his colleagues (Anderson, Chinn, Waggoner & Nguyen, 1998; Anderson, Chinn, Chang, Waggoner & Yi, 1997) revealed that extended engagement in argumentation enhanced student performance.

The possible explanations for why the intervention did not have an impact on the students' content score can probably be explained in the context of the literature review in terms of the lecturers' predominant view of the nature of knowledge and nature of writing in engineering, as well as the manner in which scoring was designed. As discussed in the literature review, the nature of learning and learning how to write in science is influenced by whether teachers predominantly adopt an empiricist, social, relativist or evaluativist perspective. As illuminated earlier, until fairly recently, much science education predominantly adopted an empiricist view, presenting science as absolute and that it can be effectively learned through hands-on laboratory work.

The empiricist perspective tends to focus on what Norris and Phillips (2003) refer to as the *fundamental sense* of science, with little or no reference to how science is shaped by technology, society, economics or even law (*derived sense*). Moreover, within this perspective, little value is given to other strategies by which science can be learned, such as the use of writing to learn, the effect of the social nature of writing and specifically, the use of argument and critique. In a similar fashion, the predominant perspective regarding the nature of knowledge in engineering pedagogy seems to be based on engineering fundamentals i.e. the application of basic scientific, mathematical and engineering knowledge to solve engineering problems.

Although ECSA documentation and that of the Engineering Council of UK, emphasize the *derived sense* of engineering, that is, how the field of engineering interacts with the social, political, economic, ethical, legal and even the environment; currently, writing pedagogy in the Department of Mechanical Engineering at NMMU, first year level, does not seem to incorporate such a perspective. Instead, attention and even the evaluation of writing predominantly focuses on the empirical and the *fundamental sense* of engineering learning, as if the two senses, *fundamental* and *derived* were separable. This thesis argues, firstly, that the two *senses* are interdependent and they should not be viewed separable. Secondly, this thesis argues that engineering literacy incorporates proficiency in elements of both the fundamental and derived senses. Therefore, writing pedagogy as well, needs to consider ways in which writing can be conceptualised as a social act and how the use of argumentation can enhance both, the fundamental and derived senses of engineering sciences. Thirdly, this thesis argues that the conceptualisation of learning as being individually and socially constructed supports the development of argumentation and critical thinking through writing to learn.

As a consequence of focusing only on the empiricist view to engineering learning, students' laboratory reports were also marked accordingly, and the effect of argumentation (which measured statistically significantly) was not recognised by engineering staff who allocated the content score. This issue draws attention to issues of assessment and expected outcomes. These results also suggest that in the context of this study, argumentation was not only lacking in the comparison group's mechanical engineering laboratory report writing but also, argument and critique seemed to be absent from the lecturers' pedagogic practices. Lastly, the content scores may not have been positively affected by the statistically significant increase on argumentation because the rhetorical task of coordinating written arguments (e.g. claim-evidence), may not have been recognised as one of persuasion by engineering staff (Sandoval & Millwood, 2008).

5.2.3.3 Language score results

The language score results were similar to the argumentation score results as statistically significant differences were observed between the intervention groups and the comparison group. The statistically significant difference, as indicated by the Scheffe test was favourable to the:

(i) online intervention groups when compared to the comparison group and also;

(ii) the paper-based intervention group when compared to the control group

The reasons for the differences could be explained in terms of the literature review and the theoretical framework in the sense that, success in attaining the argumentative discourse correlates with success in attaining linguistic competence. Due to the low-proficiency language levels reported for most South African students entering tertiary institutions, and the unfamiliarity of majority of participants in this study, a language rubric (in addition to the argumentation rubric) was provided as part of the intervention. Thus, the intervention template provided prompts that scaffolded not only argumentation, thinking and writing but also, language use.

The examples of how to write modelled the use of written argumentation and prompted students' to make use of logical connectives and other argument-based vocabulary whereas the use of argumentation discourse and academic language was neither modelled nor explicitly taught for students in the comparison group. Ross, Fisher and Frey's (2009) results were similar as they found that "many young science students benefit from language frames [that] scaffold the use of academic language and vocabulary to formulate arguments and counter-arguments" (p.29). In addition, argumentation is often referred to as "the language of science" (Tippet, 2009, p.17) in order to indicate how argumentation as discourse, is used to construct scientific understandings (Tippet, 2009; Yore et al., 2003). Jacobs (2005) found that the benefits of collaborative work between disciplinary and language/communication teachers, is the attainment of 'metaknowledge' or 'metaunderstandings' of the discipline. It can be argued that the language rubric which was developed in consultation with engineering lecturers and according to their expectations on students' writing, may have scaffolded students' discourse and communicative competence better than the standard template.

5.2.3.4 Analysis of co-variance

As indicated by the analysis of co-variance (ANCOVA) results, when all three elements under investigation i.e. argumentation, content and language (ArCoLa) were subject to inferential statistics, the final result confirmed that the intervention groups performed statistically significantly better than the comparison groups in terms of argumentation and language. The ANCOVA results verify the significant effect of the Science Writing Heuristic approach as analysis of variance (ANOVA) with only the post-test scores was not adequate evidence of the significant effect of the treatment. Including the pre-test scores in the analysis as a covariate, eliminated its effect on the post-test scores.

5.2.4 Focus group interviews with students

Focus group interviews were held with selected participants from each of the three groups to provide a richer context to the study of writing laboratory reports in mechanical engineering and a better understanding of the identity of students entering mechanical engineering courses at level one at NMMU. First, the cohorts' high school experiences, knowledge and practices of writing discipline specific texts such as laboratory reports and conducting scientific experiments are discussed as 'disciplinary literacy practices at university entry level'. Second, the same practices were explored in the cohorts' university context as 'introduction to laboratory report writing at university' and their perceptions of literacy practices post-intervention. The findings gleaned from both the intervention and comparison groups will be discussed at the same time, drawing some comparisons where necessary. Where possible, reference to this study's *a priori* themes will be made.

5.2.4.1 Disciplinary literacy practices at university entry level

It was envisaged that these literacy practices would indicate the participants' prior knowledge in terms of writing disciplinary text-types such as laboratory reports and also, the disciplinary practice of conducting scientific investigations. This study follows Wallace and Hand's (2007) proposition that, "the nature of writing laboratory reports is highly intertwined with the nature of the investigative activity itself" (p.69). Therefore, this study sought to investigate whether the cohort's disciplinary literacy practices in high school were similar or different from this premise.

Collectively, the focus group results suggest that while some of the participants might have been exposed to writing laboratory reports and conducting scientific investigations others had not been exposed to these disciplinary literacy practices. On the one hand, these findings are consistent with those of Lombard and Knott (2013) who concluded that students from more resourced schools in South Africa have been expected to write different kinds of reports, including laboratory reports, even though these often differed in terms of structure, style and what Ivanic (2004, p.233) refers to as "the certainty of the situation". On the other hand, the independent national news broadcaster eNCA (2014) reported that "a science lab is no different from other classrooms in most South African schools" and that "the closest many get to a science experiment is an illustration in a textbook". Similarly, students who claimed to have never written laboratory reports in high school also mentioned that their schools did not have science laboratories. As the majority of South African schools are poorly resourced, most high school students entering university have had little exposure and experience in terms of performing such practices. Experience with disciplinary literacies is not only part of the discipline, but an authentic and important component to science learning, and it may be argued that insufficient exposure in this area contributes to the under preparedness of most first year students entering university. Much of the early international literature on science education first called on ‘hands-on’ science learning, and later called for the coupling of hands-on work with writing, it is evident in the contemporaneous South African context that most high school students are neither familiar with hands-on laboratory work nor with writing laboratory reports based on scientific investigations. These findings confirm the *fifth a priori* theme on *lack of familiarity with the genre,* and that the quality of science learning prior to university studies is not up to the standard required.

For most of the participants who had done practical work and written high school laboratory reports, their experience was that of five standard sections, namely, introduction, method, results, discussion and conclusion. While guidance was provided by high school teachers on how participants could write each report sub-section, it can be deduced from the focus group interviews that their responses that their laboratory report writing practices were not based on scientific argumentation explicitly. Some of the participants attributed their learning from laboratory activities by being able to ‘get the answer’ based on their understanding of procedures, and *not* by

(i) attempting to draw links amongst data and claims, or claims and evidence
(ii) awareness of how their own thinking processes (metacognition)
(iii) awareness of how they have come to learn (epistemological awareness)

While these key features, i.e., argumentation, metacognition and reflection, were absent, the interview responses suggest that some learning had occurred via the traditional school template for writing their laboratory reports. For example, Student M and Student N agreed with each other that through the practice of writing laboratory reports, they were able to “see what the teacher was saying” (refer to Question 2 responses of section 2.4.1 in chapter four); and that they compared their formulae and calculations with those in their textbooks. The practice of relating disciplinary concepts with practical laboratory investigation, as well as comparing one’s own practical work with proven scientific ways of doing, provide a framework to build on when introduced to laboratory investigations and to writing laboratory reports at university. Although learning still occurs when the traditional template is used, science education research has proven that more can be learned by incorporating argumentation and by providing opportunities for students to engage in authentic meaning-making tasks that also scaffold discipline specific ways of thinking (Choi, Hand, & Greenbowe, 2013; Perker & Wallace, 2011; Nam, Choi & Hand, 2010; Poock et al., 2007; Wallace et al., 2007; Keys et al., 1999).

5.2.4.2 Student perceptions of laboratory report writing at university

Students' experiences and perceptions of using the conventional and intervention templates were established by asking them in the focus groups to compare the two templates and then comment on their experiences when using them. There were some conflicting views in terms of which template 'enhanced' or 'promoted' learning from laboratory activities better (as also reported by Wallace & Hand, 2007; Keys et al., 1999). While a few students felt that the intervention was not any better than the traditional template, the majority felt that it 'broadened their level of thinking' in that their understanding was more than just knowing the terms, but more about understanding the concepts more clearly. This finding confirms Jimenez-Aleixandre and Erduran's (2008, p. 7) synthesis of literature on "developing communicative competencies and critical thinking" which states that using argumentation orally or in writing enhances critical thinking. These results suggest that the students were not just comfortable with the intervention template simply because they were writing laboratory reports for the second or third time, but because they were made aware of their own thinking processes and how they have come to understand concepts.

The use of a semi-structured writing guide, with examples of how to write and how to argue, as well as a marking rubric, was considered to be useful. These features were deemed most necessary in the first laboratory report when writing laboratory reports was, in the words of another participant, "all new" to most students. The general response towards modelled writing was positive; but one student who was against it felt that it made him "think less". It is important to note that this person was a mature student who already had 12 years working experience as a copy writer, and who felt more confident about writing and editing his own work. So for mature students who has worked in a language specialist environment such as copy writing, modelling writing might be seen as a hindrance. However, for the average student, these examples were regarded as useful. For example, Student N shared that they he and other students preferred explicit prompts that asked them to write their understanding, such as an instruction that said "write anomalies".

The students who used only the conventional template attributed their success to writing laboratory reports at university to the lessons provided by lecturers beforehand on theoretical aspects of the topic. These teachings were considered by Group 3 students as foundational and as providing guidance for the practical investigation to follow. Some participants in the comparison group could be seen as engaging a kind of argumentation, although they might not be aware that they were doing so, since their department does not make this practice explicit. For example, one student illustrated the relationship between theory and practice; and that they were told [by their lecturer] that the theory and the practical results do not always lead to the same answer; therefore, it was necessary to compare the two. This student continues to say that "it's good to do theory and the practical and then you can *make a statement* to *say the theory is different"*. The fact that this student is able to reason and conclude that by comparing theoretical and practical results one can make a claim such as "the theory is different", suggests that this student is already engaging in some argumentation and making inferences without the support of scaffolded writing.

However, because the notion of argumentation had not been made explicit in class or the practical sessions, his attempts to draw connections remain in the abstract/ global scale i.e. between theory and practice only; and not in terms of how to develop a coherent argument based on data and claims, and how to support and qualify those claims. Arguably, this could be a possible reason why students using the conventional template sometimes struggled to discuss the results of their laboratory reports in terms of "trends, anomalies, and possible improvements", as expected by their lecturers. It is probable that if these students were exposed to argumentation, writing about 'anomalies' and 'possible improvements' could be reformulated as sources of rebuttals and being aware of possible criticism, could prompt the student to think of a counter-argument/s before concluding their discussion section. But because these students used the conventional template that did not explicitly scaffold argumentation, they did not write with an audience in mind nor did they seem to have written for persuasion. It seems as though they had just answered the questions and not paid much thought to how the argument logically developed as they progressed to the next laboratory report sub-section.

The above inference is supported by the statements of another student (student K) who was in the group that used the standard template. He shared that through the practice of writing-up on his laboratory investigation, he began to realise that it was "not good to cook up numbers" or to make up your own numbers when doing the experiment. When he had to write up his laboratory report, he could not account or discuss his findings because he had fabricated the results. In addition, Student K had previously shared that he

(i) did not like to read and he did not read the laboratory manual but he just looked at the apparatus in front of him and figured out what must be done;
(ii) did not like writing laboratory reports for practical subjects such as mechanics. He preferred to write reports for more theoretical subjects such as material science.
(iii) enjoyed practical work more than reading and writing

However, he did note that writing laboratory reports after scientific investigations is probably important for learning and had begun to realise that hands-on work alone does not contribute to cognition, as noted by many researchers in science education (Hodson, 2009).

5.2.4.3 Student perceptions of literacy practices post-intervention

Participants from all three groups realised that writing at university was more complex compared to their writing in high school, and that writing laboratory reports was even more challenging for students who had never been exposed to such disciplinary text-types. While both templates, the conventional and the intervention, attempted to scaffold the participants' writing practices in terms of what was required by their department, the incorporation of an argumentation structure in the intervention template was considered by participants as more challenging in terms of thinking, writing coherency, persuasion and writing with an audience in mind, as per ECSA's (2013) Exit Level Outcome 6 on professional and technical communication, namely that engineering students are to be taught from first year level how to engage with discipline-specific audiences orally and through written presentations, proposals and reports.

Gee (1990, p. 143) defines proficiency in the discourses of ones' discipline as gaining "a socially accepted association among ways of using language, thinking, feeling, believing, valuing, and of acting that can be used to identify oneself as a member of a socially meaningful group." The introduction of an argumentative discourse in this study sought to scaffold not only students' writing but also their thinking in relation to how the use of argumentation to promote judgment, evaluation, reasoning, analytical and creative thinking (ECSA 2012, Simpson & van Ryneveld, 2010). The students responses in the focus group interviews suggest that they did recognise that the constant struggle of wrestling with issues of content and rhetoric (a priori theme iv) helped socialise them into the professional practices of their discipline.

As the above literacies cannot be accomplished by locating learning within the individual and using writing in simple instrumentalist terms (Harran, 2011; Webb, 2007; Lea & Street, 1998), a reconceptualization of what is meant by literacy in engineering by lecturers is probably something that is sorely required. This reconceptualization includes notions of how students can be socialized in ways that allow them to be active members of their discourse communities and co-construct their learning. The use of collaborative writing is one vehicle of achieving the above aim, but one which depends on the level of participation of student peers. Despite some difficulties, the perceptions of students interviewed in this study to the use of online writing practices was generally positive, but sometimes tempered by the shock and "cognitive conflict" that was felt by some participants after viewing their partner's laboratory reports (Webb, 2007, p.137).

5.2.5 Individual interviews with staff

Individual interviews were held at the end of the semester with three members of staff (two lecturers and one laboratory technician) in the Department of Mechanical Engineering at the research site. The aim of these interviews was to gather their perceptions of the extended science writing heuristic which was used as the laboratory report writing intervention.

5.2.5.1 Lecturers' expectations from student writing

Both lecturers teaching Mechanics of Machines (I) shared similar expectations in terms of how students should write their laboratory reports. An analysis of their interview responses suggests that lecturers expect, firstly, linguistic and communicative competence evidenced by clear, concise and coherent writing, as well as legible and unambiguous sentence and paragraph construction. These expectations, which are consistent with those broadly defined by ECSA (2013) on effective oral and written communication with discipline-specific audiences, were expressed prior to the commencement of this study and were considered when preparing the prompts, examples of how to write and the language and argumentation rubrics in the writing guide.

The interview findings also indicate that the lecturers recognized the laboratory report as a 'hybrid' or a 'multi-modal' text consisting of a metalanguage (Hand et al., 2009; Hodson, 2009; Lemke, 1998), and that clarity, conciseness and coherency of writing does not only pertain to wording, but also to the overall rhetorical task of composing a meaningful text comprising of words, calculations, tables, diagrams and appendices. While it appears that they saw it as necessary to teach and support the learning of these literacy practices, it was not explicitly said who is best suited to teach and socialize students into these discipline-specific literacy practices, but the fact that the Engineering Faculty outsources language and communication teaching to the Department of Applied Studies through a generic communication course offered in the second semester, suggests that outsourcing is a preferred option.

This practice runs contrary to current literature in the sense that generic language or communication courses which are single-handedly offered by external departments, are considered to be "decontextualized" (Jacobs, 2005, p.476) since they are often removed from the authentic practices of the discipline; and they are taught by a language or communication practitioner who is also an 'outsider' in the engineering discipline. While Harran (2011) recorded strides to counter this unfavourable practice by collaborating, as a language and literacies lecturer, with engineering lecturers, as currently suggested in the literature, she found that collaboration practices were "complex and lengthy" and that lack of buy-in from engineering lecturers could be a factor that "delimit[s] specific discourse collaboration practices" (p.1). Harran (2011, p.1) also concluded that collaboration practices need to be "systematic and sustained", a finding that is supported by the observations made in this study.

The second expectation, which is related to the issues raised above on writing proficiency, is academic literacy/literacies. The practice of referencing using reliable sources in a discipline-specific matter which, in the case of Mechanical Engineering at the NMMU, is the use of the Vancouver referencing style; pre-reading the laboratory guide for practical investigations; summarizing the findings of laboratory investigations in tables and graphs; using writing as a constitutive practice and not as an "after-thought"; and working independently and originally, are the key academic literacy practices that were highlighted by the staff as essential aspects to engineering literacy. Both templates, the standard one and the intervention, had been designed to scaffold these literacy practices and support had been provided by the Department through face-to-face consultation with the laboratory technician and the provision of writing guides which could also function as self-help guides.

The third expectation is proficiency in fundamental engineering knowledge. This fundamental disciplinary knowledge includes demonstrating 'a level of accuracy during investigations, using appropriate application of theory and formulae and the accurate interpretation of instructions. The extent to which students have grasped disciplinary content and its application, relies in part, on the students' ability to articulate and appropriate engineering discourse in a manner that is accepted to the discipline. In a similar manner, Wilson, Smith and Householder (2014, p.676), use the concept of "fundamental literacy" in illustrating that proficiency in Engineering is centered around proficiency in the fundamental knowledge of the discipline, a notion first pointed out by Norris and Phillips (2003). Villanueva and Hand (2011) have also argued for opportunities to be created where science students can learn to appropriate disciplinary discourse through which they can be socialized into the ways of the discipline.

These findings in terms of what engineering staff, lecturers and engineering technicians expect from students, corroborate those of Harran (2011, p.4) who, through a collaboration project with engineering colleagues, elicited academic literacy concerns for engineering students. These were ranked by engineering colleagues as:

(i) Problem-solving skills: logic, reasoning (cognitive)
(ii) Reading: synthesizing, analyzing, summarizing and interpreting information and providing "answers relevant to questions"
(iii) Writing: rigorous, concise, coherent, cohesive
(iv) Language: own words, definitions, discipline-specific terms
(v) Visual: writing from plans, diagrams, graphs, figures
(vi) Presentations: effective presentation styles using PowerPoint
(vii) Other problems: copying and pasting, rote learning

Since the above findings were generated from the broader engineering faculty in which Mechanical Engineering falls at the NMMU four years earlier, it can be assumed that current academic literacy concerns in the engineering faculty at the research site have probably remained much the same, especially at first year level. In addition, a common thread throughout the study [and Harran (2011) makes a similar claim] was an emphasis on language and communicative competence as well as “cognitive emphasis” in learning fundamental engineering knowledge and practices (Harran, 2011, p.4). In terms of social practices the very nature of the written laboratory report is individualistic and there seems to be gaps in terms of what is offered in the engineering curriculum to socialize first year mechanical engineering students into the discourses of higher education and their disciplines and the requirement by ECSA, especially in relation to the development of reasoning, judgment, and critical thinking.

Important to note is the absence of argumentation from the staff’s expectations of student writing. This finding confirms Osborne’s (2010) claim about the absence of argument and critique in much science education. While argument and critique have been slowly integrated in school and university science curricula in most developed countries it remains a rare literacy and disciplinary practice in developing countries such as South Africa. This assertion appears to be true as the lecturers interviewed finding appeared not to be aware of argumentation as being a disciplinary literacy practice that promotes reasoning critical thinking. This non-awareness probably explains why the engineering teachers did not recognize the need to assess the students’ argumentation abilities when marking their laboratory reports. Furthermore, no staff member hinted at the importance of metacognitive tasks as a way of facilitating learning, nor was it clear how they thought that critical thinking should be scaffolded.

5.2.5.2 Perceptions of the extended science writing heuristic intervention

While the perceptions of the extended Science Writing Heuristic (intervention) by staff members were generally positive, there were concerns as well. A general conclusion was that the intervention was a “much better improvement” in terms of scaffolding students’ writing and thoughts about laboratory investigations. These findings support those of Wallace and Hand’s (2007) that the SWH can be used to promote learning from laboratory work and their conceptualisation of the SWH as a “bridge between informal, expressive writing modes that foster personally constructed science understandings, with more formal, public modes that focus on canonical forms of reasoning in science” (p.67). This way, the SWH should facilitate the understanding of content and practice by assisting students to connect their practical laboratory investigation with existing science or engineering ideas.

The use of metacognitive prompts in the intervention template was also perceived to be useful. One staff member expressed that he/she appreciated that the SWH encouraged students to "reflect and think back" because that way, the SWH "teaches students that conducting a practical investigation is not a once-off event". In addition, another staff member noted that although the prompts seem to require more effort from students, their "probing" made the student to think. These findings are in agreement with previous research on the use of modelling and metacognition (White & Frederiksen, 1998) which reports that (i) environments that foster metacognition are hypothesized to enhance argumentation (Garcia-Mila & Andersen, 2008) and; (ii) that metacognition can be developed explicitly by practices that promote explicit reflection (Jimenez-Aleixandre & Erduran, 2008). Being exposed to practices that demand the student to think and reflect not only about their learning but also, about how their own thinking might have been altered, is seen as contributing to the development of critical thinking (Villanueva & Hand, 2011; Jimenez-Aleixandre & Erduran, 2008).

A concern expressed by some members of staff interviewed was that perhaps the SWH provides "too much of a helping hand" and as a result, that might "stifle" students' ability to develop originality and creativity in their writing. This concern emanated from the idea that engineering students are prepared for the professional work and that when they reach industry, these students must already know how to structure a laboratory report and write coherently on their own. While these concerns are genuine, the extent to which this member of staff has considered the use of argumentation and its tenets (metacognition, critical thinking, communicative competence, and discourse awareness) in enhancing learning from laboratory is not known. Similarly, it is not clear whether this staff member has considered that the very nature of knowledge they seek to communicate is committed more to specific epistemological assumptions, and less on expressive writing, or that the SWH was conceptualized as a bridge between the informal and expressive modes of writing and public modes that focus on canonical forms of reasoning in the disciplines (Wallace & Hand, 2007, p.67). A final practical concern was the students' tight academic timetable that interfered with the staff being able to provide timely feedback to the students, something which was not in the scope of this study or something that relates directly to its aims.

5.2.6 Final questionnaire results

A final questionnaire was administered to all participants to evaluate their disciplinary literacy practices after being socialized into writing laboratory reports at university and after the intervention groups were socialized using the Science Writing Heuristic. Certain questions were generic, others were specific to the experimental group which used the expanded SWH approach and some were specific to the comparison group which used the intervention template. These results will be discussed based on 'writing practices' and on 'laboratory practices'.

5.2.6.1 Results based on writing practices

After being exposed to conducting three laboratory investigations and writing three laboratory reports, the majority of respondents (67%) were confident in terms of writing and how to structure a laboratory report. These findings suggests that the cohort felt somewhat *familiar with the genre* of a laboratory report *(a priori theme v)* and that the practice of writing has assisted their ability to negotiate issues of *content and rhetoric (a priori theme iv).* They attributed their confidence to the semi-structured templates provided, the written guide on the topic with examples of how to write and the metacognitive prompts of the SWH approach. Both templates could be seen to have facilitated the students' awareness of the *nature of disciplinary writing* (*a priori theme i)* but in different ways, as the results of the focus group interviews with students also suggest. Contrasting these results with those of the initial questionnaires, where 45% of the respondents said they had never writing laboratory reports in high school, it is evident that their socialization into laboratory report writing at university has had positive effects.

The experimental group indicated that their writing practices were enhanced by their use of the tailor-made rubric for language and argumentation while those in the comparison group attributed their success to the standard template and their confidence that they has always known how to write well. The use of the rubrics may be seen as having motivated the notion of literacy as being social practice, as participants shared that their classmates and their Mechanics I laboratory report writing tutor assisted them to understand the rubrics. The cohorts' disciplinary literacy in terms of writing was evident when these questionnaire results corroborated that four fifths of the participants believed that writing laboratory reports has helped them to understand and explain concepts relevant to the 'triangle of forces', 'centre of gravity' and 'friction'.

It is important to note that based on the results, the most challenging laboratory report sections to write were the 'discussion', 'reflection', 'claim' and 'theory' respectively. These findings suggest that all four sections need to be taught explicitly to the students. These results are similar to those of Peker & Wallace (2011) who concluded that there was a need for more explicit guidance to help students construct better scientific explanations. These authors also found that the explanatory genre can be taught explicitly if focus is paid on theoretical and causal explanations. Furthermore, when particular attention was paid to what students did when they wrote the ‘discussion’ section of the laboratory report, approximately three thirds of them “explain” and attempt to “address trends, anomalies and possible improvements” while less than one fifth attempt to rebut against envisaged counter-arguments or disagree with the aim or certain theoretical concepts of the experiment. These findings suggest, on the one hand that the participants were more comfortable with explanation as this genre was scaffolded in terms of students being required to address trends, anomalies and possible improvements. On the other hand, these findings suggest that it might be easier to be agreeing with the given aim or the key theoretical concepts while disagreeing would require greater conviction and the ability to use the argumentation to address counter-arguments.

5.2.6.2 Results based on laboratory practices

As noted earlier, the Science Writing Heuristic was designed to enhance learning from laboratory work by offering multiple stages of meaning negotiation through pre- during- and post-laboratory activities. The results generated in this study have been divided into these three categories, pre-laboratory activities, during laboratory activities and post-laboratory activities when attempting to ascertain whether the cohort perceived laboratory writing as a stand-alone activity; and also to ascertain the extent to which laboratory investigations and the writing of reports was shared between students and their peers.

According to the results, the most prevalent pre-laboratory activity that the majority (69%) of participants engaged in is “recalling theoretical information and calculations from previous lecturers” while some read relevant library books or read from the internet to understand theoretical terms. In the absence of the pedagogical aspect of the SWH approach which is facilitated through the teacher template, these findings suggest that students do not go to the laboratory blank and that the content taught in class by lecturers plays a huge role on the participants’ ability to carry-out and understand what is expected of them when conducting laboratory investigations.

The most common practices undertaken by participants during laboratory activities involve taking pictures of the key procedures and results; working in groups of twos or threes and recording data generated in the laboratory report writing template, and lastly, discussing and asking questions to group mates while doing the investigation. These findings suggest that much can be learned when students are not only actively involved in generating knowledge through practical investigations, but also when the laboratory investigation is an opportunity for dialogue and the sharing of ideas. Thus, the notion of knowledge being both individually and socially constructed is given meaning in such instances (Hand, 2007).

Lastly, the results revealed that the most prevalent practices that the cohort engaged in post-laboratory activities are the following: writing the first draft of the laboratory report individually, recalling the participants' beginning ideas about the investigation, formulating a claim based on observations, results and the theoretical sections of the laboratory report. These results suggest that the participants are aware that the practice of writing a laboratory report is shaped by the beliefs about the nature of knowledge in that particular discipline and that the laboratory reports itself is based on the actual work done in the laboratory. A similar conclusion is made by Wallace and Hand (2007, p.69) who posit that "the nature of writing laboratory reports is highly intertwined with the nature of the investigative activity itself."

5.3 ANSWERING THE RESEARCH QUESTIONS

The purpose of this study was to investigate the effect of a Science Writing Heuristic (SWH) approach on the writing of laboratory reports by first year Mechanical Engineering students at Nelson Mandela Metropolitan University (NMMU). Therefore, this section attempts to demonstrate how the purpose of this study has been achieved in addressing the main research question. As mentioned before, the main research question was:

> *What cognitive and linguistic literacy practices are revealed in first-year mechanical engineering students' laboratory reports before and after academic socialization using a science writing heuristic?*

Owing to the nature of the research question, which has been addressed by employing a quasi-experimental research design with pre-tests, intervention and post-tests, the 'key elements' (cognitive and linguistic literacy practices), were investigated prior, during and post intervention. In responding to the main research question, in an indepth and design sensitive-manner, five research sub-questions emanating from the main question were addressed. These sub-questions are:

Research sub-question 1:

What are the literacy practices that first year mechanical engineering students bring with them at university entry level?

This research sub-question sought to solicit the cohorts' literacy practices *before* academic socialization using the SWH, that is, at their point of entry in an institution of higher learning. This preliminary data has provided the context for laboratory report writing, and has helped ascertain whether the participants had previously been exposed to argument-based science learning strategies such as the SWH. The findings of the two initial questionnaires and focus group interviews based on the participants' high school knowledge, practices and experiences were presented under the subheading, *literacy practices at university entry level*. The results on the participants' *literacy practices at university entry level* revealed that students from well-resourced schools in South Africa had been exposed to conducting scientific investigations and writing different kinds of reports including a laboratory report, while there were high chances that those from poor schools had not been exposed to these key disciplinary literacies. These findings are similar to those of Lombard and Knott (2013).

The results of the initial questionnaires and focus group interviews indicated that the cohort had not previously been exposed to argumentative discourse, especially, in relation to laboratory report writing. This finding corroborates Osborne's (2010) lament on the 'absence' of argumentation in secondary school science education. An inference can be made that the majority of students in the cohort were not conscious of argumentation discourse at university entry level, i.e. experimental and control groups were equally underprepared in terms of argumentative discourse.

Research sub-question 2:

Are there any changes to the literacy practices of this cohort after being socialized into laboratory report writing?

This research sub-question sought to ascertain the cohorts' literacy practices *during* and *post* academic socialization using the SWH. The same literacy practices were investigated with all of the participating students using the Department's standard laboratory report template. By the end of the semester all participants had been exposed to an equal number of laboratory investigations on Mechanics and had an equal number of opportunities for writing and submitting laboratory reports. As reported earlier in the fourth chapter, there were no observable literacy practice differences between and within groups for the first laboratory report which employed the standard laboratory report template provided by the Department of Mechanical engineering. The homogeneity of these baseline findings made it possible to attribute statistically significant changes from the first to the third laboratory report to the intervention.

The intervention groups, which used the expanded version of the SWH performed statistically significantly better in the laboratory report post-test on ‘friction’ in terms of *argumentation* and *language scores,* compared to the control group which used the Department’s standard template. These results suggest that the intervention promotes argumentation and the articulation of students’ understandings about laboratory phenomena, as was initially reported by the pioneers of the SWH approach, namely Keys et al. (1999) and Wallace et al. (2007). However, there were no statistically significant changes in terms of the pre-post scores for critical thinking or conceptual understanding.

Research sub-question 3:

Are there any measurable differences between first year mechanical engineering students’ conceptual, argumentation, critical thinking and language abilities before and after using the Science Writing Heuristic?

The key elements associated with the use of the SWH, namely, conceptual understanding, argumentation and critical thinking and language or discourse awareness, were investigated individually and collectively through the following instruments;

(i) Cornell Critical Thinking Test (critical thinking) and

(ii) the laboratory reports (argumentation score, content score and language score)

Table 3.3 in chapter three presented a summary of the key elements investigated per research question, including the data sources, the types of data and the modes of analyses. First, there were no measurable differences between groups in terms of critical thinking but the puzzle was that post-test scores dropped and the cause of the drop in scores could not be satisfactorily explained by consulting literature. Second, while the test scores allocated by the engineering lecturers revealed that the average scores increased by approximately 10% across all groups there were no statistically significant differences between the improvements in terms of changes in content mean scores between groups. Quitadamo & Kurtz (2007), Stephenson and Sadler-McKnight (2015) report similar findings. What is notable though is that the intervention groups, particularly the paper-based intervention group, outperformed the comparison group in terms of argumentation and language use.

Third, there were statistically significant differences between the changes in the treatment and control groups, in argumentation and language from the first to the final laboratory report. The observable effect of the intervention in terms of argumentation and language seems to testify to the efficiency of the SWH in developing argumentation and language competency, as purported in the literature (Webb, 2010; Wallace & Hand, 2007). However, the fact that in this study, argumentation did not lead to increased gains in conceptual scores, as previously reported in the literature (Villanueva & Hand, 2011; Erduran & Jimenez-Aleixandre, 2008; Wallace et al., 2007), suggests that the development and the effect of argumentation was not recognized by the engineering lecturers who seem to value content knowledge alone. The homogeneity of the changes in content scores suggests assessment practices which focus on aspects of the investigation which are not related to understanding of argument-based evidence. This possible failure by lecturers to recognize the effect of argumentation as a scaffolded disciplinary practice explains why ECSA's (2012) requirements to develop argumentation, reasoning, and critical thinking in undergraduate engineering students seems to have received limited or no attention in engineering departments. Engineering lecturers' understanding of the nature of engineering knowledge as being purely conceptual, without a consideration of how that conceptual knowledge is constructed and articulated, may underpin the neglect of practices to develop argument in their students.

Research sub-question 4:

To what extent do students' writing and interview data match the a priori themes developed from the literature?

A priori themes were used to interpret the results of students' focus group interviews as they pertained to the nature of disciplinary writing, the link between laboratory practice and theory, familiarity with the genre, previous exposure to reading and writing as well as beliefs about writing and learning to write. The participants' responses could be matched against all the identified *a priori* themes, sometimes agreeably, and sometimes disagreeably. The uniqueness of the research context could be the reason attributed to the confirmation or disconfirmation of the *a priori* themes. For instance, focus group interviews held with students in each of the three groups in the study revealed that students were aware of the difference and the complexity of disciplinary and higher education discourses, and felt that academic support programmes were necessary in the process of academic socialization, an issue pointed out by a number of academic literacies practitioners working in engineering education in institutions of higher learning (see Harran, 2011; Skinner & Mort, 2009; Lillis &Scott, 2008; Jacobs, 2005, 2007a, 2007b; Lea, 1998). These finding correspond with the *a priori themes* addressing the 'nature of disciplinary writing', 'wrestling with content and rhetoric'; the 'familiarity or unfamiliarity with the genre' of a laboratory report, nor the 'disciplinary practice of conducting laboratory investigations'. In addition, interview data drew a link between the problem of 'relating laboratory work to disciplinary concepts', and the fact that laboratory activities are often associated with limited learning. The nexus between the *a priori* themes and their confirmation and disconfirmation in the results of the study, have also revealed, broadly, that the South African context is not too different from international contexts in terms of the challenges surrounding writing discipline-specific genres such as laboratory reports. Lastly, focus group interview data revealed instances of how students construct and co-construct their identities as 'authors of disciplinary text-types' (Lea, 1998), as 'novice' scientists (Driver et al., 1996) and as 'novice' engineers (Jacobs, 2005), engaging in authentic disciplinary practices involving performance (doing), reasoning, and writing (Wallace et al., 2007).

Research sub-question 5:

What are the lecturers'/staff's expectations and perceptions of both the conventional template and the modified templates (using the science writing heuristic)?

Based on the results of the individual interviews with staff, the overall expectations from students' writing seemed to focus firstly, on the linguistic and communicative competence evidenced by clear, concise and coherent writing. Secondly, the focus was on the students' ability to manage the rhetorical task of composing a 'hybrid' or 'multi-modal' text consisting of words, calculations, tables, diagrams, references and appendices. While attention has been paid on the linguistic, communicative, and conceptual tools of representing knowledge, (such as making accurate interpretations of the data, employing the correct formulae and representing data in recognized formats), barely have the lecturers made the point about the need to assist students to be aware of their thinking processes (metacognition) (Wallace & Hand, 2007) and how they come to know (epistemic vigilance), and how knowledge is constructed in the sciences. It seems as though students were expected to demonstrate a level of professionalism in terms of their academic writing and reasoning and yet they were not explicitly taught how to make the intellectual and the rhetoric leap from gathering data in the laboratory to how to reason about the data, and make meaningful inferences which would, in the long run, benefit their use of judgment and decision making (ECSA, 2012; Simpson & van Ryneveld, 2010). Importantly, some so the staff recognized that the SWH has potential to nurture 'reflection' and 'thinking back' so that the act of performing laboratory investigations, and reporting on them in writing, is a fluid, social practice, rather than a one-way, and once-off event.

This dissertation has also acknowledged some of the staffs' concern that the SWH approach might be providing "too much of a helping hand" and that it might "stifle" students' ability to develop originality and creativity. In response to this concern, this study argues, in light of the literature reviewed and the findings of this study that, students who have neither been previously exposed to conducting laboratory investigations, nor writing laboratory reports, and who are unfamiliar with this very genre, would need more than just socialization in the discourses of writing and learning to write, but also, in the discourses of how to reason and construct knowledge in the disciplines. Through the use of metacognitive prompts, the SWH not only inducts students in discourses of writing and learning to write, but also, into the scientific process of eliciting knowledge claims based on evidence (Garcia-Mila & Andersen, 2008; Wallace et al., 2007). Thus, this dissertation has demonstrated how this research sub-question on the lecturers expectations on student writing and the staff's perceptions of both the conventional template and the modified templates (using the science writing heuristic) are been addressed.

The principal research question

The answers to the five research sub-question provide insights into the cognitive and linguistic literacy practices of first-year mechanical engineering students' laboratory report writing abilities before and after academic socialization using a science writing heuristic. The data reveal that, in general, the students had not been previously exposed to the disciplinary practice of conducting laboratory investigations or writing the laboratory report as a discipline-specific genre before their academic socialization using the SWH. While there was differential access in terms of high school exposure to these practices, all who engaged in the SWH intervention improved statistically significantly in terms of argumentation and language scores in comparison to the control group. Conversely, as there were no gains on the Cornell test that can be attributed to the intervention, little can be said about the intervention's effects on critical thinking, apart from the fact that in focus group interviews the participants noted that the intervention had caused them to "think deeper", to be 'more aware of their writing', and how a potential 'reader might view their arguments'. Similarly, statistical analysis of the scores allocated to the students' practical reports by the lecturers showed no differences between the experimental and control groups pre- and post-intervention. This result, despite improvements in the students' literacy and argumentation practices, may possibly be attributed to the assessment practices of the lecturers.

5.4 CONCLUSIONS

As discussed, writing in the disciplines is committed to particular epistemological and ontological foundations that are characteristic of a particular discipline. This study has attempted to argue that these epistemological and ontological foundations influence the nature of knowledge, how that knowledge is taught and learned, and how students are socialized into the discourses of their discipline, including how they think, read, write and perform certain disciplinary tasks. Thus, the "context of the situation" (Ivanic, 2004, p. 233) envelopes the writing activity and, as Wallace & Hand posit, the "nature of writing laboratory reports is highly intertwined with the nature of the investigative activity itself" (2007, p.69). This is why this study refers to the laboratory report as a discipline-specific text or as a disciplinary literacy practice.

The results of the laboratory reports have clearly indicated that the Science Writing Heuristic approach had positive effects on the cohorts' laboratory report writing at first year university level. These effects have produced measurable differences between the intervention and comparison groups which indicate that the intervention groups who were socialized using the SWH approach were favoured in terms of argumentation and language scores. However, students' argumentation scores could not be positively correlated with their content score results, even though the literature reports that argumentation promotes conceptual understanding and ultimately, improves students' achievement scores (Villanueva

& Hand, 2011). The discussion, based on literature, the theoretical framework and the results of the individual interviews with lecturers/staff, revealed that the lecturers/staff concerned may not have been aware of argumentation practice and that could have been the reason why they did not notice differences between groups when the lecturers/staff allocated content score results. This finding suggests that the assessment techniques used by the lecturers deserves attention in terms of incorporating literacy and argumentation practices as expected by ECSA.

There were no statistically significant differences between groups in terms of the Cornell Critical Thinking test but there was an unexpected drop in scores in the post-test, the reasons for which remain an enigma. Lastly, questionnaire and focus group interview results reveal that students had positive perceptions about the expanded SWH approach and even though there were no measurable differences on critical thinking from pre- to post-test, the students themselves repeatedly claimed that the intervention made them to “think deeper” and enabled them to actually understand the concepts and not just the terminology.

5.5 RECOMMENDATIONS

The key finding of this study, namely, the intervention groups attaining positive gains on argumentation and language scores compared to the comparison group; and the engineering staff failing to recognize the effect of argumentation when allocating content score results, suggests the following recommendations for further fruitful research. While the student template can be sufficiently used on its own as this study has attempted, it is evident that when the teachers/lecturers who allocate scores for conceptual understanding are not aware of argumentation as a way of constructing knowledge in the discipline; their assessment of content scores miss the effects of argumentation and the SWH approach as a whole. Exposing staff to the teacher template, which enhances the pedagogic practice, would socialize them into the SWH and how the SWH scaffolds argumentation and discourse learning as disciplinary literacy practices. As such it is vital that it be iterated and re-iterated to lecturers that they must use both the student and teacher templates of the Science Writing Heuristic together as originally conceptualized by Hand and Wallace (formerly Keys) (Wallace & Hand, 2007; Keys et al., 1999) in future intervention studies.

Secondly, given that the drop number of participants from pre-tests to post-tests, I would recommend that larger sample sizes be used and better co-ordination be established in cases whereby certain scores are marked by different parties. Thirdly, as evident from the Cornel Critical Thinking test results, a longer duration for testing the intervention is required, perhaps a minimum of 12 months. In this study the testing was initiated and completed within one semester and this appears to be an inadequate period in which to expect results (as noted in the literature). Fourthly, students need to receive their marked laboratory reports and feedback before the next laboratory report is due so that they may be aware of what to improve on in the next task. Both the students and staff shared the same concern during focus group interviews and individual interviews with staff. Lastly, collaboration practices between disciplinary experts and language/literacy departments needs to be systemic, constant and occurring over longer periods of time in order to ensure reliable results. Harran (2011) has also recommended the establishment of engineering "communities of practice" (Lave & Wenger, 1991) with language and disciplinary teachers. Jacobs (2005, 2007a, 2007b, 2010) has theorized and presented evidence that establishing engineering communities of practice with language (or literacy/communication) and engineering lecturers has favourable results in terms of making explicit the tacit nature of disciplinary knowledge, without compromising the nature of knowledge of the discipline. Further research in these areas should provide fertile ground for improving teaching and learning and better understandings of what is required to attain the higher order knowledge and skills required by students in particular disciplinary practices.

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APPENDICES

APPENDIX A

This script is used for the form validation.

My World @ NMMU Web Survey

Nelson Mandela Metropolitan University for tomorrow

Questionnaire 1 for mem 1111/2

Preview Page | Re-order Page Numbers | Re-order Category Numbers by Page | Survey Summary | Survey List | User Guide

Page: 1

Page No: 1 [Edit] [Add]

Material Science questionnaire 1 for module codes MEM1111/2.

1. BIOGRAPHICAL DATA

Please respond to this questionnaire on what you know, do, experience and believe.
Click in the appropriate blocks where options are provided or type in your responses to questions.

1.1	Current level registered	[ ]s1 [ ]s2 [ ]s3 [ ]s4
1.2	Current semester registered	[ ]Semester 1 [ ]Semester 2
1.3	Age	[ ]19 or younger [ ]20-23 [ ]24-29 [ ]If over 29
1.4	Sex/gender	( )Male ( )Female
1.5	I have started my tertiary studies at the NMMU.	( )Yes ( )No
1.6	Please enter your home languages.	
1.7	Where are you living while studying at the NMMU?	[ ] NMMU residence. [ ] Off-campus close to the NMMU. [ ] Off-campus and I travel between 15 and 40 kilometers (km) a day. [ ] Off-campus and I travel more than 40 km a day.
1.8	Are you perhaps repeating MEM 1111/2 ?	( )Yes ( )No
1.9	Do you have a desktop computer or laptop?	( )Yes ( )No
1.10	How many laboratory reports did you write at school?	[ ]0 [ ]1-2 [ ]3-4 [ ]5-6 [ ]7-8 [ ]more than 8
1.11	What types of texts (e.g., textbooks) were you required to read at school?	
1.12	What types of texts (e.g., poetry) do you enjoy reading?	
1.13	What types of texts (e.g., essays, reports) were you required to write at school?	

1.14	Who read what you wrote at school, i.e., who was your audience of what you wrote?	
1.15	Please enter your student number	
1.16	Please enter the name of your high school (alma mater)	

add new question

2. PRACTICES, KNOWLEDGE AND EXPERIENCES

2.1	I use subject-specific dictionaries for formal writing.	always ( )( )( )( )( ) never
2.2	I know that well-written laboratory reports are a necessary requirement for a career in engineering.	not a need at all ( )( )( ) definite need
2.3	Explain in full what you think you need to know when writing laboratory reports.	
2.4	When I write, my first draft is my only one.	( )Yes ( )No ( )Don't know
2.5	I enjoy discussing my formal writing with different people.	( )Yes ( )No ( )Don't know
2.6	Explain why you do or don't like to discuss your formal writing with different people.	
2.7	When I experience difficulties with any type of writing,	[ ]I seek help in some way. [ ]I give up trying. [ ]I try hard to work out what to do on my own. [ ]I start all over again from the beginning.
2.8	Explain in full what you need to do when writing laboratory reports	

add new question

3. BELIEFS ABOUT WRITING

3.1	I believe writing is just applying what I know of grammar and symbols.	( )Yes ( )No ( )Don't know
3.2	I believe writing is just a technical skill similar to drilling a hole in a plate.	( )Yes ( )No ( )Don't know
3.3	I believe there is one proper way of writing based on fixed rules.	( )Yes ( )No ( )Don't know
3.4	I believe writing is a product of my creativity as an author.	( )Yes ( )No ( )Don't know
3.5	I believe writing is a practical drafting and redrafting process.	( )Yes ( )No ( )Don't know
3.6	I believe writing involves processes of thinking.	( )Yes ( )No ( )Don't know
3.7	I believe writing is a social activity.	( )Yes ( )No ( )Don't know
3.8	I believe writing is an act of power.	( )Yes ( )No ( )Don't know
3.9	I believe different types of writing depend on different kinds of purposes.	( )Yes ( )No ( )Don't know
3.10	I believe writing is linked to	( )Yes ( )No ( )Don't know

	reading and using a computer.	
3.11	Explain in detail what you believe writing to be.	

add new question

4. BELIEFS ABOUT LEARNING TO WRITE

4.1	I learn to write by writing as many types of writing as possible for different purposes and in different situations.	( )Yes ( )No ( )Don't know
4.2	I learn to write when I am required to write on interesting and relevant topics.	( )Yes ( )No ( )Don't know
4.3	I learn to write when I can be a creative author and express myself.	( )Yes ( )No ( )Don't know
4.4	I learn to write when I see and read well-written examples of the type of writing required.	( )Yes ( )No ( )Don't know
4.5	I learn to write reports based on my experiences of the type of report required.	( )Yes ( )No ( )Don't know
4.6	I learn to write reports when the teacher implements planning, drafting, evaluating, revising and editing processes and practices.	( )Yes ( )No ( )Don't know
4.7	I learn to write when I get different kinds of feedback from different readers to my reports, such as verbal and written responses.	( )Yes ( )No ( )Don't know
4.8	I learn to write when I am taught rules and patterns of symbols and words in different types of reports.	( )Yes ( )No ( )Don't know
4.9	I learn to write when teachers make clear to me what and how types of reports will be assessed.	( )Yes ( )No ( )Don't know
4.10	Explain in detail what you believe about learning to write.	

add new question

add new category

Page footer text here MEM1111/2 and MAS1122 writing questionnaire

APPENDIX B

QUESTIONNAIRE 1(b) – PRACTICAL REPORT WRITING IN ENGINEERING

Please complete the following questionnaire on your high school experiences of conducting scientific investigations and writing scientific reports. Please tick or cross the appropriate option.

1.1 Before you were registered at university, did you know what a laboratory report looked like?

Yes	
No	

1.2 I high school, how often did you do scientific investigations (experiments)?

0 times	
1-2 times	
3-4 times	
5-6 times	
7-8 times	
More than 8 times	

1.3 At school, what kind of written work did you do after a scientific investigation (experiment)?

Number of Responses	
Science worksheet	
Short explanation	
Laboratory report	
Essay	
Test	

1.4 How did you find scientific investigations while at school?

Exciting and often understandable	
Interesting and seldom understandable	
Neither boring nor exciting	
Boring but understandable	
Boring and hard to understand	

1.5 At school, how did you use scientific materials (apparatus)?

I used apparatus effectively in groups or pairs.	
Most learners shared and used apparatus effectively.	
Some learners use apparatus, others watch.	
None of the learners use apparatus	

1.6 Did you understand the link between the use of Science apparatus and the lesson taught?

My teacher used the Science apparatus as the basis for notes sketches.	
Learners encouraged to write own notes and sketches based on Science apparatus.	
Educator gave notes that had no or little connection to the Science equipment	
No connection between the Science apparatus and notes given (or no notes given at all).	

1.7 At school, how did you and your classmates feel when using apparatus?

Both boys and girls use the Science apparatus comfortably	
More girls than boys use the Science apparatus and dominate science investigations	
More boys than girls use the Science apparatus and dominate science investigations	
Very few or no girls use the Science apparatus and boys totally dominate science investigations	

1.8 What sort of difficulties have you experienced at school?

Not familiar with use of equipment in class	
Difficult to follow the lesson	
Worried that I will break or damage equipment	
Unfamiliar with science concepts taught using equipment	
Other:	

1.9 When working as groups which group of learners did you belong to?

Group of learners discussed problems, questions and activities by ourselves	
Group of learners with limited interaction/interact when teacher motivates	
Only two or three learners in a-large group interact	
Learners sit in groups but work as individuals	

1.10 As part of conducting experiments and writing laboratory reports, were you encouraged to ask questions before, during and after the laboratory activity?
(Y*ou may select more than one option*)

I asked questions before the investigation	
I asked questions during the investigation	
I asked questions after the investigation	

1.11 As part of writing your lab report, were you required to reflect on laboratory processes and note whether your thinking has changed after the experiment?

Yes	
No	
Sometimes	
Not sure	

1.12 I used dictionaries and subject specific vocabulary lists for formal writing

Strongly Disagree	Disagree	Unsure	Agree	Strongly agree

1.13 I know that well-written laboratory reports are a necessary requirement for a career in engineering

Strongly Disagree	Disagree	Unsure	Agree	Strongly agree

1.14 When did you matriculate?

2013	2012	2011	2010	2009	2008	Before 2008

1.15 What was your final mark in your matric year?

Mathematics	
Physical Sciences	
English (Home Language)	
English (First Additional Language	

Thank you for taking the time to complete this questionnaire ☺.

APPENDIX C

ANSWER SHEET - CORNELL CONDITIONAL REASONING TEST FORM X

Today's Date: ……………………………… **Student number:** …………………………………………

Program: …………………………………… **Your age on your last birthday:** ………………………

Your date of birth: month……………………………**day**…………………..**year**…………………………………

General directions:

This is a test to see how you do a particular kind of thinking. We call it "conditional reasoning". You will see that you already do some of this kind of thinking. The sample questions make clear what is expected.

Please use this answer sheet to mark your answers. Circle your chosen answer clearly. Circle only one answer per question otherwise your response will be regarded as invalid. If you are not sure about the answer, DO NOT GUESS WILDLY. There is a scoring penalty for guessing wrongly.

If you think you have the answer, but are not sure, mark that answer. But if you have no idea, then skip the question.

There is a sample of 6 questions, then 72 others. You should work as quickly as you can but do not rush. Once you do the samples, you will be able to move right along.

1	A	B	C	23	A	B	C	45	A	B	C	67	A	B	C
2	A	B	C	24	A	B	C	46	A	B	C	68	A	B	C
3	A	B	C	25	A	B	C	47	A	B	C	69	A	B	C
4	A	B	C	26	A	B	C	48	A	B	C	70	A	B	C
5	A	B	C	27	A	B	C	49	A	B	C	71	A	B	C
6	A	B	C	28	A	B	C	50	A	B	C	72	A	B	C
7	A	B	C	29	A	B	C	51	A	B	C	73	A	B	C
8	A	B	C	30	A	B	C	52	A	B	C	74	A	B	C
9	A	B	C	31	A	B	C	53	A	B	C	75	A	B	C
10	A	B	C	32	A	B	C	54	A	B	C	76	A	B	C
11	A	B	C	33	A	B	C	55	A	B	C	77	A	B	C
12	A	B	C	34	A	B	C	56	A	B	C	78	A	B	C
13	A	B	C	35	A	B	C	57	A	B	C				
14	A	B	C	36	A	B	C	58	A	B	C				
15	A	B	C	37	A	B	C	59	A	B	C				
16	A	B	C	38	A	B	C	60	A	B	C				
17	A	B	C	39	A	B	C	61	A	B	C				
18	A	B	C	40	A	B	C	62	A	B	C				
19	A	B	C	41	A	B	C	63	A	B	C				
20	A	B	C	42	A	B	C	64	A	B	C				
21	A	B	C	43	A	B	C	65	A	B	C				
22	A	B	C	44	A	B	C	66	A	B	C				

End of Test.

APPENDIX D

My World @ NMMU Web Survey

Nelson Mandela Metropolitan University *for tomorrow*

Questionnaire 1 for mem 1111/2

Preview Page | Re-order Page Numbers | Re-order Category Numbers by Page | Survey Summary | Survey List | User Guide

Page: 1

Page No: 1 [Edit] [Add]

Material Science questionnaire 1 for module codes MEM1111/2.

1. BIOGRAPHICAL DATA

Please respond to this questionnaire on what you know, do, experience and believe.
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1.1	Current level registered	[ ]s1 [ ]s2 [ ]s3 [ ]s4
1.2	Current semeter registered	[ ]Semester 1 [ ]Semester 2
1.3	Age	[ ]19 or younger [ ]20-23 [ ]24-29 [ ]If over 29
1.4	Sex/gender	( )Male ( )Female
1.5	I have started my tertiary studies at the NMMU.	( )Yes ( )No
1.6	Please enter your home languages.	
1.7	Where are you living while studying at the NMMU?	[ ] NMMU residence. [ ] Off-campus close to the NMMU. [ ] Off-campus and I travel between 15 and 40 kilometres (km) a day. [ ] Off-campus and I travel more than 40 km a day.
1.8	Are you perhaps repeating MEM 1111/2 ?	( )Yes ( )No
1.9	Do you have a desktop computer or laptop?	( )Yes ( )No
1.10	How many laboratory reports did you write at school?	[ ]0 [ ]1-2 [ ]3-4 [ ]5-6 [ ]7-8 [ ]more than 8
1.11	What types of texts (e.g., textbooks) were you required to read at school?	
1.12	What types of texts (e.g., poetry) do you enjoy reading?	
1.13	What types of texts (e.g., essays, reports) were you required to write at school?	
1.14	Who read what you wrote at school, i.e., who was your audience of what you wrote?	

1.15	Please enter your student number	
1.16	Please enter the name of your high school (alma mater)	

add new question

2. PRACTICES, KNOWLEDGE AND EXPERIENCES

2.1	I use subject-specific dictionaries for formal writing.	always ( )( )( )( ) never
2.2	I know that well-written laboratory reports are a necessary requirement for a career in engineering.	not a need at all ( )( )( ) definite need
2.3	Explain in full what you think you need to know when writing laboratory reports.	
2.4	When I write, my first draft is my only one.	( )Yes ( )No ( )Don't know
2.5	I enjoy discussing my formal writing with different people.	( )Yes ( )No ( )Don't know
2.6	Explain why you do or don't like to discuss your formal writing with different people.	
2.7	When I experience difficulties with any type of writing,	[ ] I seek help in some way. [ ]I give up trying. [ ] I try hard to work out what to do on my own. [ ] I start all over again from the beginning.
2.8	Explain in full what you need to do when writing laboratory reports	

add new question

3. BELIEFS ABOUT WRITING

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3.2	I believe writing is just a technical skill similar to drilling a hole in a plate.	( )Yes ( )No ( )Don't know
3.3	I believe there is one proper way of writing based on fixed rules.	( )Yes ( )No ( )Don't know
3.4	I believe writing is a product of my creativity as an author.	( )Yes ( )No ( )Don't know
3.5	I believe writing is a practical drafting and redrafting process.	( )Yes ( )No ( )Don't know
3.6	I believe writing involves processes of thinking.	( )Yes ( )No ( )Don't know
3.7	I believe writing is a social activity.	( )Yes ( )No ( )Don't know
3.8	I believe writing is an act of power.	( )Yes ( )No ( )Don't know
3.9	I believe different types of writing depend on different kinds of purposes.	( )Yes ( )No ( )Don't know
3.10	I believe writing is linked to reading and using a computer.	( )Yes ( )No ( )Don't know

3.11	Explain in detail what you believe writing to be.	

add new question

4. BELIEFS ABOUT LEARNING TO WRITE

4.1	I learn to write by writing as many types of writing as possible for different purposes and in different situations.	( )Yes ( )No ( )Don't know
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4.3	I learn to write when I can be a creative author and express myself.	( )Yes ( )No ( )Don't know
4.4	I learn to write when I see and read well-written examples of the type of writing required.	( )Yes ( )No ( )Don't know
4.5	I learn to write reports based on my experiences of the type of report required.	( )Yes ( )No ( )Don't know
4.6	I learn to write reports when the teacher implements planning, drafting, evaluating, revising and editing processes and practices.	( )Yes ( )No ( )Don't know
4.7	I learn to write when I get different kinds of feedback from different readers to my reports, such as verbal and written responses.	( )Yes ( )No ( )Don't know
4.8	I learn to write when I am taught rules and patterns of symbols and words in different types of reports.	( )Yes ( )No ( )Don't know
4.9	I learn to write when teachers make clear to me what and how types of reports will be assessed.	( )Yes ( )No ( )Don't know
4.10	Explain in detail what you believe about learning to write.	

add new question

add new category

Page footer text here MEM1111/2 and MAS1122 writing questionnaire

APPENDIX E

Student Name	Student Number	National Diploma	Date Submitted
Surname, Initial	205XXXX	Mech Eng or IE	xx March 20xx

Department of Mechanical Engineering

Laboratory Practical Title
Lab Report 1 (Triangle of Forces)

Laboratory / Practical Report Book

Instructional Offering	**Mechanics of Machines 1**
Subject Code	**MEC111**

Mark Allocation		
Title	Weighting (%)	Mark Allocated
General Quality of Report	10	
1.0 / 2.0 Aim/Objective and Apparatus	5	
3.0 Method	5	
4.0 Theory	10	
5.0 Results, Tables, Graphs, Sketches	30	
6.0 Discussion/ Conclusion	30	
7.0 Bibliography	10	
Total	**100**	

Contents

[Update the contents page (right click on the content table and select update field, OK > Update page number only) – delete this text in your final report]

1.0 AIM/OBJECTIVE

To verify the principle of the triangle of forces by comparing the results of a practical experiment to theoretical results.

2.0 APPARATUS

Vertical board , spring balances , slotted weights , hangers , pulleys , paper , “prestik” ‘ protractor , string , scissors , scale and ruler.

[Insert labelled pictures of the apparatus used and any additional information of each apparatus– delete this text in your report]

3.0 METHOD

3.1 Attach a sheet of A4 paper to the vertical board by means of a “prestik” behind each corner.

3.2 Arrange the apparatus as shown in Figure 1 . For optimum accuracy, ensure that enough weights are placed on the hangers to achieve approximately half deflection on the spring balance. [The spring balance are rated at 500g, therefore halfway is 250g – delete this text in your report]

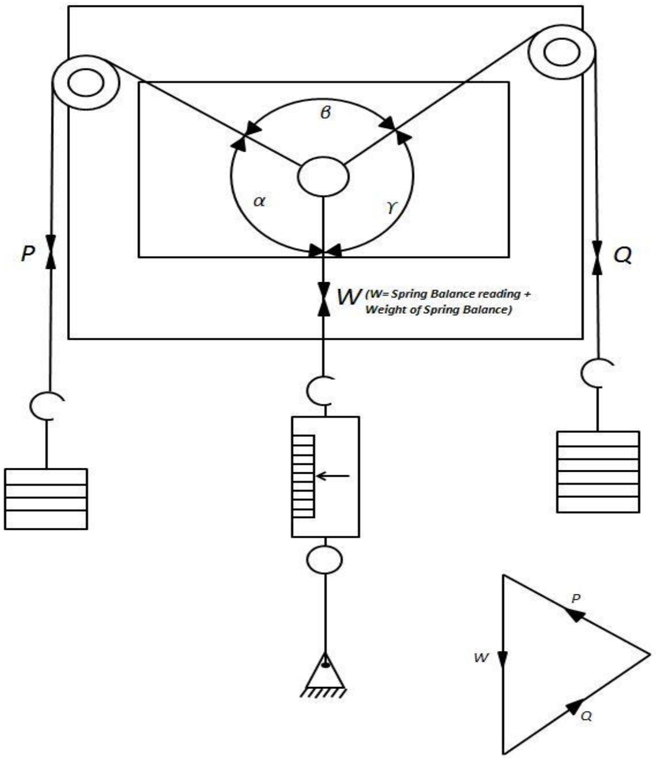

Figure 1 Setup Diagram

3.3 Copy the positions of the strings onto the paper by using a square. Place the square against the board and allow the edge of the square to just touch the string. Do this at two points along the string as far apart as possible and then join the points with a ruler.

3.4 Determine the forces in the strings by recording the reading on the spring balance, the weight of the spring balance and by weighing the hanger with the weights on the scale provided.

3.5 Draw a neat sketch of the arrangement as part of your report

[Note. Include additional steps if taken and pictures of the setup.
The neat sketch must be made using the shapes, text boxes in Microsoft Word.
The "W" force is made from two components, the spring balance reading and the weight of the spring balance combined– delete this text in your report]

4.0 THEORY

4.1 Lami's Theorem

[Include a full description of Lami's theorem. Lami's theorem is not in your text book – visit the library! - – delete this text in your report]

4.2 Triangle of Forces

[Define the term "Triangle of Forces" – delete this text in your report]

4.3 Resultant

[Define the term "Resultant" – delete this text in your report]

4.4 Reaction

[Define the term "Reaction" – delete this text in your report]

4.5 Tie

[Define the term"Tie" – delete this text in your report]

4.6 Strut

[Define the term "Strut" – delete this text in your report]

4.7 Methods to Resolve a System of Forces

[List three different methods that can be used to resolve a system of forces. – delete this text in your report]

5.0 RESULTS

5.1 Lami's Theorem

[Using Lami's theorem and the weights of the hangars and angles between strings calculate what *W* should be. – delete this text in your report]

[Note: Use equation editor for all the equations.
Where possible, draw a simple diagram in **Microsoft Word** (using the shapes, text boxes) to explain the "force/angles" of the practical (to replace the paper cut outs) and theory section (to aid the calculations – delete this text in your report]

[When inserting figures, below is an example:

The forces applied on the slider are shown in Figure01.

.

Fig01. Forces applied on the slider

5.2 Table of Results

[Tabulate your results showing clearly the difference between the theoretical and actual spring balance readings. – delete this text in your report]

The results are summarized in Table01

Table01. Summarized Results

	Spring Balance Reading [g]	Error [g]
Practical		
Theory		

6.0 DISCUSSION/CONCLUSION

[Discuss your results addressing trends, anomalies and possible improvements. **This section is very important**. Where possible, always backup your statement with evidence (e.g. calculations, pictures, observations) – delete this text in your report]

6.1 DISCUSSION

XXXXXXX

6.2 CONCLUSION

XXXXXXX

7.0 BIBLIOGRAPHY

[Use the Vancouver System of referencing – delete this text in your report]

[Once you have completed the report, adjust the formatting (i.e. page numbering, spacing. etc.) to suit your content. All text should be Font: **Arial.** Size: **10,** Colour: **Automatic** – delete this text in your report]

[Attached the original plotted sheet as the addendum – delete this text in your report]

Rename the word file as shown below:
Surname_Prac1 (e.g. Lalla_Prac1.docx)
Please email an electronic (soft) copy of the practical to amish.lalla2@nmmu.ac.za and Kholisa.Papu2@nmmu.ac.za . The **hard copy** (printed version) date and time are shown below:
21st Feb group – Hand in is on the **3rd March before 10h00 (at the start of the lecture)**.
28th Feb group – Hand in is on the **10th March before 10h00 (at the start of the lecture)**.
– delete this text in your report]

APPENDIX F

Nelson Mandela Metropolitan University
for tomorrow

Student Name	Student Number	Date Submitted
Surname, Initial	205XXXX	18 July 20xx

Department of Mechanical Engineering

Laboratory Practical Title

Laboratory Report 3 (Friction)

Laboratory / Practical Report Book

Instructional Offering **Mechanics of Machines 1**

Subject Code **MEC111**

Mark Allocation

Title	Weighting (%)	Mark Allocated
General Quality of Report	10	
1.0 / 2.0 Aim/Objective and Apparatus	5	
3.0 Method	5	
4.0 Theory	10	
5.0 Results, Tables, Graphs, Sketches	30	
6.0 Discussion/ Conclusion	30	
7.0 Bibliography	10	
Total	**100**	

TABLE OF CONTENTS

Use section headings as table of contents. Number section headings and include page numbers.
To edit the Table of Contents, click anywhere on the Contents then click 'update table' and make the necessary change/changes (delete this instruction before submitting).

8.0 AIM

To determine the coefficient of friction between various materials.

9.0 INTRODUCTION (exploring your beginning ideas)

2.1 Before the investigation, did you understand anything about the coefficient of friction between various materials? Could you represent your ideas in a drawing? If yes, what did you understand this coefficient to be?
2.2 How is the angle of repose associated with the coefficient of friction between various materials?
2.3 What is needed to determine this coefficient?
2.4 Before the investigation, did you think this coefficient can be verified at all?

Example: ***(Use your own words when writing!)***

2.1 Before the investigation, I did not understand anything about the coefficient of friction and I could not represent my ideas in a drawing. The reason could be that … [give a reason if there is one]
2.2 The relationship between the angle of repose and the coefficient of friction is…
2.3 Mention what one needs to know/do to be able to determine this coefficient.
2.4 Before the investigation, I did not think this coefficient of friction can be determined because…[it is important to give a reason/reasons to support your answer].

10.0 METHODS AND MATERIALS[1]

Materials

- Adjustable plane
- sliders with various types of material on the sliding surface
- weight hanger
- string
- protractor
- spirit level
- pulley
- scale and
- slotted weights

[Insert labeled pictures of the apparatus used and any additional information of each apparatus– delete this text in your report]

Methods

3.6 Place the slider on the horizontal plane and attach the string to it.
3.7 Pass the string over the pulley and attach the hanger to the end of the string.
3.8 Add just enough weights to the hanger so that the slider moves slowly with constant velocity.
3.9 Weigh the hanger complete with weights.
3.10 Repeat the above steps with additional weights packed on the slider
3.11 Determine the angle of repose of the slider alone by placing it on the inclined plane and increasing the angle till the slider just moves down the plane with constant velocity. (The slider must not have weights packed on it nor must it have a string attached for this part of the experiment)
3.12 Repeat steps 3.1-3.8 with two different sliders materials

[Note: Include additional steps if taken and pictures of the setup – delete this text in your report]

Questions:

3.1 Write a summary of the key procedures you have followed in this investigation.
3.2 Include additional steps if taken and pictures of the set-up
3.3 What variable/variables did you keep the same in this investigation? [give reasons]

Examples: ***(Use your own words when writing!)***

---

[1] ***Hint: How to write the Methods and Materials section in a Lab Report***

i) Decide on the correct level of detail for someone else to be able to repeat the experiment.
ii) Do not simply list materials used in the investigation, rather mention materials and equipment as they are used and as you write the method/procedure followed.
iii) Write this section in past tense, in either active or passive voice, do not simply copy and paste the given methods/procedures as they are.

3.1 To summarize the methods used in this investigation, I have tried to determine the coefficient of friction between…. I have done this by…
3.2 The additional steps I have taken are… / There were no additional steps taken because…
3.3 The variable that I kept the same in this investigation was… because…

7.0 OBSERVATIONS

4.1 What role did the additional weights packed on the slider have on the angle of repose, if at all?
4.2 What must the angle of repose be for the slider to move down the plane with constant velocity? Does the absence of additional weights have an impact on this thing angle? [Use your own words to explain your experience and what you have observed – use full sentences.]

Examples: ***(Use your own words when writing!)***

4.1 During the experiment, my aim was to determine the coefficient of friction between various materials which are… I put on additional weights on the slider in order to …
4.2 For the slider to move down the plane with constant velocity, the angle of repose must be … Angles lesser/greater than … [mention how these angles affected your investigation]

8.0 THEORY

5.1 Discuss the **significance of the angle of repose** and what can be calculated if one knows this angle. Refer to engineering theory or to library books and support your argument by giving reasons.

5.2 Discuss the **change in coefficient of friction** (if any) when the normal force between friction surfaces is changed. Refer to engineering theory or to library books and support your argument by giving reasons.

5.3 What is meant by the **theoretical term "smooth surface"**. Refer to engineering theory or to library books.

5.4 What are the different **laws of friction**? List these laws.

9.0 RESULTS

10.1 Show sample calculations (with the aid of figures) using the Equation Editor in Microsoft Word – delete this text in your report.

Below are an examples of how to insert figures:

6.1

a) The forces applied on the slider are shown in Figure01. ← Heading / Title of the figure

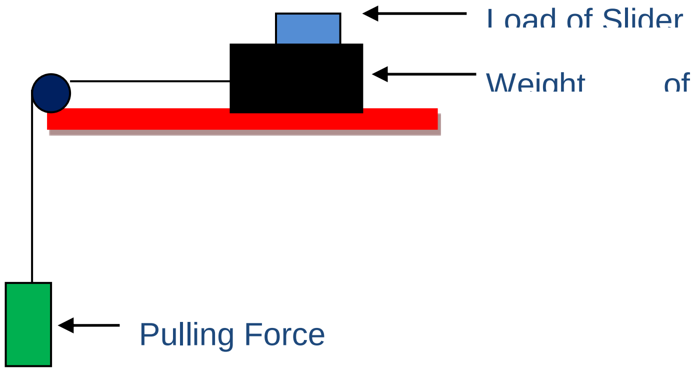

Fig01. Forces applied on the slider ← Caption / Subtitle of the figure

b) The Nylon Slider results are summarized in Table01 ← Heading / Title of the table

Table01. Nylon Slider Summarized Results ← Name of the table

Slider Material:		Angle of Repose Xx Degree		
		Coefficient of friction calculated from angle of repose xx		
Weight of slider	Load on slider	Total normal force between slider and plane	Pulling force	Coefficient of friction calculated
	0			
Data Collected	Data Collected	Calculated	Data Collected	Calculated

c) The Wooden Slider results are summarized in Table02 ← Heading / Title of the table

Table02. Wooden Slider Summarized Results ← Name of the table

Slider Material:		Angle of Repose Xx Degree		
		Coefficient of friction calculated from angle of repose xx		
Weight of slider	Load on slider	Total normal force between slider and plane	Pulling force	Coefficient of friction calculated
	0			
Data Collected	Data Collected	Calculated	Data Collected	Calculated

d) The Laminated Wooden Slider results are summarized in Table03 ← Heading / Title of the table

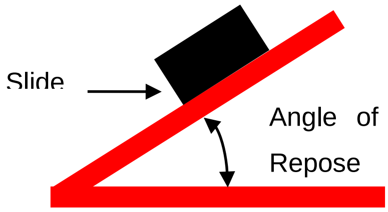

Table03. Laminated Wooden Summarized Results ← Name of the table

Slider Material		Angle of Repose Xx Degree		
		Coefficient of friction calculated from angle of repose xx		
Weight of Slider	Load on slider	Total normal force between slider and plane	Pulling force	Coefficient of friction calculated
	0			
Data Collected	Data Collected	Calculated	Data Collected	Calculated

10.0 CLAIM

7.1 What is the main thing I found out in this investigation (based on the methods, theory and your calculations?)

Example: ***(Use your own words when writing!)***

Based on the methods, theory and calculations, the main idea that I found out in this investigation is ….

11.0 DISCUSSION / CONCLUSION [more marks are awarded in this section – answer all questions!]

Discussion

8.1 Discuss your results addressing trends, anomalies and possible improvements. This section is very important!
8.2 What might I expect someone else to say if they thought I was wrong?
8.3 How would I convince them that I am correct?

Conclusion

8.4 What are your conclusions?

Example: ***(Use your own words when writing!)***

Discussion

8.1 Based on the results of my investigation, the common trend (tendency/common factor) was… The presence of this common trend suggests that …

The anomaly/anomalies (irregularity/inconsistency/glitch) found in the results of this investigation were…
The presence of such an anomaly/anomalies could be due to…

I have identified the following possible area/areas of improvement… (give reasons)

8.2 If anyone had a different opinion to mine they would say/suggest that…

8.3 Since I am convinced that I am correct I would say… because…

Conclusion

8.4 I conclude that…

12.0 BIBLIOGRAPHY

[Use the Vancouver System of referencing – delete this text in your report]

[There is no addendum for this practical – delete this text in your report]

[Once you have completed the report, adjust the formatting (i.e. page numbering, spacing. etc.) to suit your content. All text should be Font: **Arial.** Size: **10,** Colour: **Automatic** – delete this text in your report]

APPENDIX G

Laboratory / Practical Report Book

Instructional Offering **Mechanics of Machines 1**

Subject Code **MEC111**

Mark Allocation

Title	Weighting (%)	Mark Allocated
General Quality of Report	10	
1.0 / 2.0 Aim/Objective and Apparatus	5	
3.0 Method	5	
4.0 Theory	10	
5.0 Results, Tables, Graphs, Sketches	30	
6.0 Discussion/ Conclusion	30	
7.0 Bibliography	10	
Total	**100**	

APPENDIX H

SECTION	ENGINEERING WRITING HEURISTIC: ARGUMENTATION				
1. Aim	**Is the aim stated?** Aim not stated	Aim clear and incomplete	Aim clear and complete		
	1	2	3		
2. Introduction (*Warrants*)	**Is the exploration of beginning ideas about the subject clear?**				
	No beginning ideas	Beginning ideas unclear	Beginning ideas fairly presented	Beginning ideas clear but incomplete	Beginning ideas well-presented
	1	2	3	4	5
3. Methods and materials (*Backings – in terms of rigour of the investigation)*	**Is the method clearly stated to persuade readers that the investigation is firmly grounded (Thoroughness of investigation)?**				
	Investigation not thorough, poor persuasion	Almost thorough investigation, poor persuasion	Mostly thorough and fair persuasion	Thorough investigation, and good persuasion	Thorough investigation and very good persuasion
	1	2	3	4	5
4. Observations (*Data and backings*)	**Is there a clear understanding of the data to be generated?**				
	Unclear understanding	Some understanding shown but with flaws	Understanding shown	Understanding clearly shown but with flaws	Understanding clearly and thoroughly shown
	1	2	3	4	5
5. Theory (*Backings*)	**a) Have key theoretical terms been listed and defined with the support of accredited sources to show understanding?**				
	No listing or definition	Listing and definition done but with omissions	Fair attempt	Listing and definitions done with no omissions	Listing and definitions well done
	1	2	3	4	5
	b) Have library sources been used to support observations made during the investigation?				
	No support from credible sources	Some support evident but not from credible sources	Support fairly done	Support clearly done with credible sources but incomplete	Support clearly done with credible sources
	1	2	3	4	5
	c) Have key theoretical terms been used when reporting on observations?				
	No reference to key theoretical terms	Limited reference to theoretical terms	Fair attempt	Good reference to theoretical terms	Reference to theoretical terms well done
	1	2	3	4	5
6. Results (*Data and backings*)	**a) Are the data generated clearly and suitably presented (tables, graphs, pie charts or calculations)?**				
	No suitable representation, incomplete	Suitable but not complete and often incomplete	Suitable, mostly complete	Suitable, complete	Well done, clear, complete, suitable
	1	2	3	4	5

	b) Are there explanations provided to support the data? No explanations given (1) · Explanations given but are unclear (2) · Fair attempt (3) · Clear but incomplete support (4) · Clear and explicit narrative support (5)
7. Claim *(Based on evidence, warrants and backings)*	**a) Is an appropriate claim made?** No claim made (1) · Inappropriate claim made (2) · Weak claim made (3) · Clear but incomplete claim made (4) · Clear, explicit and appropriate claim made (5) For example: *The position of the centre of gravity can be determined.* *b)* **Are there any qualifiers, that is, conditions or limits of strength to claims?** No qualifiers made (1) · Inappropriate qualifiers made (2) · Weak qualifiers made (3) · Implicit qualifier made (4) · Clear, explicit and appropriate qualifier (5)
8. Discussion *(Rebuttal)*	**Are the results discussed addressing trends, anomalies and possible improvements?** Results not discussed adequately (1) · Fair description of Trends and anomalies No improvements (2) · Only trends, anomalies, and improvements – no rebuttal (3) · Weak rebuttal and weak qualifier made (4) · Both rebuttal and qualifier made (5)
9. Reflection *(Understanding of Validity of claim)*	**Is there a visible understanding of the process of producing a valid claim?** No clear reflection. The process of generating a valid claim is not clear (1) · Inappropriate reflection (2) · Appropriate reflection made but with some flaws (3) · Appropriate reflection but incomplete link with the given aim (4) · Clear reflection revealing the process of generating a valid claim (5)
10. References	**Is there at least one reliable source (library source) cited and listed (fully) in the bibliography?** No source cited or listed in the bibliography (1) · There is either a citation and no bibliography or vice-versa (2) · Both citation and bibliography are incomplete (3) · Either Citation present but bibliography incomplete (4) · Both citations and bibliography are well done (5)

APPENDIX I

LANGUAGE MARKING RUBRIC: WRITING PRACTICES

Laboratory Report :

Student Evaluated: **Student Number:** **Date:**

SECTION	SCALING				
1. Language Usage	**1) Writing is concise and specific**				
	Wordy and vague or imprecise	Less wordy and more precise	Somewhat concise and specific	Frequently but not consistently	Consistently concise and specific
	1	2	3	4	5
	2) Grammatical conventions (punctuation, editing extra words, concord)				
	Poor use of grammatical conventions	Inconsistent application of conventions	Fairly good use of conventions	Good use of Conventions	Excellent use of all conventions
	1	2	3	4	5
	3) Consistent verb/tense correctness				
	Poor use of tenses and often incorrect	Fairly consistent and correct	Appropriate for articular lab report section	Tenses generally consistent and correct	Tenses always consistently effectively used
	1	2	3	4	5
	4) Writing shows clarity and no ambiguity				
	Frequently unclear and ambiguous	Seldom clear and unambiguous	Fairly clear and unambiguous	Good use of clarity and no ambiguity	Consistently clear and unambiguous
	1	2	3	4	5
	5) Academic vocabulary is used with understanding and references are provided				
	No academic language or references	Some references but no show of understanding	Limited understanding	Used regularly with understanding	Effectively woven to demonstrate understanding
	1	2	3	4	5
	6) Words are often spelt correctly				
	Regularly incorrect and distracting	Sometimes incorrect but not distracting	Minor inconsistencies with spelling	Frequently correct	Consistently correct
	1	2	3	4	5

2. Coherent Writing

1)There is evidence of one controlling idea or aim or objective

Poor or no evidence of a controlling idea or aim	Fair use of a controlling idea	Good use of a controlling idea	Regular and effective reasoning and argumentation	Excellent use of reasoning and argumentation
1	2	3	4	5

2) There is a visible link between report sub-sections

Poor or no link between report sub-sections	Fair use of links report sub-sections	Good use of links between report sub-sections	Regular and effective use of links between reports sub-sections	Excellent use of reasoning and argumentation
1	2	3	4	5

3) Full sentences are used and syntax

Poor or no use of full sentences and syntax	Fair use of full sentences and syntax	Good use of sentences and syntax	Regular and effective use of full sentences and syntax	Excellent use of full sentences and sentence flow
1	2	3	4	5

4) There is evidence of reasoning and argumentation (i.e. use of words like but, however, contrary to, because, if…, then…)

Poor or no use of reasoning and argumentation	Fair use of reason and argumentation	Good use of reasoning and argumentation	Regular and effective use of reasoning and argumentation	Excellent use of reasoning and argumentation
1	2	3	4	5

5) References are woven with own writing

Poor or no weaving of references with own writing	References fairly woven with own writing	Good weaving of references with own writing	Regular and effective weaving of references with own writing	Excellent weaving of references with own writing
1	2	3	4	5

APPENDIX J

My World @ NMMU Web Survey | Nelson Mandela Metropolitan University

QUESTIONNAIRE 2 for Mechanics of Machines (MEC1111)

Preview Page | Re-order Page Numbers | Re-order Category Numbers by Page | Survey Summary | Survey List | User Guide

Page: 1

Page No: 1 [Edit] [Add]

Please provide your Student Number here..................

1. TEACHING MATERIALS, KNOWLEDGES AND PRACTICES

Please click an appropriate option.

1.1 I know how to structure a laboratory report.

strongly disagree ○ ○ ○ ○ ○ strongly agree

1.2 What helped you to write a laboratory report? (You may choose more than one option)

- [ ] The written instructional guide on the topic.
- [ ] The written instructional guide on the topic with prompts (questions) and examples of how to write.
- [ ] The template for a laboratory (lab) report.
- [ ] The language marking rubric used for lab report two and three.
- [ ] The argumentation marking rubric used for lab report two and three.
- [ ] Feedback questions helped me to think critically when writing lab reports.
- [ ] The labwrite website
- [ ] The Wrise website

1.3 I was confident with using the marking rubric.

strongly disagree ○ ○ ○ ○ ○ strongly agree

1.4 Who or what helped you to understand the assessment rubric for a laboratory report? (You may choose more than one option from the list)

- [ ] The MEC 1111 lab report writing tutor
- [ ] The MEC 1111 lecturer
- [ ] A classmate
- [ ] A respondent at the Writing Centre
- [ ] The English language teacher in the Writing Centre
- [ ] Another mechanical engineering lecturer
- [ ] A teacher from another department.
- [ ] The assessment rubric was clear enough for me to interpret by myself.

1.5 Who used the rubric to assess your writing before you submitted your laboratory report for marking?

- [ ] I used the language and argumentation marking rubric to do this.
- [ ] A peer used this rubric to review my laboratory report before I submitted it for marks.
- [ ] The Writing Centre used the marking rubric for a laboratory report to respond in writing to my draft.
- [ ] All of the above.
- [ ] I did not use a marking rubric to assess my lab report.

1.6 When using the marking

	rubric, who used the corresponding lab report sub-headings as a checklist to assess your writing before you submitted your lab report for marking?	☐ I used the corresponding lab report sub-headings in the argumentation marking rubric to do this. ☐ A peer used these corresponding lab report sub-headings to review my laboratory report before I submitted it for marks. ☐ The Writing Centre used these corresponding lab report sub-headings to do this. ☐ All of the above. ☐ I did not use the corresponding lab report sub-headings in the argumentation marking rubric as a checklist. ☐ I did not have this marking rubric.
1.7	I know how to use precise, formal language when writing a laboratory report.	strongly disagree ○ ○ ○ ○ ○ strongly agree
1.8	What helped you to use signpost words (e.g. however, similarly, therefore) and phrases to link sentences and paragraphs together in the laboratory report?	○ The written instructional guide on the topic with prompts (questions) and examples of how to write. ○ A list of useful signpost words and phrases from the Writing Centre ○ Knowledge gained from another lab report writing module or communication module ○ I have always known how to use signpost words and phrases to link sentences and paragraphs together in a laboratory. ○ I am still not sure when and how to use signpost words. ○ I dont know what signpost words are
1.9	The prescribed textbook helped me to write the laboratory reports for Mechanics of Machines 1.	strongly disagree ○ ○ ○ ○ ○ strongly agree
1.10	I used a subject-specific dictionary from the internet or library when writing the laboratory reports for Mechanics of Machines 1.	○ Yes ○ No
1.11	Writing a laboratory report has helped me to understand and explain concepts relevant to investigating the triangle of forces, centre of gravity and friction.	strongly disagree ○ ○ ○ ○ ○ strongly agree
1.12	What helped you to sequence numbers and link these to full references in your laboratory report using the Vancouver system? (You may select more than one option from the list).	☐ The two-page Department of Mechanical Engineering Vancouver referencing guide ☐ The longer Vancouver referencing guide compiled by the Writing Centre ☐ The examples of different publications in the well-written report ☐ Examples that I found after searching on the internet ☐ All of the above ☐ Insert Endnote using numerical reference Style ISO 690 in Microsoft Word
1.13	Based on what I know now, I expect to do well in writing laboratory reports in future engineering modules.	strongly disagree ○ ○ ○ ○ ○ strongly agree

1.14 Please provide your student Number.

add new question

2. PRE-LABORATORY ACTIVITIES

(Please the appropriate option. You may choose more than one option)

2.1 What kind of activities were you engaged in before completing a laboratory investigation?

- ☐ Downloading and pre-reading the laboratory report instructions guide
- ☐ Downloading and pre-reading the laboratory report instructions guide with prompts (questions) and examples of how to write
- ☐ Recalling theoretical information and calculations from previous lecturers
- ☐ Reading relevant library books to understand theoretical terms
- ☐ Reading about the specific theoretical terms from the internet
- ☐ Skimming through the laboratory report writing guide
- ☐ Bringing a printed copy of the laboratory report writing guide to the laboratory practical
- ☐ Other

add new question

3. DURING LABORATORY ACTIVITIES

Please choose the appropriate option. You may choose more than one option.

3.1 What kind of activities did you do during the laboratory investigation?

- ☐ Referring to the printed laboratory report instructions guide when doing the investigation
- ☐ Active involvement in doing the laboratory investigation
- ☐ Recording data generated in the laboratory report writing template
- ☐ Working in groups of twos or threes
- ☐ Comparing our laboratory procedures with our classmates
- ☐ Consulting the laboratory technician when unsure or when experiencing difficulties with the investigation
- ☐ Taking pictures of the key procedures and results
- ☐ Discussing and asking questions to group mates while doing the investigation
- ☐ Connecting theoretical themes with procedures and observations
- ☐ Generating authentic data
- ☐ Fabricate or cook-up data
- ☐ Identifying my beginning ideas for the investigation
- ☐ Other

add new question

4. POST-LABORATORY ACTIVITIES

(Please the appropriate option. You may choose more than one option.)

4.1 What kind of activities did you do after the laboratory investigation?

- ☐ Writing the first draft of a laboratory report individually
- ☐ Recalling my beginning ideas about the investigation
- ☐ Comparing my beginning ideas with the aim of the investigation, observations, and results of the investigation
- ☐ Re-writing the methods and materials section as it appears in the laboratory report instructions guide without making any changes
- ☐ Re-writing the methods and materials section in past tense, active or passive voice mentioning how materials were used
- ☐ Formulating the claim based on observations, results and the theoretical sections of the laboratory report

☐ Including in-text references in the theoretical and discussion area of the laboratory report

☐ Include technical graphics such as labelled graphs, tables and pie charts

☐ Other

add new question

5. GROUP WORK

(Indicate your group by referring to the alphabetical list)

5.1	Which group were you part of?	(please select)
5.2	Group 1 ONLY must answer this questions 5.2 - 5.10. Are you part of Group 1?	○ Yes ○ No
5.4	I used the Moodle/Learn online platform.	○ Yes ○ No
5.5	If your answer is No, give a reason.	
5.6	I uploaded and shared my laboratory reports with my partner.	○ Yes ○ No
5.7	If your answer is No, give a reason.	
5.8	I received feedback from my partner based on my laboratory reports.	○ Yes ○ No
5.9	If your answer is No, give a reason.	
5.10	What kind of feedback did you give to your partner?	☐ Written feedback ☐ Verbal Feedback ☐ Both
5.11	Group 2 ONLY must answer question 5.11 - 5.19. Are you part of Group 2?	○ Yes ○ No
5.12	I have used the Email system to share my draft laboratory reports with my partner.	○ Yes ○ No
5.13	If No, give a reason.	
5.14	I received feedback from my partner based on my laboratory reports.	○ Yes ○ No
5.15	If No, please give a reason.	
5.16	I gave feedback to my partners laboratory reports	○ Yes ○ No
5.17	If your answer is No, please give a reason.	

5.18 What kind of feedback did you give to your partner? Yes No

5.19 If your answer is No, please give a reason.

5.20 Group 3 ONLY must answer question 5.20 - 5.26. Are you part of Group 3? Yes No

5.21 Did you draft, revise and edit your laboratory report before final submission? Yes No

5.22 If your answer is No, please give a reason.

5.23 Did you ask a classmate to read your first draft and comment on it? Yes No

5.24 If your answer is No, please give a reason.

5.25 Did you ask a lecturer to read or comment on your first draft of a laboratory report? Yes No

5.26 If your answer is No, Please give a reason.

5.27 Did you require assistance from the Writing Centre? Yes No

5.28 Did you read and comment on a classmates draft laboratory report? Yes No

5.29 If your answer is No, please give an answer.

5.30 What kind of feedback did you give to your partner? (please select)

add new question

6. BELIEFS ABOUT WRITING AND LEARNING TO WRITE

(Please tick the appropriate option.)

6.1 When I write the laboratory report, I am aware that I am advancing a particular argument. strongly disagree strongly agree

6.2 I believe that the argument must be backed by experimental data. strongly disagree strongly agree

6.3 When I write the lab report I am aware that I have to synthesize the data generated in practical investigation with theory. strongly disagree strongly agree

6.4 The most challenging laboratory report section to write is the:

- Aim
- Introduction
- Methods and materials
- Observations
- Theory
- Results
- Claim
- Discussion
- Reflection
- Reference

6.5 I believe writing in engineering requires:

- A thorough understanding of content knowledge (i.e. Theory & calculations)
- A thorough understanding of how do engineering principles & theory interact with the society & environment.
- Persuasive writing by using accurate graphs &concise written language.
- An aim / a strong thesis statement that seek to answer specific questions.
- May explain results that dont conform to predictions.
- Problem solving
- Logical presentation of events from problem/aim to background, experiment, findings & discussions
- Proficiency in reading
- Application of critical thinking

6.6 When I write the Discussion section of a laboratory report, I use the Results of the investigation to:

- Compare & contrast
- Explain
- Argue in support of my claim
- Address trends, anomalies & possible improvements.
- Rebut against the aim or a certain theoretical concept (e.g. Lami's Theorem)

add new question

add new category

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