Understanding of Non-technical Words in Chemistry: A Case Study of Saudi EFL (English as a Foreign Language) College Students

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I certify that all material in this thesis which is not my own work has been identified and that any material that has previously been submitted and approved for the award of a degree by this or any other University has been acknowledged.

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ABSTRACT

The purpose of this research is to explore Saudi English as a Foreign Language (EFL) college students' understanding of non-technical words in chemistry. The study is premised on constructivism as a theory of learning. Although studies have been conducted on English Language Learners and non-technical words in general science, they are limited with respect to adult learners. Similar studies in the discipline of chemistry are even more scarce; and that pertaining to Saudi EFL college students appears non-existent. This thesis adopts a case study design that incorporates a mixed methods research design variant termed sequential explanatory design. There are two distinct phases in this design. The first phase is a corpus-based study whereby corpora made from the Saudi students' chemistry textbook were analysed through the production of keyword lists. This led to the identification of 46 potentially problematic non-technical words of various kinds including both common and uncommon everyday lexis, as well as those situated as verbs, nouns and adjectives. The second phase involved interviewing eleven Saudi EFL college students to explore their understanding of eleven non-technical words derived from the first phase. The findings from this thesis make several original contributions to existing knowledge in the field of chemistry education. This includes the identification of numerous potential non-technical words related to secondary chemistry. Also, the findings gave insights into the nature of Saudi EFL college students' comprehension of these words including commonalities and idiosyncrasies in their conceptions of concepts in chemistry. Further, it was found that their first language has a bearing on how non-technical words are understood in English. The students' varied proficiencies in both English and their mother tongue, Arabic, have similar consequences in this regard. Solutions are suggested for a dilemma in this research context related to the conflicting aims of English and chemistry courses in Foundation Year programs. As a result, this novel study identifies several areas for future research within this area of study.

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LIST OF ABBREVIATIONS

CEFR	Common European Framework of References for Languages
EAL	English as an Additional Language
EFL	English as a Foreign Language
ELL	English Language Learner
EMI	English as a Medium of Instruction
HCA	Hard Core Axioms of Constructivism
KSA	Kingdom of Saudi Arabia
KWIC	Keyword in Context
MoE	Ministry of Education
RQ	Research Question
ZPD	Zone of Proximal Development

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

The introduction begins with a rationale for this study which is based on a general interest in the role of language in science, and chemistry more specifically, and the study context, Saudi Arabia. The differences between everyday language, and what could be considered as the language of science are explored, followed by a focus on one important aspect of language, lexis, or more precisely, non-technical words. The disadvantaged position of Saudi English as a Foreign Language (EFL) college students is argued with reference to the demands of the language of science. An overview of the adopted theoretical model, constructivism as a theory of learning, is offered, and thereafter the research questions are presented, and the potential significance of the study findings are discussed. The chapter closes with a brief description of the subsequent chapters in this thesis.

1.2 RATIONALE

The rationale for this study is derived from my teaching experiences of chemistry in the UK and in Saudi Arabia. In the UK, during my teacher training course, approximately 12 years ago, I had the opportunity to work with the English as an Additional Language (EAL) department in one of my placement schools. Though the EAL support given there had no direct connection with the science department, it led me to think that if these students were to get specialist support, then science, and chemistry in particular as my sub-speciality, would become more accessible. I found through my own experience and discussions with science teachers that the language of science was not often perceived as an obstacle. Some teachers seem to believe that it requires little, or no, attention. Wellington and Osborne (2001) share such experiences and acknowledge that learning the language of science is one of the ‘major difficulties’, but “tragically, this is not a message that has reached the science teaching profession, for experience would suggest that science teachers often consider it to be of marginal relevance” (p.1).

More recently, I have had the opportunity to work in Saudi Arabia which is a very different context to the UK in terms of language and culture. I have found through my working experience in Saudi Arabia that the linguistic demands for subjects taught in English to Saudi students can be a significant hindrance to learning a subject. There are students who study in the medium of Arabic for their whole schooling life (up to age 18), and then have the task of studying subjects in the medium of English as they must undertake a one year compulsory course (Preparatory/Foundation Year) prior to continuing their education at undergraduate level. They are daunted with the task of learning a new language, English, and dealing with the demands of the language of science. Johnstone and Selepeng (2001) elaborate on this matter:

> Learning material couched in complex, unfamiliar language requires a lot of room in the Working Space to transform it to an understandable form…science is found to be a difficult subject…its language requires too much processing…second-language learners…are faced with an even more complex task of dealing with the processing of two unfamiliar languages, that of science and that which is used as the medium of instruction. What then passes to Long Term Memory may be quite minimal or transient. (p.23)

Chemistry is a fascinating subject as it allows us to understand the world at a level beyond our sight. The unique experimental aspect of chemistry can appear mystical as chemical reactions are full of colour, extraordinary sights and spectacular sounds; it touches on all our senses. Knowledge of chemistry is vital for our daily life. Unfortunately, general conclusions from studies show that most students from all parts of the world may not consider pursuing it as a career (Ramsden, 1998; Salta & Tzougraki, 2004; Belge Can, 2012). In the UK, the ASPIRES project has explored how students aged 10-14 develop aspirations to pursue science related careers (Archer et al., 2013). The findings show that while students enjoy science, and appreciate its importance, only a minority would consider it as a career, as other subjects like business are more appealing to them. A recent guidance report has provided science teachers in England with seven recommendations to improve teaching practices in the hope that more young people would study science at higher levels (Holman & Yeomans, 2018). Fortunately, one of the recommendations draws teachers' attention to the importance of language in science, demonstrating that this is still a matter of concern. Despite this, literature on the language of science in relation to Saudi Arabia appears non-existent. University preparatory programs in Saudi Arabia offer intensive English courses to support students in understanding subjects such as chemistry, showing the importance given to general English language as a subject, but not necessarily equal importance to the language of science itself. This suggests that there are two important issues here which I will unpick in the next sections of this chapter: the issues of learning the language of chemistry in English, and the specific issues faced by Saudi EFL college Students who are learning chemistry in the medium of English.

1.3 THE LANGUAGE OF SCIENCE AND NON-TECHNICAL WORDS

The present thesis is concerned with the issues arising for Saudi EFL College students with respect to the language of science and particularly, non-technical words in chemistry. These words have dual meanings, one for what could be thought of as its everyday meaning, and the other as its scientific meaning. In this study a non-technical word is taken to mean a word which has both an everyday usage, and when embedded in the discipline of science, it carries a specific meaning linked to the understanding of science concepts (Oyoo, 2012). Research indicates that non-technical words are problematic as “students often see or hear a word and assume its meaning, without assessing the context in which it is used” (Childs, Markic & Ryan, 2015, p.433). Previous research has explored issues in learning Science arising from distinctions between everyday and scientific meaning of non-technical words: the present study further explores this issue in a particular educational context in which non-technical words are translated between Arabic and English, as well as between the language of everyday English and the language of science. In the remainder of this section, the issue of science as a language in itself is discussed, and the role and nature of non-technical words within the language of science is highlighted.

1.3.1 Everyday Language & The Language of Science

Language is a very comprehensive term and includes numerous facets, including and not limited to, specific syntax structures, lexis and associated collocations, devices which aid coherence etc., and these are situated within receptive skills (reading and listening) and productive skills (writing and speaking). To claim that something is a language would partly require it to have features which are different from other languages. Halliday (2004) outlines several characteristics of scientific English: interlocking definitions; technical taxonomies; special expressions; lexical density; syntactic ambiguity;

grammatical metaphor; and semantic discontinuity. In the following extract from a science textbook the interlocking feature can be illustrated:

> …scientists now believe that the **nuclei** of **atoms** are made up of **protons** and **neutrons**. These two components of the **nucleus** are usually referred to as **nucleons**. The **electrons** occupy the space outside the **nucleus**. (Fullick & Fullick, 1994, p.26)

In order for one to understand each of the bold typeface words above, they would need to understand these words in relation to the other bold words. So an atom according to the extract can be understood as something which contains protons and neutrons. Protons and neutrons together can be referred to as nucleons, and electrons are something outside the nucleons. So we can begin to see that the words are 'interlocked' as key words are understood in relation to other key words. The high lexical density of scientific text can be made evident using the following example:

(a) But we never did anything very much in <u>science</u> at our <u>school</u>. (2)
(b) My <u>father</u> used to <u>tell</u> me about a <u>singer</u> in his <u>village</u>. (4)
(c) A <u>parallelogram</u> is a <u>four-sided figure</u> with its <u>opposite sides parallel</u>. (6)
(d) The <u>atomic nucleus absorbs</u> and <u>emits energy</u> in <u>quanta</u>, or <u>discrete units</u>.(8) (Halliday, 2004, p.168)

The example above begins with clauses (a) and (b) which are typical of spoken language; clause (c) is representative of written language; and clause (d) is writing in science. The numbers in the parenthesis relate to the number of words which are considered as high lexical terms. The scientific writing consists of eight highly lexical items which reflects its high density, whereas everyday spoken language has only two items.

Chemistry has been referred to a language in itself (Laszlo, 2013), and even named as 'Chemish' (Markic & Childs, 2016), but it may not necessarily mean that it is a different language to science as it is a sub-speciality of science. When considering the context of a science classroom, it is quite complex. The teacher's instruction could include language which we consider as typical of everyday language, and at times the language may be situated in the context of chemistry. As such, the dividing line between what we use as everyday language and what we could consider as the language of science is an unclear one, though, there are some clear distinctions between everyday language and scientific language as outlined above. Moreover, there are some noticeable differences between everyday ordinary language and the language of science, and chemistry in particular:

- it has a large, specialized, precise, and unfamiliar vocabulary, for example, hydrophilic, autotroph, cytokinesis, amphoteric;
- many technical words are encountered only a few times so that they do not become familiar; the roots of many scientific words and terms are based on Greek and Latin, which are unfamiliar to today's students, for example, poly-, -mer, hyper-;
- it uses terms with different meanings in a science context to their everyday use, for example, solution, force, current;
- it has challenging written and oral demands, with polysyllabic words and complex sentences, for example, oligosaccharide, hypothesis, photosynthesis;
- it uses symbolic language, which contributes to students' difficulties with science, for example, CH_4, NH_4^+
- it uses diagrams to represent structures, which are a vital part of chemical discourse;
- it uses many logical connectives and command words, for example, therefore, because, explain, describe;
- mathematics and its symbolic language are a key part of science, for example, PV=nRT;
- there is a lack of practice in using the language of science in writing/reading or speaking/listening except in school;
- there is a greater requirement for accuracy and rigor in scientific discourse, particularly spelling, for example, alkane versus alkene.

(Childs, Markic & Ryan, 2015, p.430-431)

Thus, there are numerous distinctive features that makes the language used in chemistry considerably different to how we use language in an everyday sense.

1.3.2 Words in Science

One of the notable and significant aspects of language in science is its vocabulary. Though lexis is only a part of what constitutes a language, it is an important distinguishing feature of science:

> Words can have a power and influence quite out of proportion to their triviality as mere marks on paper or vibrations in air. When circumstances are right they can excite people's minds and move their imaginations, in science as in any other area of human activity. (Sutton, 1992, p.1)

In general, words in science can be classified into three groups: scientific words, semi-technical words, and non-technical words (Wellington & Osborne, 2001). Wellington and Osborne (2001) describe scientific words as those that are unique to the discipline such as *cathode*. Semi-technical words generally are used both within and out of the science context, and as they point out, some of these words have dual meanings (e.g. *positive*), and this can lead to difficulties in learning the language of science. The third category, non-technical words (e.g. *initial*), is common in most subject disciplines such as mathematics and physics, and is also widely used in science. Oyoo (2012) uses the term 'non-technical words' instead of 'semi-technical words' for words which can be used both in an everyday and science context, and he extends the classification of non-technical words to include metarepresentational terms, and logical connectives. Metarepresentational terms are metacognitive and metalinguistic language. In general, metarepresentational words represent high order expression and thinking such as the word 'deduce'. Logical connectives are words such as 'because' and 'therefore', and they are important in making links between processes and inferences.

In the field of linguistics, words with more than one meaning are referred to as polysemous words. Polysemy is:

> …a phenomenon that exposes multiple relations and connections between syntax, semantics and pragmatics, and between language, cognition and social interaction. It can only be studied if we try not to isolate one from another. (Nerlich & Clarke, 2003, p.16)

The concept of polysemy dates back to 429-347 B.C. amongst Greek philosophers. However, linguists refer to Michel Breal as the researcher who originally used the term polysemy in the 1890s (Nerlich, 2003). Breal was intrigued with the fact that people do not get confused with the multiple meanings of a word, and this is possible, according to Breal, because words occur in a specific context in discourse and in particular situations (Nerlich, 2003). So the other possible meanings of a word are eliminated in contexts, hence polysemy involves even the social interaction and cognition aspect.

1.4 SAUDI EFL COLLEGE STUDENTS

A number of studies have focussed on English Language Learners (ELLs) in science in recent years, and some studies go as far back as a few decades ago (Mali & Howe, 1979). While some hold that the English proficiency of ELLs has little bearing on achievement in science providing they have a strong background knowledge in science in their mother tongue (Hayes & Mansour, 2016), others argue that their achievement in science is still of concern as recent research shows that there are “large achievement gaps between” ELLs and non-ELLs (Garza et al., 2018, p.1501). Nonetheless, it is clear that ELLs are at a disadvantage when learning science as they have the task of understanding the language of science in a medium which is foreign to them:

> … students from diverse languages and cultures bring to the science classroom ways of knowing, talking, and interacting that are sometimes different from those in the mainstream. When disparities abound between school science and students' cultures, the quality of educational experience suffers if Western science is imposed on students who do not share its system of meanings, symbols, and practices. (Lee, 2001, p.499)

Saudi EFL college students, I argue, are faced with more challenges than those ELLs described in related past studies who are learning in schools in Western countries where English is the main language spoken. Some ELLs in Western schools, though non-native English users, may have been exposed to enough English by the time they enter secondary school for the barrier of learning in English to be reduced. Other students, as is found in schools in England, might have access to specialist EAL support staff who could help a student progress in acquiring the language. In comparison, Saudi EFL college students learn science in the medium of English in a country where English is a foreign language, thus having less exposure to English than those who study in Western countries, and “it is clear from the literature [that learning under these conditions] can present great problems to students whose mother tongue is not English” (Rollnick & Rutherford, 1993, p.371).

Another important factor is that not all ELLs are the same in terms of their proficiency in English, and most Saudi EFL college students begin studying English in a preparatory year program having completed their schooling life in Arabic medium schools. A preparatory year is a one-year compulsory program of study that students must pass in order to progress on to proceed to their designated bachelor’s degree. English language is a core subject within a preparatory year. The English course in the context of this study, as most other preparatory year English programs, use mainstream published material that adopt the CEFR (Common European Framework of References for Languages) levels as a reference point (Cambridge ESOL, 2011) where students begin studying as A1 learners of English. The CEFR is a framework which describes the linguistic ability of learners with respect to the core skills in language: reading, writing, listening and speaking (Council of

Europe, 2001). According to the CEFR document, research began as early as the 1970s with a concern for what learners can do in terms of meaningful tasks such as describing their surroundings and so on. The six main reference levels are: A1, A2 (Basic User); B1, B2 (Independent User); and C1, C2 (Proficient User). A descriptive account for each of these levels can be referred to in the introduction of Council of Europe (2001). Essentially, such preparatory programs enrol students who are 'basic users' of English: it is these students who are the focus of this thesis. Given that research suggests that ELLs are at a disadvantage in general with respect to learning science in the medium of English, we can assume that the challenge is greater for Saudi EFL college students who have previously learned science in their mother-tongue, Arabic, and are now, as adults, learning science in a language (English) where they are 'basic users'.

1.5 THEORETICAL FRAMEWORK

The theoretical framework for the present study is based on "constructivism as a perspective on learning that has consequences for how to teach canonical knowledge" (Taber, 2016, p.117). A more detailed discussion of this theoretical framework is presented in chapter three and extends to language based theories drawn from Vygotsky and Bakhtin with their ideas being confined to the 'hard core axioms' of constructivism. The perspective of constructivism taken in this thesis is premised on seven (hard) core axioms:

Premise 1. Learning science is an active process of constructing personal knowledge.
Premise 2. Learners come to science learning with existing ideas about many natural phenomena.
Premise 3. The learner's existing ideas have consequences for the learning of science.
Premise 4. It is possible to teach science more effectively if account is taken of the learner's existing ideas.

Premise 5. Knowledge is represented in the brain as a conceptual structure.
Premise 6. Learners' conceptual structures exhibit both commonalities and idiosyncratic features.
Premise 7. It is possible to meaningfully model learners' conceptual structures. (Taber, 2013, p.7)

The first premise is the most fundamental feature of this form of constructivism. Knowledge is not transferred to a learner, rather it is understood that a learner actively constructs his or her own personal knowledge, in other words, ideas as abstract principles are subjectively experienced by learners (Taber, 2009). The construction of personal knowledge would imply that learners already possess ideas about natural phenomena (Premise 2), and this would have consequences on their learning of science (Premise 3). Teachers should facilitate learning of a school curriculum (target knowledge) by taking into account students' existing ideas (Premise 4). As we attempt to make sense of our world, we resort to our memory and revisit ideas as knowledge is represented in our brains (Premise 5). Learners may exhibit ideas that may be common to other learners, but also idiosyncratic features as knowledge is personally constructed (Premise 6), and though complex as we do not have direct access to a learner's thoughts, these conceptual structures could be modelled (Premise 7).

1.6 RESEARCH QUESTIONS

The research questions listed here have been developed from a review of the present literature (see Chapter Three) and is being introduced here for the purpose of clarity and to facilitate the reader's reference to them throughout the thesis. Though research has been conducted on non-technical words which includes participants who are ELLs (Cassels & Johnstone, 1985; Marshall, Gilmour & Lewis, 1991; Farrell & Ventura, 1998; Childs & O'Farrell; 2003; Garza et al., 2018), the reported non-technical words were not based on chemistry specifically. Chemistry is unlike the other science disciplines (physics and biology), especially as it is represented at three levels: macroscopic, submicroscopic, and symbolic levels (Treagust & Gilbert, 2009). Research which has focussed, or at least included, findings relevant to non-technical words in chemistry is emerging with respect to non-traditional chemistry students. Moreover, the phenomenon of Saudi college students who study chemistry in the medium of English as a Foreign Language (EFL) is relatively under-researched, and research pertaining to their understanding of non-technical words in chemistry appears non-existent. Therefore, the overarching research question for this study is:

- How do Saudi EFL college students understand selected non-technical words from their core chemistry textbook?

In order to address this research question, several related sub-research questions are needed:

- **Research Question A (RQA)** What non-technical words are there in the Saudi EFL college students' core chemistry textbook?
- **Research Question B (RQB)** How familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words?
- **Research Question C (RQC)** To what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry?
- **Research Question D (RQD)** What is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?

This requires identifying potential non-technical words from the Saudi EFL students' core chemistry textbook (RQA), and exploring this conjecture through mainly interviewing these students. The core chemistry textbook is the main reference book the students' chemistry course is built upon – essentially it is the curriculum. The participants of concern in this study have a limited proficiency in English in comparison to native speakers of English, and to some extent, other ELLs. As such, it would be of interest to understand their familiarity of the selected non-technical words (RQB). Non-technical words can be problematic as the embedment of the everyday meaning in the context of chemistry would lead to a non-canonical account of chemistry and thus possibly influencing students' conceptions of the target concept (RQC). The Saudi students' first language is Arabic, and with their limitations in English, it is expected that they would need to resort to their first language, and this may have consequences on their understanding of non-technical words (RQD).

1.7 SIGNIFICANCE OF THE STUDY

The findings of this thesis have the potential to make a contribution to the field of study both nationally and internationally. As mentioned earlier, to the researcher's knowledge, nothing has been reported with respect to Saudi EFL college students' understanding of non-technical words in chemistry. Therefore, it is anticipated that the findings will enrich our understanding of the issues arising from concurrent translation between Arabic and English, and between 'everyday' and 'scientific' language, as these learners study chemistry in English. In particular, the study has the potential to contribute to understanding the difficulties posed in students' understanding of non-technical words due to limitations in their use of English. Moreover, exploration of how these students utilise their first language, Arabic, to make sense of chemistry concepts studied in English may offer insights into how students construct their scientific knowledge and understanding. In doing so, the findings may be relevant to a range of stakeholders, for example those involved in curriculum design of similar preparatory college programmes; teachers of chemistry in English to adult ELL learners who have previously learned chemistry in Arabic; and potentially chemistry teachers with native Arabic speaking ELL learners in other contexts, including mainstream schooling and schooling in Western countries.

1.8 OUTLINE OF THE THESIS

Following this introductory chapter, a brief description of the remaining six chapters is outlined. **Chapter Two** describes the context of the study, the Kingdom of Saudi Arabia, including details outlining the educational system. **Chapter Three** is a literature review. It begins with introducing the adopted theoretical framework for this study, constructivism as a theory of learning. The key ideas of Bakhtin and Vygotsky, in relation to words, are explored within the limits of the assumptions of constructivism adopted in this study. A range of studies are reviewed showing the importance of words in science, and in particular, non-technical words in chemistry. This includes a metasynthesis of non-technical words in chemistry. Finally, a key gap is identified in terms of research in relation to Saudi EFL college students and their understanding of non-technical words in chemistry, and the research questions are presented as a result of this. **Chapter Four** outlines the research methodology of this study. It begins with a discussion of case study research as the chosen research methodology to address the research questions. This section explores various debates within this field and justifications for its use are provided. The chapter continues with a description of the overall research design detailing the procedures and analysis of a corpus based approach to identify non-technical words and interviews of Saudi EFL college students understanding of a selection of these identified non-technical words. **Chapter Five** presents the findings and analysis of the corpus based analysis. With the construction of 12 IGCSE chemistry based corpora, hundreds of keywords were analysed in search for potential non-technical words within the participants' core chemistry textbook. **Chapter Six** reports the findings from the case study. This involved conducting semi-structured interviews with eleven Saudi EFL college students. **Chapter Seven** discusses these findings in relation to the theoretical framework and research questions of this study and relevant literature in the field. The final chapter, **Chapter Eight**, concludes the study with implications for teaching and methodology, outlining the study's contribution to knowledge, limitations, and recommendations for future research in the field.

CHAPTER TWO

CONTEXT OF STUDY

2.1 INTRODUCTION

This chapter begins with a general overview of the Kingdom of Saudi Arabia (KSA), and then outlines the education structure, elaborating on school English and science. The notion of English as a Medium of Instruction (EMI) is discussed in relation to KSA, and specifically in university preparatory year programs. Several challenges of teaching Saudi EFL college students are cited, and then this section closes with a general description of the context of the present study.

2.2 THE KINGDOM OF SAUDI ARABIA

KSA covers a significant proportion of the Arabian Peninsula whilst sharing its borders with several countries including Yemen, Oman, Qatar, Bahrain, United Arab Emirates, Kuwait, Iraq and Jordan. All of these surrounding countries are Arabic speaking countries, and Arabic is the official language in KSA. The country consists of 13 regions with the capital city, Riyadh, located in the centre. KSA is a monarchy with the king of the country having complete authority over the government and ruling the country on a constitution based on Islam and giving great attention and concern to Saudi citizens. The constitution is dictated by the ‘Holy Book’, the ‘Qur’an’, and the prophetic traditions of the last ‘Prophet and Messenger’ in Islam, Muhammad (‘Peace be Upon Him’) with strict adherence to worshipping God alone without any mediators. Islam is a fundamental aspect of KSA, with Makkah, situated in the Western region, being the birth place of Prophet Muhammad (‘Peace be Upon Him’) approximately

1500 years ago. Makkah is the holiest city in the world for Muslims and as such over two million Muslims perform the obligatory holy pilgrimage, Hajj, in this city once a year, and visiting the second holiest city, the Prophet’s city of Madinah, which is located approximately 400 km north-east of Makkah. Moreover, life in KSA revolves around Islam and this extends to the opening and closing of stores around prayer times, the Hijri calendar (based on Islamic months), religious holidays, and reduced working hours in the holy month of Ramadan (month of fasting). According to the General Authority for Statistics (2019), the current population is 33,413,660 with 12,645,033 (38%) accounting as foreigners (non-Saudis). The statistics also show that there is a large young generation; as of mid-2019, approximately 17 million of the population was below the age of 30. Of relevance to the present study, there are presently (2019) 76,046 (18-22 year-old) students enrolled in pre-university programs. The great wealth amounted from oil has resulted in major developments in numerous aspects including education establishments, healthcare, and recreation in what was once a predominantly desert region.

2.3 SCHOOL EDUCATION SYSTEM: ENGLISH & SCIENCE

Schools in Saudi Arabia operate under the authority of the Ministry of Education (MoE) which oversees all aspects of the educational system, which includes the school curriculum, examinations and related policies. The MoE was established in 1975, though it went through several transformations dating back to 1925 (Ministry of Education, 2019). The general education structure in Saudi Arabia consists of five levels:

> Kindergarten, elementary, intermediate, secondary, and higher education. Kindergarten includes three divisions … infant, nursery, and preliminary. The elementary level spans grades 1 through 6 [ages 6-12], the intermediate and secondary levels are 3-year cycles, the former

> including grades 7, 8, and 9 [ages 12-15] and the latter grades 10, 11, and 12 [ages 15-18]. (Al-Seghayer, 2005, p.127)

A number of subjects are taught at government funded schools in Saudi Arabia ranging from those which are typical of most schools around the world (English, maths, science, geography etc.) and those which are based on their constitution and relates to Islam such as Tafsir (explanation of the Qur'an). With the exception of English, all these subjects are taught in the medium of Arabic. Once students reach grade 10, they must choose to pursue a science path of study, or a humanities path; with the former a route to study science related subjects such as medicine and engineering, and the latter for studies in business, English, and history for example.

English is the only compulsory foreign language taught at Saudi public schools, and for many university programs. Al-Seghayer (2005) provides an account of the history of English in Saudi Arabia. Shortly after the country's establishment in 1932, and the expansion of the oil sector, English was introduced by the government due to the need to communicate with the outside world. The great wealth generated through the oil industry allowed the country to carry out large national projects in the 1970s thus increasing the need to train their citizens, and English language was an important part of this training. English is seen "as a skill almost obligatory for a modern professional in any field" (Tamtam, Gallagher & Naher, 2012). Students take four periods of English instruction a week in their schooling years, and since the 2002-2003 academic year it was taught at elementary level, as prior to that it was only compulsory for grades 7 through 12.

Science is a compulsory subject in Saudi Arabia and taught to school students of all ages and this includes the teaching of general science in both primary and middle school. In the latter stage (grades 10 – 12), science is sub-divided into four science disciplines (physical science, earth science, life science, and chemistry) whereby students get taught these as separate subjects (Aldahmash, Mansour, Alshamrani & Almohi, 2016). Though little is known about the contact hours of these science programs at various ages, Aldahmash et al. (2016) report that in middle school, students typically have four science class periods a week (45-minute classes). In the 1970s, science experts from the American University in Beirut made considerable changes to the science education curricula, but following the dissatisfaction of this curricula in terms of fulfilling the needs of Saudi society, coupled with the low achievement of Saudi science students, this led to the beginnings of a reform focussed on “inquiry-orientated instruction in science…in 2003” (Mansour, Alshamrani, Aldahmash & Alqudah, 2013, p.33).

Khaddoor, Al-Amoush and Eilks (2017) have found that little research has been conducted on Arabic science textbooks, and more so with chemistry books in Saudi Arabia. They report that in the Saudi education system, there is total reliance on school science textbooks by all stakeholders as the government uses them to convey matters pertaining to national identity, and teachers and students consider them to be the curriculum (Alghamdi, 2019). According to Aldahmash et al. (2016), “in Saudi Arabia, 100% of teachers depend totally on textbooks and teacher guidebooks for science instruction, lesson aims, and learning activities as well as homework” (p.881). A change to Saudi science textbooks within the last decade has involved translating American science textbooks, specifically the publisher McGraw-Hill, into Arabic and this has been accepted with mixed views (Albadi, Harkins & O’Toole, 2019). “Many teachers considered the previous science textbooks to be boring and monotonous, to lack information, and to focus on mathematics exercises that did not encourage student participation in experimental work" (Albadi, Harkins & O'Toole, 2019, p.703). Those against this change on the other hand complained about the loss of meaning through translation and the difficulty of teaching books in modern standard Arabic. They thus resort to local dialects to teach the subject, and the addition of some English terms adding to the confusion. Despite the translation of Western textbooks into Arabic, cultural and religious aspects are still noticeable such as one middle school chemistry textbook reported to include pictures of people wearing thobes (Saudi traditional attire), and mentioning the great ability of God in the first chapter (Khaddoor, Al-Amoush and Eilks, 2017).

2.4 EMI IN PREPARATORY YEAR PROGRAMS

After grade 12, Saudi students typically proceed to study in a university preparatory program (also known as Foundation Year). This is a compulsory program of study for those desiring to obtain a bachelor's degree. The MoE also governs this sector even though it was formerly under the Ministry of Higher Education between 1975 and 2015, after which the two ministries merged and named as the MoE (Ministry of Education, 2019). In preparatory year programs, students undertake intensive English lessons of approximately 550 hours of instruction, alongside other basic sciences (Shamim, Abdelhalim & Hamid, 2015). The basic sciences are taught in the medium of English and these subjects include chemistry, biology, physics, mathematics and IT. The teachers on these programs are not necessarily bilingual (English and Arabic), and even if they are, they must teach these subjects in the medium of English.

Macaro (2018) reviewed numerous definitions to describe the instruction of subjects in a foreign language and found that there was a lot of inconsistency. Several terms were used interchangeably: English Medium Instruction (EMI), Content-Based Instruction (CBI), Immersion education, Content and Language Integrated Learning (CLIL). Part of this problem relates to the geographical location of the research and what is commonly known in that region, as for example, in Europe the term CLIL is used. In this study, the term EMI is used and defined as:

> The use of the English language to teach academic subjects (other than English itself) in countries or jurisdictions where the first language of the majority of the population is not English. (Macaro, 2018, p.1)

EMI under this definition has a number of defining features. The second language (L2) is not spoken locally; L2 is used for teaching in English only; the teacher is a content specialist; the majority of students are nationals of the country; and teaching material is written by native speakers (Macaro, 2018). EMI has been accepted by teachers and students in Saudi Arabia with mixed views, and it will remain a controversial issue (Al-Kahtany, Faruk, Al Zumor, 2016). At the opposing end, teachers feel that it is difficult to teach a specialist subject in English to students who are weak in English, and students feel that they can learn the content better in their first language. However, those who see benefit in EMI point out that learners benefit from both content and language learning at the same time, and refer to the ease of finding suitable academic material that would not be found in the first language (Macaro, 2018).

2.5 CHALLENGES OF TEACHING SAUDI EFL COLLEGE STUDENTS

Teaching Saudi EFL college students in the medium of English can be challenging and this has resulted in studies reporting on the low achievement of these students in English language (Al-Seghayer, 2014). Alrabai (2016) cites several reasons for the low achievement of Saudi EFL students including: the extensive use of the Arabic mother tongue (L1) by teachers when teaching English; social, cultural and religious issues as they feel greater importance needs to be given to Arabic to preserve such matters; too much reliance on the teacher and a lack of willingness to study out of class; and faults in the education system, for example English exams which encourage rote learning practices. Suliman and Tadros (2011) stress that the challenges are not purely linguistic, but due to differences in educational cultures. They highlight this case with nursing students:

> …on joining college, nursing students are expected to switch from using Arabic as a medium of instruction to English as the language of study and workplace, from sitting as passive listeners at school to negotiating and participating in the learning process at college, from being spoonfed to being responsible for their own education, from total reliance on the teacher to reliance on their own judgment, and from being a repository for rote-memorization of facts to being critical thinkers. In other words, the students are expected to move from school where critical thinking is at bay to where they are expected to negotiate, make decisions and justify their choices. (p.402)

Rote learning has been regarded as the opposite of meaningful learning. In both cases of learning “the actual reproduction of retained material is…affected by such factors as cultural or attitudinal bias by the specific situational demands of the reproduction setting itself” and these differences give meaningful learning “superiority” (Ausubel, 2000, p.4). However, rote learning can be useful as it could “presumably lead to sequenced firing of the same neural components, leading in turn to strengthening synaptic connections” (Taber, 2013, p.287). Mayer (2002) draws the distinction between the two as a matter of problem solving, since in rote learning the learner can recall retained facts but is not able to apply (transfer) these facts in situations which require application of what was learnt in novel situations. He elaborates that both retention and transfer are required in meaningful learning in which the cognitive processes for retention involve remembering, and transfer involves understanding, applying, analysing, evaluating and creating. The issue is that the importance of memorisation in Saudi Arabia has its roots in the religion that the country was founded upon, Islam:

> In the Islamic tradition, memorization of sacred, revealed knowledge is an appropriate first step in the process of learning, understanding, and in developing reason and discipline. Learning, understanding, and the development of reason and discipline are, in turn, ultimately meant to lead the student to greater knowledge of God and the world. (Boyle, 2006, p.494)

Similarly, Tan (2015) argues that Chinese students' practice of memorisation and repetition does not equate with rote learning and their lack of deep understanding, "on the contrary, memorisation (but not rote-learning as it implies a lack of understanding), is a strategy for the Chinese students to achieve deep understanding, logical thinking, and strong application" (Tan, 2015, pp.436-437). The point is that the move from rote learning to meaningful learning practices can be challenging for learners.

Shamim et al. (2016) conducted a study at a public university in Saudi Arabia on student and teachers' views of EMI in one university preparatory year. Data were mainly collected from classroom observations and semi-structured interviews. Most teachers thought that their subjects should be taught in English, as one teacher said, "English is the language of science" (p.39). Students who had a high proficiency in English were also in favour of EMI, but those with low proficiency levels in English felt it was unfair as prior to the Preparatory Year Program they were doing well in secondary school as the medium of instruction was in their first language (i.e. not English). The teachers were teaching the English material in the students' first language (Arabic). The students mainly faced problems with the sciences (physics, chemistry), but not with mathematics as it mainly involved numbers. As they had already learnt this material in high school, any "new learning mainly comprised the learning of scientific terms in English" (p.41). Teachers complained that students who had a low proficiency in English were unable to read the textbook, making their jobs more demanding. This resulted in students relying on lecture slides and memorising words to pass the exams.

2.6 THE STUDY SETTING

This study is situated in a small vocational college located in Riyadh, Saudi Arabia. The yearly intake of male students is approximately 100. Prior to joining this college, the students, who are Saudi male nationals, studied in public Arabic secondary schools, completing their secondary schooling aged 17-18. The medium of instruction for their schooling years was Arabic. Though having studied English as a subject during those years, this college was their first encounter with a majority English medium curriculum. In this vocational college, the students must complete their preparatory year (Foundation Year) before proceeding to their subject specialism, which is at a diploma level, and if they successfully pass their course, they are guaranteed a job in their related field. At the time of this study, the only diploma open for enrolment was the Diploma in Nursing. The diploma program consists of seven semesters which is divided into a Foundation Year (2 semesters), Clinical Specialism (4 semesters), and Clinical Practice Placement (1 semester). The Foundation Year spans over two 15-week semesters. The last two weeks of each semester is for examinations, and there is a one-week break between semesters. Students can have up to seven periods in one day.

Table 2.1 outlines the courses taught in the Foundation Year. English has the largest number of weekly instructional hours in both semesters while chemistry, biology and physics is introduced in the second semester. All the subjects are taught in the medium of English, except for self-study skills and Islamic studies, which are taught in Arabic. They follow an English curriculum based on the CEFR levels with respect to the materials used in class and assessment practices in anticipation that students leave the Foundation Year with the proficiency of CEFR A2, and thus ready to study at level CEFR B1.1. Along with English, they study basic science subjects, namely: chemistry, physics and biology. The students study three hours of theory and take two hours of practical lessons per week in the second semester. The theoretical sessions are normally lecture based lessons where students follow the teacher's PowerPoint presentations, whereas the practical lessons are lab based with the students carrying out experiments under the teacher's guidance.

The chemistry content taught in the Foundation Year is equivalent to what students studied in the last year of high school before joining this program. Meaning that the students are expected to know the content of this course, but now they have to study this in the medium of English. This requires studying all the topics in their core chemistry coursebook which for this college is an IGCSE chemistry textbook (Harwood & Lodge, 2014). Though several other colleges use the same textbook, other colleges may have their own in-house chemistry material as opposed to a chemistry textbook. All courses produce in-house examination papers which are prepared by staff from the relevant department. The breakdown of how the marks are weighted for English and chemistry are shown in Table 2.2.

Table 2.1
Courses Taught in the Foundation Year Program

Semester One (15 weeks + 2 weeks examination)		
Course	**Weekly Instructional Hours**	**Medium of Instruction**
English Language I	21	English
Computer Studies	3 (1 theory + 2 lab)	English
Mathematics	2	English
Self-Study Skills	2	Arabic
Semester Two (15 weeks + 2 weeks examination)		
Course	**Weekly Instructional Hours**	**Medium of Instruction**
English Language II	15	English
Chemistry I	5 (3 theory + 2 lab)	English
Biology I	5 (3 theory + 2 lab)	English
Physics I	5 (3 theory + 2 lab)	English
Islamic Studies	2	Arabic

Table 2.2
Weighting of Marks for English and Chemistry

Course	First Midterm	Second Midterm	Continuous Assessment	Practical Exam	Final Exam
English Language I & II	15 %	15%	20%	N/A	50%
Chemistry	15%	15%	20%	10%	40%

2.7 CHAPTER SUMMARY

KSA is a large country that has developed much in terms of establishing its educational system, especially in terms of the provision of science and English. EMI remains a controversial policy and is accepted with mixed views by both students and teachers in Saudi Arabia. Part of the challenge appears to be due to the different educational practices between Western English-speaking countries and that of Saudi Arabia. This chapter ends with details of the specific study setting for the present research by outlining pertinent features of the educational setting.

CHAPTER THREE

LITERATURE REVIEW

3.1 INTRODUCTION

The literature review begins with a description of the adopted theoretical framework for this study which is constructivism as a theory of learning. This form constructivism is underpinned by seven axioms (or hard core axioms). Vygotsky and Bakhtin’s ideas are explored in relation to words, and attempts are made to reconcile these ideas and confine them under the limitations set out in the hard core axioms of constructivism adopted in this study as essentially this study is focussed on non-technical words in chemistry. Following this, research related to words in science is reviewed, which then builds into studies particular to non-technical words in chemistry. A metasynthesis is conducted with respect to non-technical words in secondary school chemistry as this is the level of chemistry that the participants of this study are learning. This chapter finishes with a justification of an identified area of research worthy of studying, that being Saudi EFL college students’ understanding of non-technical words in chemistry, and consequently, the research questions are formulated.

3.2 CONSTRUCTIVISM AS A THEORY OF LEARNING

The theoretical framework for the present study is based on “constructivism as a perspective on learning that has consequences for how to teach canonical knowledge” (Taber, 2016, p.117). This perspective is premised on seven hard core axioms of constructivist research (Taber, 2006), and is referred to later in this section. First, the term constructivism is explored in terms of how the notion is used by researchers of different interests, followed by a description of the form of constructivism that is adopted in the present study. The section ends with justified responses to some reported criticisms of constructivism.

3.2.1 Many Forms of Constructivism

Despite there being a relatively shared understanding of constructivism, the term has a very broad meaning, and as such, many forms of it exists (Phillips, 1995; Doolittle & Camp, 1999; Bodner & Klobuchar, 2001). Constructivism can be understood on a continuum where at one end there is cognitive constructivism; at the other end is von Glasersfeld's radical constructivism (Doolittle & Camp, 1999). Also, there is social constructivism, with the main difference between this and the cognitive and radical forms are that social constructivism is firmly embedded on the belief that knowledge is constructed socially through language and not just individually (Prawatt & Floden, 1994). The emphasis of cognitive constructivism is on accurate mental constructions, and radical constructivism is on a working model of knowledge through experiential experience, both of which some claim lack focus on the social nature of knowledge (Doolittle & Camp, 1999).

One of the most prevalent ideologies in the past regarding teaching and learning was that of a positivist view in that knowledge is simply transferred from the teacher to the learner like a sponge; and this view has been challenged by advocates of constructivism, most notably Dewey, Piaget and Vygotsky (Allen, 2010). Dewey was in opposition to earlier scholars view of mind and matter being different, and though some thought of him as a relativist, what he believed was that as the world is ever changing, and so knowledge is not final (Taber, 2013). We are continuously acting in a changing world, and our knowledge can only act as a guide. Piaget (1964) claimed that “learning is subordinated to development and not vice-versa” (p.184). He proposed that development occurs in four stages from birth to adulthood, and four factors influence the developmental stages: maturation, experience, social transmission, and equilibrium. Social transmission refers to the input a learner gets from, for example, education. However, from these factors, he regards the equilibrium factor to be of central importance to development. Equilibrium operates at levels, and a person can only increase a level if the previous level has been obtained. For instance, a 5-year old child cannot assimilate undergraduate level of knowledge until what has come before has been acquired within his/her schema. A schema is a structure which has been made internally in the developmental process. He is suggesting that learning will only occur if the stimulus incorporates into the learner's schema. This means that a response is made from the schema, and the stimulus will not assimilate without the structure being present. So in essence, this theory of how learning takes place is fundamentally an internal process. Vygotsky's idea of social interaction enlightening a learner's internal developmental process is a key differentiating point in comparison to Piaget's theory. Vygotsky (1978) proposed that there are two developmental levels. The first, the actual developmental level, pertains to those mental functions that are fully matured. The second is related to development as a result of external guidance and he names this as the zone of proximal development:

> It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (Vygotsky, 1934/1978, p.86)

So, in effect, development is behind learning as through the zone of proximal development, development reaches maturation.

3.2.2 Hard Core Axioms of Constructivism

Much research has been conducted on children's alternative conceptions which has contributed to the development of the hard core assumptions of constructivism which has been adopted as the theoretical framework for this study. In this thesis, an alternative conception means "conceptions formed by learners that are judged to be inconsistent with canonical concepts presented in science curriculum" (Taber, 2016, p.144).

Gilbert and Swift (1985) proposed a Lakatosian research program for what they termed as the 'alternative conceptions movement'. They believed that emerging research on alternative conceptions was at a preparadigmatic phase as research was 'uncoordinated' though there was increased attention from the concerned research community (Gilbert & Swift, 1985, p.682). Lakatos (1978) states:

> … the typical descriptive unit of great scientific achievements is not an isolated hypothesis but rather a research programme. Science is not simply trial and error, a series of conjectures and refutations. 'All swans are white' may be falsified by the discovery of one black swan. But such trivial trial and error does not rank as science. Newtonian science, for instance, is not simply a set of four conjectures - the three laws of mechanics and the law of gravitation. These four laws constitute only the 'hard core' of the Newtonian programme. But this hard core is tenaciously protected from refutation by a vast' protective belt' of auxiliary hypotheses. And, even more importantly, the research programme also has a 'heuristic', that is, a powerful problem-solving machinery, which, with the help of sophisticated mathematical techniques, digests anomalies and even turns them into positive evidence. (p.4)

Lakatos (1978) believed that rival programmes could coexist even if one was 'progressive' and the other 'degenerative' as the degenerative programme could be turned into a progressive one. Gilbert and Swift (1985) recognised the alternative conceptions movement as an emerging research programme which required a 'hard core', a 'protective belt', and a 'heuristic', and that could coexist and compete with the 'Piagetian School' orientated programme. In a Lakatosian research programme there are methodological rules which indicate what research paths to avoid, negative heuristic, and which to pursue, positive heuristic (Lakatos, 1978, p.47). The hard core is the set of assumptions in a research programme which are irrefutable and are the defining assumptions of that programme. A protective belt surrounds the hard core which is basically a series of auxiliary hypotheses that are coherent with the hard core. The difference being that these auxiliary hypotheses, unlike the hard core, can be changed, or even dismissed and thus a successful research programme "leads to a progressive problem shift [and] unsuccessful if it leads to a degenerating problemshift" (Lakatos, 1978, p.48).

Gilbert and Swift (1985) regarded Piaget's stage theory as the hard core assumptions in the Piagetian School. They believe the development of Piaget's stage theory provides evidence of the protective belt, or refutable variant. It is different to the hard core assumption of stages, as the protective belt relates to how these stages are manifested. As for the positive heuristic, they use Arlin's (1975) proposal of an additional fifth stage to overcome evidence showing that progressive changes can occur beyond the formal operation stage, or as Lakatos considers as digesting the anomalies. Despite this, they believe advocates of the Piagetian School hold it as irrefutable, and so a positive heuristic cannot operate with this mode of thinking. In comparison to the Piagetian School programme, Gilbert and Swift (1985) proposed their set of hard core assumptions:

1. The world is real.
2. All observations are theory-laden.
3. Individuals use personally appealing explanatory hypotheses to cope with events in their environment.
4. The individual tests these hypotheses through interaction with reality against personally appealing criteria.
5. Reality provides guidance as to the adequacy of these hypotheses so tested.

6. When hypotheses are judged inadequate by such testing, either the hypotheses or test criteria by which they were judged are modified or replaced. (p.689)

The alternative conceptions movement was in its infancy in their time, and as such, the protective belt and positive heuristic at that time were not developed. They did suggest the notion of conceptual change, proposed by Hewson (1981), to be representative of the protective belt.

Taber (2006a) revisited the proposed Lakatosian research programme three decades later with a revised hard core set of axioms based on evidence from key seminal papers on alternative conceptions dating between 1978 and 1983. The present study is premised on these hard core set of axioms. Taber (2013a) outlines these as:

> Premise 1. Learning science is an active process of constructing personal knowledge.
> Premise 2. Learners come to science learning with existing ideas about many natural phenomena.
> Premise 3. The learner's existing ideas have consequences for the learning of science.
> Premise 4. It is possible to teach science more effectively if account is taken of the learner's existing ideas.
> Premise 5. Knowledge is represented in the brain as a conceptual structure.
> Premise 6. Learners' conceptual structures exhibit both commonalities and idiosyncratic features.
> Premise 7. It is possible to meaningfully model learners' conceptual structures. (p. 7)

Premise 1 is at the heart of constructivism as a theory of learning. Knowledge cannot be simply transferred to a learner, but instead, the learner actively constructs his or her own personal knowledge. In terms of personal knowledge, a clear distinction is made between ideas as abstract principles and ideas as experienced (Taber, 2009). Ideas in the form of abstract principles are subjectively experienced by learners, thus such knowledge is personally constructed. If learners are constructing their own knowledge, then this would imply that they do not come to a science classroom with a blank mind with respect to the target knowledge (Premise 2) and would influence how the target knowledge (school curriculum) is understood (Premise 3). The student may hold alternative conceptions, in that his/her ideas are at odds with the target knowledge (Taber, 2009), and the student's experience of the target knowledge may not necessarily displace these alternative conceptions.

Premise 4 is a logical consequence of premise 3 (Taber, 2006). Instructional methods need to be put in place do deal with students' ideas which are not in conformity to the target knowledge. In order to rectify a misconception, the new concept must appropriately explain the learner's experiences better than the preconception (Bodner, 1986; Diver, Squires, Rushworth & Wood-Robinson, 1994; Allen, 2010). The term 'conceptual change' is the general term used to describe rectifying a student's misconception from a constructivist's point of view, whereby:

> the pre-instructional conceptual structures of the learners have to be fundamentally restructured in order to allow understanding of the intended knowledge, that is, the acquisition of science concepts. (Duit & Treagust, 2003, p.673)

Duit and Treagust (2003) mentioned that one of the prominent models of conceptual change involves the accommodation of a new concept, providing it is "intelligible, plausible and/or fruitful" (p.673). They clarify, intelligible in the sense that the concept can be understood by the student; plausible, as in the concept is believable; and fruitful, in terms of concept being able to solve problems other than the intended one. Despite this, they claim that no past research has shown that a misconception can be completely removed from a person's mind, as that misconception could become apparent at a future date.

Knowledge is represented in our brains and is accessible to us, with our memory being structured (Premise 5). The information is processed in an organised fashion as we try to make sense of something or apply what we already know. In effect, “the brain represents ideas from thought in forms that allow (substantially the same) ideas to be revisited, and it does so in ways reflecting the semantic relationships that were originally understood” (Taber, 2009, p.142). This does not necessarily mean that we always revisit ideas in an identical manner to the original experience. We as humans share many things in common, whilst differing in many ways too (Premise 6). An important distinction needs to be made between a ‘concept’ and a ‘conception’ (Gilbert & Watts, 1983). A ‘concept’ is something that can be shared, but our ‘conception’ of that ‘concept’ would vary from one person to another. Taber (2013a) adds:

> Similarly we could say that a person’s concept (e.g. of metal) may change over time because at different times they have different conceptions. Again we can use the term concept to refer to what is considered to have continuity and conception to refer to the particular – here at a moment in time. It is the ‘same’ concept in the sense in which the reader is the same person they were as toddler or the way a mature tree in the garden is the same plant as the sapling planted there many years before. (p.284)

A group of learners who come from the same sociocultural background would be expected to have similar conceptual structures as they interact with a similar world, for example, the same teacher; yet, what they may experience in their day-to-day life would vary, thus having conceptual structures with idiosyncratic features. With regards to Premise 7, though ‘complex’, a learner’s ideas could be modelled as a meaningfully representation of their conceptual structures (Taber, 2009). It is complex, as we cannot have direct insight into learners’ minds and have to rely on learners giving an accurate representation of their ideas. In addition, the researcher would need to accurately interpret this representation.

3.2.3 Criticisms of Constructivism

Taber (2006b, 2009b, 2016) has outlined several scholarly criticisms of constructivism and has provided reasonable responses to these criticisms.

These critics' claims include constructivism's 'relativist' perspective not fitting well, or contradicting, with the nature of science (Mathews 1994, 2002; Scerri, 2003); constructivist research is not progressing in terms of pedagogy, and the social aspect of learners is not given importance (Solomon, 1994).

One main criticism of constructivism in science education is that it is founded upon a relativist view of knowledge:

> Most of what constructivists maintain about knowledge is completely mistaken, but if "belief is substituted for knowledge in their accounts, then a lot of the claims are perfectly sensible and some of them may even be right. Whether they are right or wrong is a matter of psychological investigation, that simply has nothing to do with epistemology or with deciding whether some claim constitutes knowledge. (Mathews, 2002, p.126)

Gilbert and Swift's (1985) first point of their proposed hard core assumptions, stated above, assumes that the world is real. Moreover, in constructivism, the definition of knowledge as true justified belief is problematic (Taber, 2009). We measure what a student knows in relation to a school curriculum, and even then we cannot really know if a student has demonstrated that he 'knows' as he may hold the curriculum to be true whilst holding conflicting conceptions to be true too. Though some may take a relativist stance, most constructivists in science education believe that an external reality does exist, but absolute knowledge of that reality is not possible (Taber, 2016). Our representation of the external world is imperfect.

Another critique is that constructivism is not concerned with the social aspect of learning:

> Like George Kelly writing of personal construct theory, von Glasersfeld considers only the solitary experiences of the knowing individual. This will not do to describe either everyday knowledge, or scientific knowledge, or the learning of school science. Personal knowing is notoriously precarious and subject to brain-washing, unless socially reinforced. (Solomon, 1994, p.15)

This is a matter of how the research is framed. In constructivist research the social aspect is not excluded, but the focus is on the individual. As Taber (2016) states:

> Personal constructivism with its cognitivist or psychological flavour tends to treat the brain or mind of the individual as the primary focus for considering learning and cognition, and as a corollary treats other people as more peripheral features. (p.131)

Leach and Scott (2003) share Solomon's concern, and find little use of producing mental models of learners as they believe a number of input variables would invalidate learner conceptual models such as different teaching approaches. Solomon (1994) criticised other aspects of constructivism such as making claims that not much has progressed in terms of teaching as "understanding their (pupils) content is not synonymous with having a method of instruction which will change them" (p.11). On the contrary, there has been and there still is progress in constructivism in science education. The findings from the Leeds National Curriculum Science Support Project which was undertaken in the years 1988-1992 has informed many science educators about the ideas that children bring to the classroom (Driver, Squires, Rushworth & Wood-Robinson, 1994). Taber (2006b) believes that the Research Programme was set out to inform teaching practices, as the teacher would be a "facilitator'' in terms of providing "appropriate opportunities for the pupils to undertake the construction – including exposure to conflict situations and construction and evaluation of new ideas" (p.208). More recently, Taber and Garcìa-Franco (2010) shifted away from studies on the Particulate Nature of Matter which have been dominated with an explicit propositional knowledge perspective, as they believe this does not account for students having a multifaceted approach to understanding concepts. They drew on the work of diSessa (1993) who suggested that students have common underlying mechanisms which they use to justify concepts, or otherwise known as phenomenological primitives (p-prims). Taber and Garcìa-Franco (2010) clarify that a p-prim is different from explicit propositional knowledge which can be used as a principle for an argument such as fire needing oxygen to burn. Rather, a p-prim is something which is intuitive and "leads to a form of perception that the student must then actively conceptualize" so that an explanation can be given (Taber & Garcìa-Franco, 2010, p.110).

3.2.4 Summary

Constructivism is used in the literature in different and loosely connected ways. Constructivism as a theory of learning premised on the seven hard core axioms outlined above is adopted as the theoretical framework in this study. It is seen as a progressive Research Programme for science education. The criticisms of constructivism raise interesting arguments, such as the role of the social aspect in learning. However, this form of constructivism does not exclude this aspect, but focusses on the learner. In the next section, key ideas of Vygotsky and Bakhtin, who some believe are social constructivists, are discussed in relation to the social aspect of words as essentially the focus of the present study is on non-technical words in chemistry. These ideas are then situated within the boundaries of the hard core axioms of constructivism.

3.3 VYGOTSKY & BAKHTIN

Vygotsky and Bakhtin both have much to offer as their theories can illuminate our understanding of non-technical words in chemistry which is the interest of this thesis. Though these theories have been referred to by strong social constructivists who do not give importance to individual minds, there is no reason why social constructivist’s theories of learning cannot complement personal constructivist's theories of learning (Taber, 2016). Duit, Roth, Komorek and Wilbers (1998) based their study "on an inclusive view that incorporates a discourse perspective into 'classical' conceptual change view" emphasising both the "individual and social construction of knowledge" (p.1059). However, for the present thesis, such social constructivist theories must be consistent with the hard core assumptions of constructivism as a theory of learning, and therefore must be understood within these boundaries. I begin with Vygotsky's work on 'Thought and Language', and Bakhtin's notion of dialogism, followed by a section highlighting key differences and similarities between the two and attempt to accentuate the benefit of utilising both their ideas. The final section shows how these theories can be taken within the limitations of the hard core axioms of constructivism adopted in the present study.

3.3.1 Vygotsky on Thought and Language

Vygotsky's concept of Zone of Proximal Development (ZPD) is undoubtedly "among the most useful, both theoretically and practically, of the many productive concepts he advanced" in (Cheyne & Tarulli, 2005, p.134). The ZPD is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1934/1978, p.86). This concept is fundamental to the teaching of science as well as other subjects. In essence, a child progresses in manageable steps with the aid of a more knowledgeable other person who is able to skilfully lift this child to the next level of competence; such a process is also known as scaffolding (Cheyne & Tarulli, 2005). This concept cannot be fully appreciated without reference to Vygotsky's work on

'Thought and Language', and the remaining section will primarily focus in this area due to its importance and relevance to this study.

'Thought and Language' (or ‘thinking and speech', depending on the translation) was first published within a year of his death and translated into English in 1962 (Vygotsky, 1934/1986). Several key ideas can be extracted from Vygotsky's work in this area that are applicable to the understanding of words in science. The most fundamental proposal was the link between thought and speech: "word meaning is a phenomenon of thought only insofar as thought is embodied in speech, and of speech only insofar as speech is connected with thought and illuminated by it" (Vygotsky, 1934/1986, p.212). It is the meaning of a word which cannot be solely attributed to just speech or to thought alone. He points out that if one was to remove meaning from a word, so that only sound remains, it would appear that meaning is only linked to speech. From a psychologist’s perspective, meanings are generalisations and concepts which are attributed to thought. Therefore, a word’s meaning unites thought and speech which can be understood as verbal thought; it is inseparable. In terms of development, with consideration to verbal thought, it is not only the actual content of the word that changes overtime, but also how an individual's perception of reality influences the meaning of a word. Vygotsky discusses two planes of speech, the semantic and the phonetic aspect. The phonetic, or external, part of speech develops from a part to a whole. In other words, the child first grasps words, then sentences, followed by complex sentences until speech is coherent. The semantic part of speech is the inner meaningful speech which develops in the other direction, from whole to part, as the child in the developed stages can differentiate the meaning of individual words. Through this, thought finds its reality and thus the existence of thought comes through words as it connects things together and forms relationships. Essentially, “verbal expressions cannot emerge fully formed, but must develop gradually” (Vygotsky, 1934/1986, p.222).

Delving deeper, Vygotsky differentiates between inner and outer speech. The most obvious difference is that inner speech is for oneself and outer speech is for others. Vygotsky believed that the development of inner speech originated from egocentric speech, as at schooling age egocentric speech disappears as inner speech develops. Inner speech has its own syntax, and it is not just merely speech without sound. It is similar to egocentric speech where a child omits certain words, mainly the subject of the sentence, as the meaning of what is being said is clear to the child and may not be to others. Such abbreviated speech also occurs between people, for example, if one person was to ask the other, "how are you doing?," the response could be either, "I'm fine," or just, "fine," and in the latter response the questioner will understand the full meaning. We could imagine that there could be occasions where one of the two interlocutors has a different subject in mind, and in this case, this would lead to confusion, such as pupils misunderstanding their teachers and vice versa.

Vygotsky proposed that inner speech involves the minimal amount of words, and it operates semantically and not phonetically. He drew on the work of French psychologist Fredric Paulhan (1856-1931) to elaborate on the semantic uniqueness of inner speech. A distinction can be made between the 'sense' of a word and its 'meaning', whereby sense refers to "all the psychological events aroused in our consciousness by the word" (Vygotsky, 1934/1986, p.244). Sense is not stable due its dynamic nature and the only stable part of sense is meaning; therefore, meaning is a part of sense and "no more than a potentiality that finds diversified realization in speech" (Vygotsky, 1934/1986, p.245). At the same time 'words' and 'senses' are not dependent on each other. A whole sentence can have certain words replaced without changing its sense. As a rule for inner speech, Vygotsky said that sense always prevails over the meaning. Another characteristic of inner speech, as determined through egocentric speech, is the combination of several words into one noun which represents multiple words thus forming a complex idea. Furthermore, the sense of words forms links between each other, so that earlier senses of words are integrated with those that come about later. With all these characteristics of inner speech one could imagine how complex it becomes and essentially incomprehensible to others.

As for the status of inner speech, Vygotsky regards it as a monologue, just as he does with written speech. Written speech is regarded as a monologue as it is written for someone who is absent and therefore it has to be written in full and unabbreviated. Despite inner speech being the opposite as it is in an abbreviated form, there is no other person involved for a dialogue to take place. A dialogue, as Vygotsky points out, involves a partner, and the speech has a tone and is assisted with facial gestures. On the other hand, monologue is a complex form of speech which can be approached at one's own leisure in the consciousness. However, not all advocates of Vygotsky take this stance with respect to inner speech being a monologue as it is believed that he was not explicit in claiming inner speech to not be dialogic (Wertsch, 1980).

Returning to the ZPD construct, there is a dialogue taking place where there is a power asymmetry between the interlocutors, such as the difference between the role of the teacher and a student in dialogue. Cheyne and Tarulli (2005) elaborate on the dialogue aspect in the ZPD and indicate that the voices involved are not just two people, but there is a third voice. This third voice can appear in three different circumstances for the ZPD. They name the first one as the ‘Magistral dialogue’ which is “characterized by a superiority of the first (Magistral) voice over the second (novitiate) voice” (Cheyne & Tarulli, 2005, p.137). The first voice resorts to a third voice in order to maintain power asymmetry between the two. This third voice could be drawn from an authoritative source such as the school curriculum. As a scenario in a science classroom, it could be imagined that the teacher would interpret information from a science textbook, the target knowledge, in order to guide the student (second voice) to the end of the conversation.

Such a description of dialogue is idealistic for the ZPD, yet there are other forms of third voices which would lead to different types of dialogue; these are ‘Socratic’ dialogue and ‘Menippean’ dialogue (Cheyne & Tarulli, 2005). In the Socratic form of dialogue, the second voice becomes suspicious of the authoritarian third voice and finds it difficult to reach a consensus; therefore, there is no scaffolding taking place. The second voice does not simply accept what is being put forward and begins questioning the first voice which results in the first voice seeking the third voice, yet with no success. This 'meandering' from the first voice may be due to a lack of knowledge, limited knowledge or "rather reflect substantive differences in understanding" (Cheyne & Tarulli, 2005, p.139). The power is shifted to the second voice, and the subject matter may be left misunderstood, or even cause the first voice to have doubts about the third voice. This could happen in a science class where the teacher lacks the required subject knowledge to overcome a child's misconception. In the case of Menippean dialogue, a child may begin to exploit the weakness of the teacher, for instance through mocking and being rebellious, and go further than being suspicious of the curriculum and rejects it.

3.3.2 Bakhtin on Dialogue

Researchers within the science community who concern themselves with the language aspect of science have drawn from Bakhtin's theories. (Kubli, 2005; Martins, 2007; Rosebery, Ogonowski, DiSchino & Warren, 2010). According to Clark and Holquist (1984), Russian born Mikhail Bakhtin (1895-1975) referred to himself as a philosophical anthropologist and towards the end of his life, his focus shifted more towards the philosophy of language. One of Bakhtin's most central concepts is that of dialogism. Emerson (2000) explains that Bakhtin did not mean dialogue to be merely the exchanging of words, but:

> …the idea that each word contains within itself diverse, discriminating, often contradictory "talking" components. The more often a word is used in speech acts, the more contexts it accumulates and the more its meanings proliferate…[therefore] dialogue becomes a model of the creative process. It assumes that the healthy growth of any consciousness depends on its continual interaction with other voices or world views. (p.36)

Bakhtin's social-cultural theory of dialogue is a relative one, in the sense that the utterance is defined by those outside the utterance, and so the outsider makes meaning from these utterances (Holquist, 2004). In other words, the meaning from the person's utterance is relative to how the other person constructs its meaning and our utterances will always have an element of someone else's words as this is a part of the accumulative meaning of a word. All utterances are intentional, and this is the key deciding factor in the choice of utterance we make (Bakhtin, 1981). So, according to this idea, it is as if the utterances we make are not purely ours, but our combination of constructed meanings of other peoples' utterances from varied social and cultural settings, and our intentions inform the choice of utterance in a given context. Some claim, that for Bakhtin, as dialogue involves both a speaker and a listener, it is not restricted to its verbal use, but it also includes written discourse, as “Bakhtin maintained that all spoken or written language is dialogical since it is always addressed to someone” (Zack & Graves, 2001, p.231). Clark (1990) explains that this form of dialogue occurs from within the reader through the act of understanding the text.

Another related concept to the theory of dialogue is heteroglossia:

> It is that which insures primacy of context over text. At any given time, in any given place, there will be a set of conditions- social, historical, meteorological, physiological – that will insure that a word uttered in that place and at that time will have a meaning different than it would have under any other conditions… (Bakhtin, 1981, p.428)

In heteroglossia, the meaning of an utterance will not necessarily carry the same meaning in another context; this is due to the utterance being situated in a particular society and culture. The concerned languages of heteroglossia could “contradict” or “supplement” each other (Bakhtin, 1981, p.292). Vice (1997) attempted to clarify the difference between heteroglossia and dialogism by suggesting that “dialogism is a relational property…while heteroglossia is a linguistic description” (p.50). We can appreciate that dialogism is the broad concept under which heteroglossia occurs. The relational property in dialogism is evident as it is the difference between the interlocutors which makes dialogue possible, and the meaning construed is relative to how they comprehend the other person. The linguistic description of heteroglossia is embedded in its focus on the actual meaning of the word in a particular context.

The central importance of dialogism to educationalists is its ability to help us comprehend how language could be used to help us understand pedagogy and improve on it. Researchers who have applied Bakhtanian theories to a variety of classroom disciplines found that differing, rather than agreement, amongst interlocutors is productive in terms of knowledge building (Zack & Graves, 2001). Relevant to science, the concept of heteroglossia gives us insight into the difficulties of the language of science. Rosebery et al. (2010) give an example of the use of the word ‘cold’. To the general person, the understanding of cold is something which comes through our sensory experience of it. They mentioned, for instance, that if third graders (8 – 9 years old) were to hold an ice cube, they would explain this as the ice cube making their hand cold. On the other hand, a physicist would explain this as there being a difference in energy levels between the child’s hand and the ice cube, and so the energy in the form of heat is being transferred from the hand to the ice cube leaving the child’s hand feeling cold. They explain that this difference in usage of the same word is due to the difference in the historical context of the term, as each individual had their own experience of the word. They further elaborate that this does not necessarily mean that all third graders share the same meaning of cold, as a child from a hot country would not explain cold in the same way as a child from a colder country.

Rosebery et al. (2010) used the concept of heteroglossia in a science classroom in Massachusetts. Their study involved an attempt to encourage third and fourth graders (8 – 11 years old) to develop their understanding of some of the physical concepts of science such as heat transfer. They anticipated that the development of the student’s understanding would occur by engaging the students with heteroglossia through dialogue amongst their peers, as students came from various backgrounds. For instance, one student who was from Haiti, found the idea of water freezing outside as amazing and this inspired other students who would normally take this for granted. Although not planned, in one situation the researchers observed the benefit of heteroglossia due to a change in environment. The researchers placed a poster in the students' classroom about heat transferring from an object of higher temperature to that of a lower one, and they had engaged in some activities related to this in the classroom. During the students' class, the fire alarm went off and so they had to go outside in the cold without their jackets. The researchers found that the students were engaging in the language of science related to heat transfer and reinterpreted its meaning in their new context. A similar engagement of the language would not have occurred in the classroom due to the climate difference between the classroom and outside the classroom. Despite Bakhtin's theory of dialogism and its related concepts appearing abstract, it does have relevance in science education by illuminating the importance of language in the understanding of science.

3.3.3 Ideological Reconciliation of Vygotsky and Bakhtin

Although there is no evidence of Bakhtin and Vygotsky ever meeting, it has been said that Vygotsky is a predecessor of Bakhtin (Emerson, 1983; Stetsenko, 2007). From the previous discussion on Bakhtin and Vygotsky, it appears that their views are similar, as Stetsenko (2007) states:

> The two scholars are clearly very close in their viewpoints at a very deep, metatheoretical level of analysis that they both adhere to a relational ontology of a shared world as the source and fulcrum for human being and development. (p.753)

It is apparent that both of them had an interest in the social aspect of language as a result of their dissatisfaction with the positivist models of language in their time. As an example, in Vygotsky's theory of Zone of Proximal Development, the social interaction exists in the form of one who is more knowledgeable guiding the other; and with Bakhtin, social interaction occurs due to some difference between the interlocutors which is possibly due to sociocultural factors. Clear differences are also apparent. For example, Bakhtin came from a literalist background, as he had an interest in dialogue in written and oral format. In contrast, Vygotsky was a psychologist and was interested in observing interactions amongst individuals.

One of the similarities between Vygotsky and Bakhtin is the recognition of the link between language and consciousness. In 'Thought and Language', Vygotsky (1934/1986) states:

> If language is as old as consciousness itself, and if language is a practical consciousness-for-others and, consequently, consciousness-for-myself, then not only one particular thought but all consciousness is connected with the development of the word. The word is a thing in our consciousness… (p.256)

Both are also in agreement that the inner self originates externally as it occurs from the social to the individual. Bakhtin, in his views about external signs, speaks of ideological meanings as something which is determined socially and has meaning (Emerson, 1983). There are four 'social factors' that make this sign comprehensible: firstly it is experienced externally. Secondly, there has to be some social connection for the sign to be meaningful. Thirdly, ideologies from the sign exist in relations between, for instance, a speaker and a listener and thus there is continuous 'interrelation' and 'interaction'. Finally, the words in the discourse are connected to its earlier contexts, and words originated from dialogue where the utterances (dialogic word) hold a meaning under a maximum potential meaning (or dictionary meaning) (Emerson, 1983). Bakhtin takes the two extremes of 'abstract objectivism' (language being independent of the interpreter) and 'individualistic subjectivism' (language being dependent on the interpreter) and reconciles them. Bakhtin proposed that there are lateral and vertical relationships occurring between the outside world and the individual's psyche. In the lateral activity, the individual is involved in speech acts with others; and in the vertical activity, there is a relationship between the external act and the inner self, or the psyche. Therefore “individual consciousness is a socio-ideological fact...there is no…independent consciousness” (Emerson, 1983, p.250). Similarly, Vygotsky, in his notion of 'internalization', suggested ‘egocentric’ as one of the four stages of development in a child. He found that in this stage of a child, 'the direct outgrowth (or, better, ingrowth) of speech…had been from the start socially and environmentally oriented' (Emerson. 1983, p.253). Furthermore, according to Emerson (1983), Vygotsky believed “external society is the starting point of consciousness” (p.252). Since self-consciousness is originated socially, people would view themselves based on how others have related to them.

Wegerif (2008) argues that people have mistakenly synthesized Vygotsky's and Bakhtin's theories since they are actually incompatible. He argues that the key difference is that Vygotsky's theories about education are dialectic; whereas Bakhtin's theories are dialogical. Dialogic in this instance means that the difference that occurs between voices is essential for meaning, and by overcoming them, there remains no meaning as no difference remains. In the dialectic, the differences are seen as contradictions, and for learning to take place, this difference needs to be overcome. In Vygotsky’s zone of proximal development, mutual understanding is achieved, as an agreement is reached between the two. This would not be acceptable for Bakhtin because of the importance he gives to the dialogical, where there must be ‘dialogic interaddressivity’ as Matusov (2011) explains:

> For Bakhtin…a gap in the mutual understanding between people is a necessary condition for dialogic, humane communication, and for the entire human relationship…This dialogic orientation of the participants on expectation of their mutual surprise from each other, of their mutual wonder about each other, of their mutual interest in each other, of their mutual respect of one another’s agency of decision-making – this interest and respect is not instrumental but rather goal- and value-defining – is what I call dialogic interaddressivity. (p. 103)

Therefore, Vygotsky would view Bakhtin's dialogical approach as 'anti-developmental,' likewise, Bakhtin would think that Vygotsky's:

> instrumental approach is monologic and inhumane. Children are seen as objects of pedagogical actions of educated adults and objects of psychological research by developmental psychologists, rather than being conscious and having equal rights. (Matusov, 2011, p.104)

Matusov (2011) believes that for Vygotsky, consciousness has transparency as a result of the "shared mediation in the zone of proximal development" (p.100). Whereas, he argues that Bakhtin believes that consciousness is not transparent. Vygotsky's approach to inner speech is mono-consciousness, whereas Bakhtin's is multi-consciousness. Vygotsky did not discuss the '*I*' and '*me*' of inner speech and so for him there is no interaddressivity internally. As for Bakhtin, if within that one consciousness everything is transparent and comprehensible, speech is not possible as there is no difference in meaning. "Transparency and oneness of the consciousness preserves tasks and goals but kills communication and relationship" (Matusov, 2011, p.114).

Matusov (2011) related his experience of a visit to a science museum where he came across a sign about a stone stating, "The heaviest stone in the world, 1 litre is 3.3 kilos" (p.104). This claim raises several scientifically based confusions, such as differences between weight and density, and between weight and mass. Density is not the same as weight, for instance 1kg of water weighs the same as 1 kg of cement, but this has nothing to do with the density of the material. The confusion is founded on their usage of 'heaviest'. Matusov (2011) believes that the wording was used as such to relate to an individual's experience rather than making the wording in a way that not all could relate to it. In terms of Vygotsky's theory of zone of proximal development, such a sign would not lead to a learner's development as they would only apply what they know heaviest to mean from their own experience. In contrast, in terms of Bakhtin's notion of heteroglossia, such a sign would allow dialogue due to its interproblematic nature. So, although there is educational benefit from the sign, this benefit cannot be reconciled between both scholars. Another point of difference is their view on the status of written speech. Vygotsky (1934/1986) regards written speech as a monologue as it is written for someone who is absent and therefore it has to be written in full and unabbreviated. A dialogue, as Vygotsky points out, involves a partner, and the speech has a tone and is assisted with facial gestures. On the other hand, monologue is a complex form of speech which can be approached at one's own leisure in the consciousness. Bakhtin on the other hand categorises written speech as dialogue since there is a point where the reader makes meaning out of what is being read, and the response occurs in social interaction about the text (Clark, 1990).

I would argue that although there are ideological differences between Bakhtin and Vygotsky, which in the most part is based on interpretations of their ideas by others rather than explicitly deriving from them, it is unfair to purely label the former as dialogical and the latter as dialectical. I believe it is more appropriate to say that Bakhtin’s approach is generally dialogical and equally, Vygotsky’s is generally dialectical. Matusov (2011) addressed the need of ‘interproblematicity’ in Bakhtin’s dialogical approach. This is where the subject of focus in the dialogue is found interesting and problematic by the interlocutors. This suggests that there is some similarity in the consciousness with regard to the topic of interest and contradicts the notion of ‘interaddressivity’ to a certain degree. In addition, for something to be problematic could mean that there is perhaps a solution, and this could indicate a diaelectical nature. Vygotsky (1934/1987) explained that although mutual understanding is reached between an adult and child, the mental pathway taken to reach this may be different between the two. This suggests that even though learning has taken place by the two overcoming the problem (mutual understanding), there remains a difference between the two sets of consciousness due to the mental pathways taken. Hence, one could argue that there is a degree of the dialogical in Vygotsky's approach. At times, a dialogical view would be best, as in the museum example mentioned earlier; and at other times, a dialectical approach may be more appropriate. It is all dependent on what outcome is intended. An additional similarity can be found in Cheyne and Tarulli (2005) expansion of the ZPD in terms of different types of dialogue (see section 2.2.1); they used the work of Bakhtin to inform their expansion of zone of proximal development. For instance, Bakhtin (1986) establishes:

> In each epoch, in each social circle, in each small world of family, friends, acquaintances, and comrades in which a human being grows and lives, there are always authoritative utterances that set the tone - artistic, scientific, and journalistic works on which one relies, to which one refers, which are cited, imitated, and followed …there are particular traditions that are expressed and retained in verbal vestments: in written works, in utterances, in sayings, and so forth. (pp. 88-89)

This could relate to the authoritative third voice in the ZPD, though, which was not explicitly mentioned by Vygotsky.

3.3.4 Ideas on Words Under the Hard Core Axioms

Section 3.2.2 introduced the hard core axioms of constructivism adopted in this thesis. This section has so far shown that both Vygotsky and Bakhtin have valuable ideas with respect to the nature of words, and this is relevant to the current study as it is based on non-technical words in chemistry. Also, I have demonstrated through the literature, that although Vygotsky and Bakhtin's ideas appear contradictory in some areas, there are many similarities and by combining both these scholars' thoughts, it can enrich our understanding of words. However, there are “some forms of social constructivism” that offer “suitable ‘refutable variants’ of the RP”, but “other notions of the social nature of human learning would indeed seem inconsistent with the hard core” (Taber, 2009, p.192). Therefore, in this subsection, I attempt to extract the key ideas of Vygotsky and Bakhtin presented in this section, and demonstrate how it could be consistent with the hard core axioms of constructivism adopted in this research.

Salomon and Perkins (1998) discussed the relationship between individual and social learning with a view of uniting both positions. The first of three propositions is that “individual learning can be less or more socially mediated learning” (Salomon & Perkins, 1998, p.17). They used an example of a basketball player who practices alone as still being situated in a larger social context with other team members and a coach, and when practicing alone that larger social context can ‘impinge’ through memories of that larger context. In other words, whether learning takes place entirely individually, or socially, one would impose on the other to some extent. The second proposition is that “individuals can participate in the learning of a collective, sometimes with what is learned distributed throughout the collective more than in the mind of any one individual” (Salomon & Perkins, 1998, p.18). The basketball player through solo training is acquiring skills that would benefit the team as a whole, or whilst practicing together, there are certain collective skills that require all members of the team and not just an individual. The third proposition is that:

> individual and social aspects of learning in both senses (Relations 1 and 2) can interact over time to strengthen one another in what might be called a “reciprocal spiral relationship”…in other words, the student learns through different learning systems with varying degrees of social mediation and collectively at different moments…(Salomon & Perkins, 1998, p.18)

So studying social aspects of learning could aid in understanding individual learning, however, a distinction needs to be made between ‘social constructivism’ and ‘constructionism’. The former “emphasises the role of social processes in the individual’s coming to knowledge,” and the later “sees knowledge as well as knowledge construction as something that exists on the interpersonal or social plane” (Taber, 2009, p.194). As social constructivism in this sense recognises the importance of personal knowledge, it would be more acceptable within the hard core assumptions, but constructionism cannot be accepted as personal knowledge may have no relevance.

Emphasising the point that personal knowledge is represented in the mind of the individual, and relating this to the ideas of Vygotsky and Bakhtin presented here thus requires reconceptualising, and even dismissing, some the points mentioned in this section. Table 3.1 is a list of key ideas derived from these scholars and presented in this section (3.3.1-3.3.3), though it is not meant to be an exhaustive list of Vygotsky's and Bakhtin's ideas. Nevertheless, these key ideas are pertinent to the discussion of the extent to which they are consistent with the hard core axioms listed in section 3.2.2. Besides each idea in Table 3.1 are cautionary notes, in that the idea is either consistent with the hard core axioms, or it is inconsistent as it opposes one of the core axioms.

TABLE 3.1

Compilation of Vygotsky’s and Bakhtin’s Ideas and Cautionary Notes

Point	Idea	Cautionary Notes
1.	The inner self originates externally as it occurs from the social to the individual.	Rejected (inconsistent with Hard Core Premise 1)
2.	Inner speech is an abbreviated form of speech which is incomprehensible to others.	No direct access
3.	All external speech has thought embedded in it.	Not a perfect representation of thought

4.	Both inner speech and written speech has the potential to be a dialogue.	Rejected (inconsistent with Hard Core Premise 5)
5.	The meaning of a word is an attribute of both speech and thought, and together this is known as verbal thought.	Not a perfect representation of thought
6.	Meanings are generalisations and concepts which gradually develop through life experience.	Constructed in the mind of learners
7.	A word accumulates meaning from multiple contexts.	Knowledge is not transferred
8.	Words carry a meaning potential which varies between individuals.	Acceptable (Hard Core Premise 6)
9.	The meaning of an utterance will not necessarily carry the same meaning in another context.	Acceptable (Hard Core Premise 6)
10.	The meaning from the person's utterance is relative to how the other person construes its meaning.	Not a perfect representation of thought
11.	Learning takes place at the Zone of Proximal Development.	Acceptable (Hard Core Premise 4)
12.	In an idealistic form of ZPD, the first voice draws on a third authoritative voice.	Rejected (inconsistent with Hard Core Premise 5)
13.	Learning can take place both dialogically and dialectically.	Conditional Acceptance (Hard Core Premise 1)

The first premise, and core point of the hard core axioms is that "learning science is an active process of constructing personal knowledge" (Taber, 2013, p.7). The inner self cannot be accepted as originating externally or socially constructed (Point 1). The construction of knowledge is an internal process (Point 6). Leach & Scott (2003), though not in favour of emphasising the individual learner over the social aspect, appreciate that Vygotsky's process of internalisation must involve personal interpretation rather than a direct link from the social to the personal plane:

> There must be a step of personal interpretation, where the individual comes to a personal understanding of the ideas encountered on the social plane…In this respect Vygotskian theory brings together social and individual views, sharing common ground with the various

> constructivist views in recognising that the learner cannot be a passive recipient of meanings. (pp.101-102)

Vygotsky (1934/1978) termed the ‘spontaneous’ or ‘everyday’ concepts as those which have been built early in the child through their social environment, and ‘scientific’ (academic) concepts, as that which involves formal learning:

> …school instruction and learning is in advance of children's cognitive development. Vygotsky proposes a parallel between play and school instruction: both create a "zone of proximal development”…and in both contexts children elaborate socially available skills and knowledge that they will come to internalize. (pp.130-131)

Taber (2013a) believes that a model which sees spontaneous concepts and academic concepts converging vertically, with the latter above the former is ‘oversimplified’. He suggests that there is a more of a hybrid state where spontaneous and academic concepts interact as spontaneous concepts acquire ‘abstract nature’, and academic concepts acquiring ‘concrete referents’. Taber (2013a) uses the term interconceptualisation to describe this and it is when what is “originally discrete spontaneous and academic concepts evolve into a melded concept that draws upon both an experiential base in direct experience of the natural world and culturally mediated learning relying on communication through a form of language” (p.293). In turn, concepts are represented as explicit knowledge in the conceptual structure through this process.

In Point 2, if inner speech refers to our personally constructed ideas being incomprehensible to others, in the sense that direct access to another’s thought is impossible, then it fits with the assumptions of constructivism here. Putting this limitation on Point 3, means that external speech has thought embedded in it but not as a perfect representation of one’s thought. Firstly, the way in which we represent our ideas through speech cannot be an exact representation of what is in the mind. Secondly, how one interprets what one says, is not an accurate interpretation of another’s representation of ideas. In this sense, Point 10 here can be taken as an explanation of Point 3. Similarly, in the notion of ‘verbal thought’ (Point 5), lies a problem whereby it is assumed that what we say is a precise representation of our thoughts, so what is more correct in the given premises is that the relationship between speech and thought is an imperfect one, and as such, the meaning of a word which is supposed to represent ‘verbal thought’ is also an imperfect one. Point 4 (Table 3.1) refers to inner speech being considered as a form of dialogue, and this is problematic as it implies that we have within us a dual mind system, and this does not fit in with current assumptions as we have one mind. As for written speech, it is an imperfect representation of an authors’ thoughts, and is absent of a mind and thus does not contain knowledge (Taber, 2016, p.130).

For Cakir (2008), a concept is “a way of “slicing up” and organizing the world” and is formed by “intellectual operation” such as “memory…and in which language is a guide. Putting things into word…provides a means of symbolizing thought…and is an integral part of the process of concept formation” (p.197). Despite this, in the current study, I hold that the relationship between a word to ideas is just one of many forms of representation of thoughts:

> If our ideas are purely personal, subjective experiences, then we cannot show them to anyone else. Rather we have to represent them in a public space if we wish to ‘share’ them with others. This representation can take a number of forms: we can express our ideas in prose or poems; we can draw out our ideas, act our ideas out or make films, compose music, compile photoessays or dance them out. The key point is that, whatever form representation takes, the representation is different from the original idea – the thought – and so the representation can never be a replica of the idea. (Taber, 2013, pp.69-70)

Even gestures can represent our concepts (Abels, 2016), and so the representation of our thoughts is not limited to the words we use. With this limitation, Points 7, 8, and 9, as a whole fit with the assumptions of the hard core assumptions. Moreover, if with Point 7 it implies that knowledge of the meaning of a word is transferred from one to the other, then this is not acceptable. A word can accumulate meaning from multiple contexts, and it would vary in its precise meaning between individuals though there may be a general understood meaning depending on the context of its use as “learners’ conceptual structures exhibit both commonalities and idiosyncratic features” (Taber, 2013, p.7).

If learning takes places at the ZPD, the role of the teacher is that of a facilitator (Point 11). The teacher cannot transfer knowledge to the student, but helps as a scaffold. As for the authoritative voice (Point 12), perhaps a school curriculum, then this is only a representation of one’s ideas which would require the teacher to interpret the ‘target knowledge’ and represent this target knowledge in an imperfect way for a student who also interprets this representation. In other words, there is no ‘authoritative voice,’ but only possible stored ‘memory’ where the teacher revisits what was “originally understood” (Taber, 2009, p.142).

3.3.5 Summary

This section explores Vygotsky and Bakhtin’s ideas in relation to words, which is pertinent to the focus of the present thesis as it relates to non-technical words in chemistry. Their ideas were reconciled and understood in a manner that makes them consistent with the hard core axioms of constructivism adopted in this study. The next few sections review relevant literature on words in science.

3.4 STUDIES ON WORDS IN SCIENCE

Many studies have focussed on words in general science (biology, chemistry, and physics). According to Johnstone and Selepeng (2001), studies that have developed our knowledge of students' understanding of words in science have been reported as early as the 1940s. The ones which are reported in this section are broadly divided into three parts with each one based on the source of data collection. Following an outline of classification of words in science, I will review word based studies that have been derived from three distinct areas, namely: questionnaires, classroom dialogue, and science textbooks.

3.4.1 Classification of Words in Science

The 'introductory chapter' (section 1.4.2) broadly outlined scientific words as three kinds of words. Words which are specific to science, words which have a meaning and usage both within and out of science, and words which are common to most subject disciplines. Bakhtin believed that words contain some aspect of their historical usage (Emerson, 1983). These words have a meaning potential, whereby the one who produces the word uses a meaning from within this potential. The words used in science today also have a historical context, though they have evolved in terms of its usage:

> When he developed the 'burette' as an instrument for such assay, Gay-Lussac must have adapted some pre-existing item of equipment from the kitchen or the vestry or the vineyard, but he also adapted a pre-existing word, and started a new branch of talking. (Sutton, 1992, p.9)

We could imagine that children might first encounter words from science in their social surroundings through dialogue with their parent or guardian, and later through their formal education with their teachers and course material, and various forms of media like the internet. Vygotsky (1934/1987) states:

> Thus the meanings of the child's words frequently coincide with those of the adult; the meanings of a given word for the child and the adult often intersect on the same concrete object. This allows for mutual understanding between the adult and the child. However, the mental paths or modes of thinking that lead to this point of intersection are completely different. Even where the meaning of the child's word corresponds partially with that of the adult's speech, it is derived from entirely different mental operations. (p.134)

The meaning of the words will not be understood in exactly the same for every individual, possibly due to the individualised mental pathways. In science, words carry specific technical meanings, for instance the word ‘endothermic reaction’ is a chemical reaction in which heat is taken in from the surroundings. Such a word would commonly be found in a science context, and related experiences and understanding of that word would not be as common in daily life. Therefore, it might be expected that there would not be a great difference in the mental operations that lead to its usage due to its limited contextual use. Science is replete with these subject specific words, and it is vital for an educator to ensure that they are being used in the correct context, and a child’s correct use of the word could be an indication for showing correct scientific understanding.

Wellington and Osborne (2001) provide a classification for words that are specific to science, and they classify them into four levels: naming words, process words, concept words, and mathematical words. Naming words includes words which could be explained by everyday familiar words, such as *saliva* for *spit*. Some words in this category cannot be explained by familiar everyday words as they are only found in science contexts like *conical flask*. Process words include the words *evaporation* and *combustion*; these processes can be visually demonstrated, but some process words (e.g. *evolution*) are not directly observable. The third level, concept words:

> …denote concepts of various types: words like ‘work’, ‘energy’….this area of learning in science is surely the one where most learning difficulties are encountered….they are a part of a network of other words…without prior understandings, the structure collapses. (Wellington & Osborne, 2001, p.21)

They continue to explain that these words can be learnt through experience, such as the colours red and yellow. Additionally, they can carry a meaning in both a science and an everyday contextual meaning (e.g. *power*); and they could be theoretical words like *elements*. Mathematical words relate to words which have numerical associations such as centimetres. In general, words in science are of different kinds: those that are restricted to science as a discipline; and words which fall between science and a context out of science.

3.4.2 Questionnaire Based Studies

Many questionnaire based studies have replicated research conducted by Gardner (1980), and Cassels and Johnstone (1980, 1985). Gardner (1980) carried out a survey of the most frequently found logical connectives in science reference material. The participants were secondary students in Australia from grades 7-10 (ages 11-14). The data was gathered using a multiple choice test consisting of gap-filling and sentence completion exercises. 180 logical connectives were tested in both a scientific and an everyday context. It was found that students found difficulty with logical connectives related to contrast (e.g. *although*, *however* etc.). Despite this, there was a steady growth of comprehension of logical connectives over the secondary schooling years. In contrast, Cassels and Johnstone (1980, 1985) focused their research on non-technical words in science which they thought to be problematic. They conducted a large scale survey involving 200 schools. Overall, they found that students had a weak knowledge base with respect to non-technical words. For instance, some students were confused with the opposite meanings of words like *initial* for *final*. Since these studies, researchers have replicated this study with a slightly different focus and various samples such as gender and students from a variety of countries (see examples in Marshall, Gilmour, & Lewis, 1991; Pickersgill & Lock, 1991; Farrell & Ventura, 1998; Johnstone & Selepeng, 2001; Childs and O'Farrell, 2003).

Pickersgill and Lock (1991) followed up Cassels and Johnstone's research whilst making some adjustments because of what they believed to be shortcomings in Cassels and Johnstone's choice of key vocabulary for testing, and the use of testing words in other questions. For instance, if the word 'factor' was being tested in one question, they would have found this same testing word in the actual question of another testing word (i.e. not being used as the testing word). This is unreliable as they have made an initial assumption that the word 'factor' is a problematic word, yet by including this word in a sentence of another testing word, they have assumed that it is not a problematic word. Pickersgill and Lock (1991) selected 30 non-technical words in a questionnaire, of which there were four versions. The questionnaire consisted of 30 questions related to testing these words in science and a further 40 questions for testing verbal reasoning. The 197 participants were 14-15 year old males and females in England. They were investigating whether there was any difference with regard to understanding the non-technical words in science and its relationship to gender and verbal reasoning. They used the same testing format as Cassels and Johnstone's study. This consisted of four types of questions that were answered in a multiple choice format. The first type requires students to choose a related synonym to the testing word. The second involves choosing one of four sentences which uses the testing word correctly. The third question style has the testing word in its scientific context, and the fourth has the word in a non-science context. The main findings were that there were no significant differences between males and females in terms of understanding the non-technical words in science or by verbal reasoning (everyday context). However, they did find that there was a positive correlation between the verbal reasoning and non-technical words in science scores.

Although Pickersgill and Lock (1991) generally kept to Cassels and Johnstone's question style word for word, they also made simplified versions of their questions by removing what they believed to be complex words. Even then, they found that there were no significant differences due to changing the wording of the questions. From the four styles of questions, the lowest scores were found with the question where the student had to choose a related synonym. They suggest that the reason for this is that the other question styles have a context from which the meaning of the word can be deduced, whereas the synonym question does not have a context. A closer analysis of the mistakes revealed that students confused similar looking words such as 'negligent' for 'negligible' and 'retract' for 'contract'. Furthermore, students confused words that are antonyms (opposite in meaning) such as choosing 'scarce' rather than 'abundant'. According to Pickersgill and Lock (1991), this could be due to the students not having enough exposure to the words concerned and they recommend teachers to spend time with their students in clarifying the meanings of non-technical words. Despite the interesting finding of this study the reliability of it is questionable. This issue is founded upon their assumption that all the students who participated are the same. It would have been interesting if they had monitored the students' choice of answers as individuals. It is understandable that it would be time-consuming, but if they had followed up on several students' answers in an interview, this would have given strength to their findings and perhaps revealed further insights into the difficulty of the selected words.

Farrell and Ventura (1998) focussed on both non-technical and technical words with pre-university physics students. The study took place in Malta, where English is the second language, in the form of a vocabulary test. An additional aspect of the test was that the students were asked whether or not they knew the meaning of the word. In their analysis, they compared by percentage the claimed knowledge of knowing the words (in the form of a *yes or no* answer) and the actual knowledge of the words as attained from the test. They found that there were significant differences between the mean values for claimed and actual knowledge. For both technical and non-technical words, the mean was found to be higher with respect to claimed knowledge. This suggests that students claim to know words which they failed to understand in the test. The students' mistakes found in this study had several causes: clear misinterpretation of the word; confusing the meaning of the word with its opposite meaning; mistakes due to the graphological or phonetic nature of the word (e.g. finite and fine); and morphological mistakes, such as understanding dielectric to mean two electrical fields. The findings here are similar to Marshall et al. (1991) in that English language learners also face difficulties with non-technical words in science.

3.4.3 Classroom Dialogue Based Studies

The studies discussed in the section above used data in the form of questionnaires to examine students' understanding of words in science. Other studies have used data from classroom dialogue to gain further insight into the nature of such words. One of the most fundamental roles of a science teacher is to explain (Ogborn, Kress, Martins & McGillicuddy, 1996). For instance, when a science teacher carries out a demonstration of a practical activity or experiment, it may not be sufficient to just show the demonstration. The teacher needs to explain what is happening. At times, the science teacher has to explain things which are unobservable, such as atoms. Research into classroom dialogue is well established with studies dating back to the early 1970s (Howe & Abedin, 2013). Such dialogue studies within the field of science education have covered areas such as teacher-student interaction, student-student interaction, effective questioning, argumentation and other areas. (see examples in Chin, 2006; Aguiar, Mortimer & Scott, 2010; and Louca, Zacharia & Tzialli, 2012). However, very few studies in the classroom dialogue field have focussed on specific lexical items within a specific science domain.

Wilson's (1999) study used discourse from a chemistry classroom to examine the use of metarepresentational terms, which consist of metacognitive and metalinguistic terms. The study is based on Vygotsky's proposition of higher mental function in humans occurring through collaborative activity. She suggests, for example, that by using metalinguistic verbs in place of the verb 'to say', such as define, and by using metacognitive verbs in place of the verb 'to think', such as deduce, students may be able to engage in thinking and expressing thought in chemistry. The main purpose of the study was to investigate whether or not chemistry classroom teachers encourage the thinking and expressing of thoughts through language; in other words, investigating if they refer to metarepresentational terms. The participants were five chemistry teachers who taught upper-secondary chemistry students. A total of 69 lessons were recorded and transcribed from a unit named 'Chemical Equilibrium', which is a year 12 module (students aged 17-18). In addition, a compilation of metacognitive and metalinguistic verbs was made from the syllabus for the purpose of comparison against the teachers' discourse.

On average, a teacher used 2,545 words in a lesson. Based on this, metarepresentational words were found to occur on average, for all the teachers, as 112 per 10,000 words of the teacher's talk. With regard to the use of specific metarepresentational words, a frequency of 4 per 10,000 words would indicate that the word occurred, on average, at least once per lesson. An occurrence of 0.3 per 10,000 words would mean that the word came at least once in the unit. Only nine metarepresentational words had a frequency of 4 per 10,000 words, namely: look at, see, write, work out/through, tell, know, think, explain and say. Wilson (1999) believes that reliance on such simplified words would not aid students in expressing concepts comprehensively, as this can only be achieved through the use of words with more specific meaning. Wilson (1999) pointed out that the low frequency verbs did include some more defined metarepresentational words such as ‘estimate’ and ‘calculate’, but these verbs were used more than those which one would normally expect in a chemistry classroom like ‘experiment’ and ‘observe’. At the same time, she appreciates that the topic of ‘Chemical Equilibrium’ is more mathematical, yet this does not justify the low frequency of more defined metarepresentational words.

Teachers rarely referred to the actual text of the textbook, and this is where these specific meaning carrying metarepresentational words would be found. Therefore, only a fraction of the metarepresentational words that were found in the curriculum document were actually used in the teachers’ talk. The curriculum document contained 61 metarepresentational words, and nine of them were found in the discourse with a frequency of at least 1 per 10,000 words. This finding supports Pickersgill and Lock's (1991) view with regard to the lack of exposure that students encounter with specialised vocabulary (technical), and as a result, such words become problematic for the learner. Another issue with the use of these simplified metarepresentational words is that they possess multiple meanings. Wilson (1991) illustrated this point with the words ‘look/at’, and ‘tell’ in the following extract (researcher’s implicit meaning is given in parenthesis):

> The following extracts from Robin' s 1997 transcripts illustrate the multiple meanings associated with the terms *look* and *look at…I want you to look at this exercise and tell me the answer* (solve or calculate), *look at the demonstration* (observe), and *today we shall look at the concept of* . . . (consider or examine). Similarly, the word *tell* was used by Martin to convey different senses, for example, *tell me what will happen* (predict), *tell me how or why this happened* (infer or explain), *tell me what has happened* (describe or explain), and *tell me what would happen if* . . . (predict or hypothesize). (p.1076)

The use of such words could prevent the student grasping the meaning of a concept, or perhaps even leave the student in a state of confusion. The researcher acknowledges that the study does not necessarily prove that there is a correlation between the teachers' metalanguage and the improvement of students' learning outcomes; or that the findings could be generalised to all chemistry classrooms due to their only being five participants. Despite this, this study shows that teachers need to be aware of such terms and especially metarepresentational words that possess multiple meanings.

3.4.4 Textbook Based Studies

Textbooks are one of the major resources in a science classroom. Kubli (2005) points out several functions of a science textbook which include it being a resource for presenting the subject and its scope, and it acting, as what Vygotsky would describe, as a scaffold for learning. A textbook is a scaffold because it ideally contains content that would allow a learner to progress from their current learning level to a higher one. Kubli (2005) also stresses that this cannot be achieved with a textbook alone as the teacher shows how to learn the content of the textbook. Nevertheless, students would find the subject difficult "if there is nothing written on which they can rely" (Kubli, 2005, p.512). Some claim that in a Bakhtanian sense there is a dialogue between the writer of the text and the reader. Clark (1990) claims that in Bakhtanian sense, the content of the written material involves a dialogical interaction with the reader in terms of the actual utterance and the act of understanding. The reader constructs an understanding of the utterance as a silent utterance from within, at which time the reader makes meaning, and the response to the utterance of the text would be found externally in the "reader's actual social life" (Clark, 1990, p.14). Despite this belief, in this study I hold that a text is a representation of one’s thought, and so a textbook is a representation of what people in authority believe to be the target knowledge that students must learn. This text is interpreted by both learners and teachers in different ways as such an experience is subjective.

According to Menon and Mukundan (2010), there has been a substantial amount of research on scientific writing, whilst research in other areas has been limited, "especially, that of scientific English used in textbooks" (p. 243). Wellington and Osborne (2001) compared a science textbook page from a 1959 publication to one from a 1990 publication. The older textbook page did not have any illustrations, long sentences (as much as 47 words in one sentence), a passive approach to language, and the use of unfamiliar connectives such as ‘hence’. On the other hand, the textbook page which was published 30 years later had much shorter sentences (as small as 4 words for a sentence), an almost non-existent passive style, and no logical connectives. Overtime, text density has massively been reduced and there is much more use of illustrations. Laszlo (2013) points out that the ever-growing knowledge of chemistry has driven the continuous and regular changes to chemistry textbooks in particular. He further believes that these changes are also due to commercialism and consumerism. Wellington and Osborne (2001) claim the primary reason behind this change is because authors have recognised the need to make texts more readable and this has come about due to studies into the readability of science texts from around the 1980s. However, they point out that by only judging textbooks based on readability, this hinders other important aspects of judging texts. They recommend that texts should be judged on their ‘understandibility’ with a focus on the taxonomy of words. Another recommendation was to judge the text in its ability to guard against misconceptions in science, as they believe that science textbooks have been a major influence in students developing misconceptions. In the rest of this section, three distinct studies of textbook analysis are drawn upon. They are distinct in both the opted analytical approach and the textbooks used in the study.

Fang (2005) took a systemic functional linguistics approach in analysing several American elementary and middle school textbooks for the purpose of highlighting the unique linguistic features of science text. Systemic functional linguistics was developed by Michael Halliday and his team in the 1960s and it is regarded as a “useful descriptive and interpretive framework for viewing language as a strategic, meaning-making resource” (Eggins, 2004, p.2). When we speak or write we are making grammatical choices, knowingly or unknowingly, on how we would like to construct a sentence to get a specific meaning across. In essence, grammar is linked to meaning, and by understanding these systematic grammatical structures we can deduce these underlying meanings. Fang (2005), similar to Halliday (2004), described four features as a result of the analysis of the textbooks which he labelled as informational density, abstraction, technicality, and authoritativeness. Informational density is similar to what Halliday (2004) refers to as lexical density, though Fang (2005) uses the term lexical density as an index where the percentage of content words is calculated with respect to the number of clauses found in the text. Fang (2005) points out that in scientific text, high lexical density is a result of condensed noun phrases which would normally exist in a number of clauses in everyday speech.

Abstraction, referred to as nominalization by Halliday (2004), involves the transformation of processes into participants; where processes are represented by verbs and adjectives and participants are expressed as nouns (Fang, 2005). Fang (2005) explains that when this occurs in scientific texts, the semantic information becomes hidden and ambiguous in meaning. He further explains that nouns are needed in science because they can be used for the purpose of defining, explaining, or classifying, and this occurs a lot in science. The technicality feature in textbooks involves words that are normally marked in bold in textbooks. These bold words are typically technical vocabulary that are specialised for science. The technical words in a textbook can also include commonsensical terms which when used technically have a meaning other than their vernacular meaning such as the word *faults* in the sentence, "movements along faults can make it harder for geologists" (Fang, 2005, p.342).

Fang (2005) describes how scientific English involves the use of an authoritative tone for the purpose of appearing objective and factual, for instance, the first person (I, you etc.) is not used. However, in his analysis he found that the science textbooks under study used some informal language and appear more interactive by the use of clauses which are interrogative and imperative. He further explains that this makes "scientific texts appear more personal and less alienating…draw[ing] readers into the text and to stimulate their engagement" (Fang, 2005 p.343). This relates to what Laszlo (2013) pointed out regarding changes to textbooks occurring due to consumerism. The aforementioned features may be typical of some science textbooks; however, it is possible that there would be differences amongst textbooks of different age groups and publishers from different countries, especially due to the continuous development of textbooks to meet present day needs.

Menon and Mukundan (2010) applied a corpus linguistic approach in their analysis of upper secondary (16-17 year olds) science textbooks in Malaysia. Corpus linguistics is widely accepted as an approach to linguistics rather than a branch of linguistics such as syntax or phonetics (McEnery & Wilson, 2001). Although this approach had fierce criticisms from rationalists in the past, it has since gained popularity, partly due to the efforts of the creators of the first computer corpus known as the Brown Corpus (Meyer, 2002). The term ‘corpus’ means body in Latin and is essentially a body of text, but when the term corpus linguistics is used it implies more than this simple meaning as it is "more accurately described as a finite-sized body of machine-readable text, sampled in order to be maximally representative of the language variety under consideration" (McEnery & Wilson, 2001, p.32). For instance, if someone wanted to gain an understanding of how a particular aspect of phonetics is used within a community of people who use English as a second language in Scotland, then the researcher would ideally gather several recordings of conversations from this particular community and transcribe them. These recordings would become a corpus for this community and therefore the phonetic aspect could be analysed. This corpus could be compared to other corpora in terms of frequency of words and collocations amongst, for example, verbs and prepositions.

Menon and Mukundan (2010) focussed on the collocational and colligational patterns of semi-technical words. They define semi-technical words as words that have an extended meaning in a particular field of study, and they claim that research has shown that these types of words have been the most troublesome to students due to their nature of having more than one meaning that is context dependent. They used the following definitions for their use of collocation and colligation:

> Collocation in this work is taken as the tendency of two or more words that co-occur in discourse which are lexically or syntactically fixed to a certain degree…colligation refers to the inter-relationships of words and grammatical items or the grammatical company a word keeps and the position it prefers… (Menon and Mukundan, 2010, p.244)

A corpus of approximately 500,000 words was made using 12 science textbooks and then analysed with Wordsmith (software used for analysing word patterns). A corpus needs a reference corpus to make comparisons, and they found the British National Corpus, which contains approximately 100 million words, to be most suitable. The study corpus is compared with the reference corpus, and any words which occur more, or less, frequently than the reference corpus are extracted. They set out to extract the most unusually frequent words in comparison to the British National Corpus and this yielded 3,113 words. These words were coded according to four categories of vocabulary: non-technical (40%), sub-technical (20%), semi-technical (9%), and technical (31%). The four most frequent semi-technical words were extracted from the original 9%, and these words were namely: reaction, cell, pressure, and mass.

Their detailed collocational and colligational analysis revealed similar patterns in terms of usage amongst the four semi-technical words under study. For instance, the word ‘reaction’ was found to have three types of collocations: noun + noun, adjective + noun, and noun + verb. The noun + noun collocation of reaction, where reaction is in the base position, as in redox reaction, revealed that reaction’s semantic prosody is linked to types of processes. The adjective +

noun collocation came with two prosodic groups, one with ‘types’ such as endothermic reaction (i.e. type of reaction), and the second group was related to ‘degree’ as in fast reaction (i.e. the extent of the reaction). The word reaction colligated most frequently with present tense verbs, for example, ‘reaction occurs’. In the noun + noun collocation of cell, the meaning of each word in the collocation did not change in some cases when ‘cell’ was used at the base or head position. For example, each of the two pairs of words in the collocations ‘cell body’ and ‘blood cell’ retain the same meaning when used independently (i.e. not as a collocation). However, they found that in the collocation of some words, there was an extended meaning for one of the words in the collocation. In the word ‘guard cell’, the word guard has one meaning on its own, as in to protect, and in the collocation of ‘guard cell’, the meaning is related to the stoma in leaves. Furthermore, they found that general English grammar rules cannot be applied in some cases to deduce meaning. They highlighted this by comparing the words ‘cell body’ and ‘cell membrane’. Both compound nouns have the same syntactic pattern of noun + noun, but semantically in a grammar sense, they are different. Cell membrane is a type of membrane, so the word cell is modifying membrane. “In the compounds ‘cell wall’ and ‘cell body’, the words ‘wall’ and ‘body’ are postmodifiers to the word ‘cell’, thus bringing about the meaning, ‘a part of the cell’ – the wall of the cell, the body of the cell” (Menon and Mukundan, 2010, p.250-252). In all cases, cell is at the head of the compound noun, yet its grammatical function is different. They recommend that students should be taught these collocational and colligational patterns so that they can infer meanings from the science texts, as general rules in English are not always applicable to scientific English.

It appears that very few studies have been conducted in relation to the language analysis of chemistry textbooks. A more recent analysis of lower-secondary chemistry textbooks was carried out by Rusek and Voljir (2018) using a method named Nestler-Prucha-Pluskal which calculates the difficulty of reading texts. However, these authors used textbooks from Czech Republic, and thus were not in English. Pekdag and Azizoglu (2013) qualitatively analysed 15 chemistry textbooks published in the USA, France and Turkey, in terms of how the 'amount of substance' concept appears from a semantic and didactics perspective. Judging by the references to the textbooks, they were written in the language of the country, yet no explanation was given regarding any translation issues. Didactics, as they describe, is the study of how scientific knowledge is transferred in the process of teaching and learning. The Bureau International des Poids et Mesures (BIPM: International Bureau of Weights and Measures) (2006) ensure that a unified measurement system is being implemented internationally. The 'amount of substance' is "the quantity used by chemists to specify the amount of chemical elements or compounds" and the unit used to measure the substance is called 'mole' (BIPM, 2006, p.114). The mole has been defined as:

> 1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon 12; its symbol is "mol".
> 2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles. (BIPM, 2006, p.115)

One of the most established models of representing chemical knowledge has been referred to as the 'triplet model' (see section 3.5.1 for further details), which involves communicating chemistry on a macroscopic, submicroscopic, and symbolic level (Talanquer, 2011). The macroscopic level refers to what is tangible; the submicroscopic level is activities related to matter, such as the orbiting of electrons around a nucleus; and the symbolic level relates to the chemical symbols such as those found in chemical formulas (Talanquer, 2011). The concept of ‘amount of substance’ makes a connection between the macroscopic level and the submicroscopic level (Pekdag & Azizoglu, 2013).

The content analysis revealed three emerging semantic errors: missing concepts, inappropriate expressions, and mismatching. Missing concepts were found at all three levels (macroscopic, submicroscopic, and symbolic). BIPM (2006), in their definition, state that, "when the mole is used, the elementary entities must be specified" (p.115); however, Pekdag and Azizoglu (2013) found that the submicroscopic form was not mentioned. In one of the textbooks, the publisher wrote, "How many grams is 0.5 mol H_2O?" and so this has a missing concept at the submicroscopic level (Pekdag & Azizoglu, 2013, p.121). They clarify that the publisher should have written, "What is the mass (in grams) of 0.5 mol H_2O molecules?" as the entity, 'molecules’, is used (Pekdag & Azizoglu, 2013, p.121). They found that some textbooks used expressions at the incorrect level. One textbook used the inappropriate expression, "1 mol hydrogen gas," where instead it should have been read as, "1 mol hydrogen molecules" (Pekdag & Azizoglu , 2013, p.122). In this case, the macroscopic level term, gas, was used instead of the submicroscopic term molecules. The third semantic mistake (mismatching) occurred in some cases where the authors of the textbooks equated units that should not have been made to be the same. For example, one of the textbooks wrote, "Mass, m, corresponds to n mol" (Pekdag & Azizoglu, 2013, p.123). The author has incorrectly equated n with m, as the correct way to express the relationship would be by writing, "The mass of a substance is related to the amount of substance via $m = n \times M_A$" (Pekdag &

Azizoglu, 2013, p.123). Pekdag and Azizoglu (2013) are concerned that students may develop misconceptions as a result of these semantic mistakes. The difficulties from the textbook primarily occur due to some expressions containing multiple concepts in one sentence, and the students would inevitably find it difficult to grasp the concept (Pekdag & Azizoglu, 2013).

3.5 NON-TECHNICAL WORDS IN CHEMISTRY

The previous section has shown that non-technical words could be problematic for learners, and although studies on such words have been conducted over the past few decades, it is not abundant. Even with this, most studies report on words in general science (e.g. Marshall, Gilmour & Lewis, 1991), or are not inherently chemistry as Wilson's (1999) study is actually a study of discourse in science which is situated in a chemistry classroom. Studies which are purely on non-technical words in chemistry are even less common. Therefore, the studies reported in this section deal with the limited research on non-technical words in chemistry as a discipline; in other words, which are inherently chemistry such that the words are particular to the subject of chemistry. Before reporting on these studies, a core and important model used to represent chemistry is described. This model, known as the triplet model, has become a paradigm in chemical education (Talanquer, 2012). Following this, key studies based on non-technical words within the discipline of chemistry are reviewed.

3.5.1 Three Levels of Representation in Chemistry

Chemistry Triplet Model

Over three decades ago, Johnstone (1982) proposed a three level representation of chemistry which is now considered as one of the most "powerful and productive ideas in chemical education for the past 25 years"

(Talanquer, 2011, p.179). One level is related to what is perceived or experienced of the phenomena through our senses, or what could be measured. Another level is related to explanations of the phenomena at a deeper level that is unobservable even under a microscope. Then there is a level which corresponds to the communication of chemistry through symbols, numbers and signs. Since Johnstone's (1982) proposal, there has been little consensus on the terminology for the individual levels and their precise definitions, yet, the concept of the three levels has commonly come to be known as the chemistry triplet (Talanquer, 2011). Johnstone (1991) labelled the perceptive level as the macro level, the qualitative level as the submicro level, and the quantitative level as the symbolic level, although Johnstone has also named this level as the representational level. More recent studies have generally kept to the terms macro(scopic), submicro(scopic) and symbolic (Treagust & Gilbert, 2009; Pekdag & Azizoglu, 2013; Taber, 2013; Lewthwaite, 2014).

An understanding that shows movement between these levels is an indication of someone being literate in chemistry. As an example, we can visually observe ice melt (macroscopic level) when heat is applied; the forces between particles weaken in the process (submicroscopic), and this can be represented as chemical representations of forces between water molecules using the chemical symbol H_2O (symbolic). There are many challenges in reaching this level of chemical literacy for a student, as well as for a teacher in terms of pedagogy, and there are many examples of visual representations in chemistry textbooks that could have a negative effect on a student's submicroscopic level of understanding. Andersson (1990) gave an example from a textbook which shows a dozen H_2O (water) molecules within a medium of water. This would give students an impression that at the submicroscopic level, the liquid which is water, and the water molecules, are two different entities. The one-dimensional drawing of a molecule octane poses some problems as well. Such a diagram does not illustrate the tetrahedral arrangement of the bonds (Bucat and Mocerino, 2009). To a novice chemist, this would lead to a poor understanding of the nature of this molecule as it is vital to know about bond angles to appreciate the behaviour of a molecule, though, undoubtedly this level of understanding is not applicable to secondary school students.

Bucat and Mocerino (2009) claim that these difficulties are not limited to visual representations as they are also caused by the language used to explain them. They highlighted this with a textbook reporting on a particular mechanism in a reaction known as S_N2 substitution reaction. The textbook has wording which could be understood to mean that only this one particular reaction shown in the figure is occurring at one time. On the contrary, the reality is that this reaction and several other possible reactions are occurring simultaneously due to matters such as the mechanistic orientation of the molecules at the time of reaction. The continuity aspect of any chemistry curriculum also imposes some challenges. Novice chemistry students are taught earlier in the syllabus that all atoms of the same element are identical, yet later they learn about isotopes whereby atoms differ according to the number of neutrons in the nucleus (Bucat & Mocerino, 2009). This would require students to reformulate their submicroscopic understanding.

Students' difficulties with the three levels of the representation arise from, and not limited to: insufficient exposure to the macro aspect through practical experience; holding a range of misconceptions with regard to the submicroscopic level; inability to comprehend symbols in chemistry; and difficulties in moving between the three levels (Treagust & Gilbert 2009). Treagust, Chittleborough and Mamiala (2003) investigated the role and semantical function of submicroscopic and symbolic levels of representation in relation to the understanding of concepts in chemistry. The data were obtained from a combination of two of their previous studies which took place in Australia with year 11 (15-16 year olds) chemistry classes. The data from the first study, consisting of class recordings of two teachers' explanations and follow-up interviews, was primarily used to give a teacher's perspective. The second study involved recordings of one chemistry teacher in addition to class recordings from six students; this gave the student's perspective. From the data they found that the most common types of explanations were analogical, anthropomorphic, relational, problem based and model based. Dagher and Cossman (1992) define analogical explanations as when "a familiar situation similar to the unfamiliar phenomenon to be explained is used to provide an explanation" (p.364). Analogies are regarded as "crucial in the thinking of new thoughts" (Ogborn, Kress, Martins and McGillicuddy, 1996, p.72). Anthropomorphic explanations are when human characteristics are attributed to other than humans (Dagher & Cossman, 1992).

In one of the explanations, the teacher was explaining the role of a limiting reagent in a chemical reaction. A limiting reagent is the reactant which is totally consumed in a reaction and hence the reaction cannot proceed further. The teacher used a variety of symbolic representations to explain the concept and this included a chemical equation and actual numbers to present the mass of each reactant. This particular teacher used an analogy of the ratio of dancing men to women in comparison to chemical reactants and the limiting reagent.

The use of the symbolic representations and the analogy assisted the students to comprehend the phenomena on a submicroscopic level. The researchers point out that a successful student in this particular class would be able to move from the submicroscopic, in terms of moles, to the symbolic (grams) and then to the macroscopic with respect to the observed chemical reaction. As an example of anthropomorphic explanations, the researchers used data from a teacher explaining the positions of elements in the periodic table. In one situation, the teacher attributed the term 'schizophrenic' to explain the nature of elements that are between groups two and three of the periodic table in the sense that they do not have consistent behaviour (Treagust, Chittleborough & Mamiala, 2003, p.1360). As pointed out by the researchers, this macroscopic representation, could be an obstacle for a student's understanding of this chemical behaviour because the student may not know the meaning of the word schizophrenic. They found that students can effectively communicate chemistry when both symbolic and submicroscopic representations are used simultaneously in their chemical explanations. Though Treagust, Chittleborough & Mamiala (2003) focussed on the semantic aspect of the triplet model, not all studies do. There is no doubt that the importance of practical work in the development of a student's chemistry triplet model experience is crucial (Lewthwaite, 2014), however, equally important is the language in achieving chemical literacy and this should not be undermined as "scientists, instructors and textbook writers are all guilty of loose use of language…with the result that the distinction between the macroscopic and the sub-microscopic levels is blurred, rather than sharpened" (Bucat & Mocerino, 2009, p.12).

Chandrasegaran, Treagust and Mocerino (2007) developed a multiple-choice based two-tier diagnostic instrument for the purpose of eliciting 15-16 year old students' understanding of observed chemical reactions (macroscopic) in terms of submicroscopic and symbolic explanations. The large scale study as a whole involved 787 students from Singapore. Seven commonly occurring chemical reactions were chosen from the study and they were derived from three areas of the students' curriculum: acids and bases, the reactivity series of metals, and qualitative inorganic analysis. It seems as though the researchers were not sensitive to the language aspect in the design of the instrument and the chemistry triplet model. As an example, in the compound iron (II) chloride, they referred to iron as atoms and not ions, and some students may perceive the atom as neutral which could influence their choice of conception. Elsewhere in the diagnostic instrument, they used the word dilute to refer to some acids such as nitric acid. Nitric acid is a strong acid, and even though it is dilute, it is still considered as a strong acid as all the H^+ ions disassociate in water. There is a possibility that such terms may distract the student and again influence their choice of reasoning. Similarly, using the term liquid in contexts where the ion is aqueous can be misleading for students as was found in their reference to copper ions in copper (II) sulphate. Furthermore, the researchers did not give recognition to possible influences of the students' everyday meanings to the chemical terminologies. They claimed that 11% of students incorrectly referred to the formed product of copper as a precipitate, as in chemistry precipitates are insoluble salts such as barium sulphate. Although this could be a correct description, they did not give recognition to the everyday understanding of precipitates being some kind of a deposit, and hence this could explain why they used the word precipitate to refer to the deposit of copper found as the product.

An Adapted Semantic Model

The Legitimation Code Theory (LCT) was developed from Bernstein's work on semantics and further developed in its application to science Maton (2009). Maton (2011) elaborates on two terms related to the application of LCT, that being semantic density and the other semantic gravity. Semantic density relates to the specificity of words in the sense that at one end (strong end) the words are specialised terms, similar to technical words in science, and at the opposite end (weak end) are common words, i.e. everyday words. Semantic gravity is the "degree to which meaning is dependent on its context" (Maton, 2009, p.46). So when it is strong there is a strong connection between the meaning and its context, and meaning is less dependent on the context when semantic gravity is weaker.

LCT has been used in physics with a focus solely on semantic gravity (see Georgiou, Maton & Sharma, 2014); however, concerning chemistry, Blackie (2014) wrote a conceptual paper illustrating the application of the semantic dimensions of gravity and density as an alternative to the triplet model. The application of these dimensions can be understood with the example of salt dissolving in water. The semantic gravity axis to more or less abstract concepts. The semantic density axis relates to specialised terminology which includes chemical symbols, or at the weak end, common words with their daily meaning. In effect, there are four quadrants in this model and the aim is for the student to understand the top-right quadrant in terms of the other quadrants. Blackie (2014) suggests that the top-right quadrant is like a black hole in that this is what is unknown to the student. The bottom-left quadrant is what is understood by the student, or at least what a teacher would expect a student to know. The top-left quadrant is a description of the top-right quadrant, and the main difference with the top-left quadrant and the one directly below (bottom-left) is that the description is more abstract. This can be noticed with the term ‘mix’ being replaced with ‘dissolve’.

The semantic density is stronger when there is a shift from the bottom-left quadrant to the bottom-right quadrant as the common words are now represented as chemical symbols. In essence, Blackie (2014) is suggesting that teachers at times assume that the top-right quadrant is known and that by shifting back and forth between these dimensions, students would become more acquainted with the top-right quadrant. In my opinion, the main difference between the chemistry triplet model and the application of these semantic dimensions is that the latter is more language orientated. The semantic model offers more direction to teachers in terms of how to systematically explain and make concepts comprehendible in a way that also creates awareness of the challenges of language in chemistry. Despite this, all the three levels of chemistry representation still exist in this model showing their significance in the way language is used in chemistry.

3.5.2 Non-technical Words in Chemistry

Song and Carheden (2014) report Eiss's (1961) article as one of the first to acknowledge non-technical words in science. For example, Eiss (1961) reported on the word ‘weight’ in physics having three different meanings. It could mean: relative weight, which is measured using a beam balance; apparent weight, which is measured using a spring scale; and theoretical weight, which takes into account the "gravitational attraction between two objects" (Eiss, 1961, p.345). However, it is not known exactly when studies on non-technical words in the field of chemistry were first reported, but it seems that it is a relatively under-researched area (Song & Carheden, 2014). The research reviewed here is related to non-technical words in chemistry. The following studies are divided into those which involve typical undergraduate chemistry students, and non-traditional chemistry students. Non-traditional chemistry students can be defined as those “with different qualifications or life experience in place of normally expected formal qualifications required for…undergraduate study” (Rees, Kind & Newton, 2018a, p.2).

3.5.2.1 Typical Undergraduate Chemistry Students

Gabriela et al. (1990) investigated students' understanding of the terms 'spontaneous' and 'reaction'. The study involved clinical interviews with 14 participants all of whom were studying in their final year of their chemistry degree. Though three of the authors are from Portugal, and one from UK, the report does not state the medium of instruction. The definitions used in the study for reaction is "a material process in which a new substance is formed," and spontaneous is a reaction "which has a natural tendency to occur... (whereby) products (have a) lower free energy than the reactants" (Gabriela *et al.*, 1990, p.392). They suggest the everyday meaning of reaction to be some sort of observance in change of an object or a situation, and the everyday meaning of spontaneous is something that occurs without any noticeable external factor. Therefore, in this sense, we could consider these words to be as Nerlich and Clarke (2003) mention as polysemous words which fall in between contrastive and complementary polysemy as there is no direct semantic connection in their polysemous meanings.

Gabriela et al. (1990) probed the students' understanding by demonstrating four experiments that would challenge their understanding of the terms 'spontaneous' and 'reaction' in relation to their everyday meaning through reflection. Demonstrations one and two were selected specifically for the probing of the word reaction. In demonstration one, the students were shown magnesium metal being added to dilute hydrochloric acid. In demonstration two, ammonium chloride was added to water. Due to the nature of the reaction, it is clearly visible that a reaction has taken place in demonstration one, but it is visually difficult to see any products in demonstration two. Demonstrations three and four were primarily used for testing students' understanding of spontaneous. Demonstration three involved burning paper, and demonstration four was a reaction between iron filings and sulphur. The difference here is that demonstration three is situated in an everyday context. All four demonstrations are considered to be spontaneous by definition in chemistry, even though demonstration four is an extremely slow reaction at room temperature. All the students were asked to decide if a reaction had taken place and if they regarded the reaction to be a spontaneous one or not.

After their initial answer, they were asked to expand on their answers and explain the criteria that they used to make the decision. 13 out of the 14 students correctly recognized that a reaction took place in demonstrations one and two. Generally the students used two criteria, the first, known as criterion A, is "a chemical reaction occurred because perceptual changes were evident"; and the second, known as criterion B, is "a chemical reaction occurred because new substances were formed" (Gabriela et al., 1990, p.394). Criterion A was mostly used, however, it would be difficult to use this criterion for demonstration two because visually you cannot see any products, and many students struggled to justify demonstration two as a reaction. Gabriela et al. (1990) suggested that this shows that the students' immediate unprompted answers were dominated by what they understood reaction to be in terms of the everyday meaning. Although after further questioning, they did refer back to criterion A to justify their answer as they adjusted their understanding of the demonstration on a submicroscopic level.

The students were given thermodynamic tables to calculate if the reactions were spontaneous or not. Spontaneity, in a chemistry context, is when the sum of free energy for the products of the reaction subtracted from the sum of free energy from the reactants results in a negative value, and it can be represented as $\Delta G < 0$. Free energy is the energy available for work to be done in a system. So even though a reaction may not be observable for spontaneity visually, it can be calculated using available data on thermodynamics. Students either judged spontaneity through calculations, or by saying that no interference is necessary for the reaction to occur which is closer to the everyday meaning of spontaneous. As pointed out earlier, the fourth demonstration is a very slow reaction at room temperature, and therefore its spontaneity would be judged with great difficulty through direct observance, but can be judged easily by calculation. Initially, two of the students deemed the demonstration to be spontaneous, and after calculations were made, a further three students also concluded with the same response. Out of the remaining nine students, three remained confused and six insisted that the fourth demonstration was not spontaneous, as one student said: "I think it is not spontaneous, because when I mixed the iron and the sulphur they did not react…I cannot believe $\Delta G < 0$…perhaps I am confused about it" (Gabriela et al., 1990, p.398). The students found it difficult to put aside their everyday understanding of spontaneous, as they could not see the reaction occurring. Furthermore, with the paper burning demonstration, some students thought that the reaction was not spontaneous because there was an initial interference. These students did not understand the concept of activation energy, which is basically the minimum energy required by the reactants for the reaction to take place. The initial spark is just for the need of the activation energy to be overcome, and then the reaction begins. They used their everyday understanding of spontaneous in the sense that there is no interference and decided that the reaction had an interference and was therefore not spontaneous; and this was despite having full knowledge that the calculation for free energy was negative ($\Delta G < 0$). So, there were some students whose everyday understanding of the terms reaction and spontaneous affected their scientific understanding of these words initially; and there were others whose everyday understanding of reaction and spontaneous were too dominating that it displaced the scientific meaning in their minds. The dominance of everyday meaning coupled with explaining concepts beyond visibility proves to be challenging.

Jasien (2010, 2011) conducted two consecutive studies which investigated students' use of the terms 'neutral' and 'strong'. These words are similar to the ones raised by Eiss (1961) in that they carry multiple meanings within one science discipline. Jasien (2010) carried out structured interviews with 20 participants from England, all of whom were experienced students in chemistry at undergraduate level. In the interview students were presented with five sentences that contained the word neutral in different contexts. The students were asked to elaborate on their understanding of the word neutral in the context of the sentence. He found that there were no difficulties with the following sentence situated in the everyday context, "The referee is a neutral third party" (Jasien, 2010, p.33); all 20 students correctly explained the meaning in this sentence. As for the remaining sentences, approximately half of the participants gave the incorrect answer. As an example, from the nine students who incorrectly explained neutral in the sentence, "The liquid in the glass consists of neutral molecules" (Jasien, 2010, p.33), they used words such as 'unreactive' and 'stable' to explain the meaning rather than 'uncharged'. Unreactive was the most common interpretation used in the study by the participants, and this could be due to the influence of the everyday meaning on the scientific usage of the word neutral.

Jasien's (2011) study on the term 'strong' involved the same participants as the previous reported study, and the interview format was similar. This time, the students were presented with six sentences with the word strong in different contexts, which includes the everyday context as well as its various meanings within a particular science context. Similar to the 2010 study, the students were asked to explain the meaning of strong, and relate the sentences to each other. For instance, a student may relate the sentence which mentions strong acid with the sentence that mentions strong electrolyte as having the same meaning for the word strong. The students correctly explained the word strong in the sentences which were situated in an everyday context, such as in the sentence, "That is a strong cup of coffee" (Jasien, 2011, p.1247), as they explained strong to mean the amount of coffee. However, in the scientific contextualized sentence of, "The solution contains a strong acid" (Jasien, 2011, p.1247), eight out of ten students failed to give the correct explanation and referred to strong as highly concentrated. Instead, they should have explained it in terms of dissociation of the acid. Again, this shows the influence of the everyday meaning on the scientific context resulting in an incorrect understanding. Some students could correctly relate one sentence to another, yet, they would still show signs of a lack of understanding. One student correctly linked the following sentences: "This solution contains a strong acid" and "The substance is a strong electrolyte" (Jasien, 2011, p.1247). Even though, when the student was asked to elaborate on the meaning of strong, the student replied, "ability to act on other substances" (Jasien, 2011, p.1248). The author explained that this ability to act on shows a sense of power; in other words the student incorrectly conflated the meaning of strong with powerful in this context. Furthermore, Jasien (2011) pointed out that perhaps this student correctly associated these sentences together because they have a "chemical sounding context" (p.1248). This could show that students are able to recognise the general difference between science and non-science contexts. The word 'strong' was also found to be incorrectly associated with charge in the sentence mentioning 'strong electrolyte'. In general there "was a fair amount of contextual crossover with the scientific usage" as the everyday meaning of the polysemous word influenced the scientific meaning (Jasien, 2011, p.1249). Issues pertaining to contextual crossovers were also noted with the terms ‘freezing’ and ‘boiling’ (Jasien, 2013). Students commonly experienced these terms with water and had a sense of freezing to be ‘very cold’ and boiling to be ‘very hot’. Those students who correctly understood these terms were able to relate to contexts other than water.

3.5.2.2 Non-Traditional Chemistry Students

Song and Carheden (2014) explored the role of dual meaning vocabulary (DMV) amongst college (non-science major) students in a university in the United States of America. Their definition of DMV is words which can be used in both a science and a day-to-day context. More specifically, they investigated the students' initial understanding of particular DMV words, followed by their understanding of them after studying a course. The reported study involved 13 female students, and this was not deliberate, as it was only these female students who volunteered to take part in the research. The students were studying on the 'Fundamentals in Biochemistry' course, and the researchers' purpose for choosing students from this course was because the students on these courses are generally from non-science majors. They intended that the participants would have minimal exposure to chemistry and therefore would not have a developed understanding of DMV words in chemistry. The initial list of DMV words was made with the assistance of college students (all these students were not participants in the Song and Carheden (2014) study). This list was further reduced by graduate students and suitable university professors. From this reduced list, the DMV words were selected by two course instructors and one of the authors. They based their selection on three criteria: first, words that were commonly suggested as problematic by the students; second, words that instructors deemed to be difficult in terms of conceptual understanding; and third, words that are commonly found in day-to-day contexts. The authors did not justify why they themselves did not consider the full possible list of DMV words, or perhaps at least given the students a complete list of words from which they can select the problematic words. It is possible that some crucial DMV words may have gone unnoticed. Nevertheless, eleven DMV words were selected and used for the reported study. The data were collected by conducting semi-structured interviews at three intervals, all of which involved capturing the students' knowledge of DMV words in chemistry both pre- and post- course instruction. The interviews were transcribed and reported qualitatively.

In terms of the students' initial understanding of the chosen DMV chemistry words, when asked about their meaning, they generally referred to their everyday usage. Even when they were specifically asked to give the scientific meaning of a particular DMV word, they lacked a reasonable explanation of it. Furthermore, the participants tried to use their knowledge of the everyday meaning of the DMV word to justify its meaning in the scientific context. For example, when one student was asked about the scientific meaning of the word base, she said, "like acids and bases and like lower bases are on bottoms…well…one is on top or bottom, it is the opposite of acidity" (Song & Carheden, 2014, p.133). The student recognized bases as opposite of acids. However, she brought the everyday meaning of bases being on the bottom and thinking incorrectly that this means that acids are the opposite and therefore being on top. She did not realise that they are opposite with respect to bases being proton acceptors and acids being proton donors. The interview post- instruction revealed similar misunderstandings of DMV words. Some of the participants still used their knowledge of the everyday meaning to justify the scientific meaning. For instance, one student referred to organic as its meaning in an everyday context and described it as natural as opposed to a compound which contains both hydrogen and carbon. The student was convinced that her understanding was correct. The authors believe that the everyday usage of the DMV word is very dominant and so it strongly influences the scientific meaning.

The researchers also collected data on the students' retention rates of the DMV words by comparing their pre- and post- course understanding of the scientific meaning. Electrolyte was found to have the worst retention rate, 0%, and they suggested that this is perhaps due to the infrequent usage of the scientific term. This is not surprising as such a words are not common chemistry words, unlike atoms or compounds which are more common. The students felt that if the terms were more applicable in their everyday life then they would have retained the words better. Some students admitted that they only learnt the DMV words for the exam, and had no intention of retaining the words for the future. The researchers also reported on students mixing up words such as solute and solvent, however, they did not elaborate on the reason. This could be due to the similar phonetic and morphological nature of words.

There were some aspects of this study that could be improved for future studies. Firstly, the authors did not clarify their criteria on what they believe to be acceptable scientific meanings. As an example, they regarded one student's explanation of aromatic ring as correct, as the student said, "It is an aromatic ring, which is a benzene ring I think. It is carbons and hydrogens and it is almost 3 bonds but not really, it is like 2.5" (Song & Carheden, 2014, p.135). In this student's definition of an aromatic ring, the vital aspect of the electrons being delocalized was not mentioned, yet this definition was approved by the researchers. Perhaps it would have been better to classify the students' definitions as correct, incorrect, and partially correct. Secondly, at times, the researchers did not delve into detail as to what extent the everyday meaning influences the concept behind the DMV word. In one interview, the student correctly gave H_20 (water) as an example of a polar molecule, but then followed on with an incorrect explanation. The student did not recognize that the electrons are being pulled to the oxygen and instead said that the hydrogen atom is being pulled to it. It may be that there is more to the meaning of the DMV word polar in the student's mind that would lead to this misunderstanding, and perhaps by further probing, a better insight would be gained.

Research on non-technical words in chemistry in recent years has not focussed on this aspect alone, with its significance in studies varying, and has formed part of another aspect of language in chemistry. Rees, Kind and Newton (2018a) focussed on non-traditional students' development of chemical language usage as participants move up a continuum from using everyday language to language consisting of specialised chemical terms. While Vladusic, Bucat and Ozic's (2016) study involved looking at aspects of language in chemistry in the medium of Croatian language. Cink and Song (2016) situated their study consisting of four community college students with diverse ethno-linguistic backgrounds in a college in USA. Their research was premised on three conceptual frameworks: cultural anthropological framework, discursive identity, and Snow's (2008) three level tier framework whereby the technicality of words increase from one level to another. Tier I words are everyday words; Tier II are common academic words; and Tier III are discipline specific words. In a cultural anthropological framework, science is considered as a culture, and students cross borders from their everyday culture into the culture of science:

> If the subculture of science generally harmonizes with a student's life-world culture, science instruction will tend to support the student's view of the world ('enculturation'). On the other hand, if the subculture of science is generally at odds with a student's life-world culture, science instruction will tend to disrupt the student's view of the world by trying to replace it or marginalize it ('assimilation')…Both enculturation and assimilation require cultural border crossings into the subculture of science. (Aikenhead, 1996, p.5)

The three conceptual frameworks are linked as the usage of scientific words is used as an indicator for the students' discursive identity, and consequently their cultural border crossing. The participants of the research varied greatly in terms of their ethno-linguistic and chemistry backgrounds.

In terms of DMV words, or non-technical words, most of the participants were able to use these words successfully and the authors said that this could be partly due to the laboratory setting giving them plenty of opportunities to use these words. For example, Azita was able to use the word condition (technique to prime glassware) appropriately. Another key finding was that some DMV words were not used appropriately, not because of the everyday meaning being ingrained in them, but as a result of having to learn these words in terms of their technical usage (Tier III words). In Hakim's case, he said that he had learnt everything in English after grade 7, so he "he did not have the everyday meaning of DMV ingrained deeply into his discursive identity, allowing for an accessible Tier III appropriation of the DMV" (Cink & Song, 2016, p.612). They found that the participants undertaking cultural border crossing also crossed from the culture of science to their everyday personal worlds. The participants demonstrate idiosyncrasies in their vocabulary usage.

Hakim and Yoseph, coming from Ethiopia, were accustomed to Tier II words as they were immersed in an environment where their usage of English was replete with academic words from a young age. Some of these Tier II words hold a meaning in various academic disciplines and a close but more specified meaning in Tier III (chemistry discipline), such as indicator. For instance, poor sales could be an indicator of a poor economy, and "a chemical indicator has a similar function by changing its color based on the pH…of a solution," but the two usages are context specific (Cink & Song, 2016, p.613). On the other hand, Azita and Maria struggled with the same class of words and what is interesting to note is that according to data in the report, both are fluent in English. Maria was born in USA, and while Azita was born in Afghanistan, she completed her high school in Canada. This possibly suggests that there is not necessarily a positive correlation between English proficiency and using technical words appropriately.

3.6 METASYNTHESIS OF SECONDARY SCHOOL CHEMISTRY STUDIES

The purpose of this metasynthesis is to exemplify non-canonical accounts of secondary school chemistry through interpretations of the embedment of everyday meanings in a scientific context. Comparing students' conceptions with canonical accounts could be problematic:

> …definitive statements about what a scientific concept actually is should be made with caution. That is not to suggest that researchers should avoid seeking to compare student knowledge with canonical knowledge as such research is directly useful and relevant to teaching. Rather researchers need to be aware that at best they can have a model of canonical knowledge for comparison, and that in reporting their work they should be explicit about what they take to be scientific and/ or curriculum target knowledge and on what they base this judgement…when we explore students' conceptions of any topic in depth, we tend to find nuanced, often complex patterns, often with idiosyncratic ranges of application, and with evolving levels of commitment. This means both that any simple statements about student conceptions…are likely to considerably simplify what are often actually nuanced conceptualisations. (Taber, 2013, pp.228-229)

Moreover, that interpreting findings in this manner is highly subjective. Therefore, I do not take this section as any form of findings for results in this thesis. However, I believe it is useful to some extent in exploring ways in which students could possibly embed the everyday meaning of words in chemistry resulting in interpreting this as a non-canonical account. In this thesis, an IGCSE chemistry book (Harwood & Lodge, 2014) is analysed as it is the target knowledge for the participants in this study, and this is discussed later. As such, this book is used as the target knowledge to form judgments about what is canonical or non-canonical knowledge in this sense. I acknowledge that students' use of everyday language in what may be deemed as unscientific in the context of chemistry is not necessarily a bad thing as it could be a promising sign in the sense that it could be "a healthy stage between ignorance of the atomic world and being able to express…ideas in a more physical…language" (Taber & Watts, 1996, p.564). But if students were to suffice with such explanations, then this would prevent progress to higher levels of understanding.

3.6.1 Metasynthesis

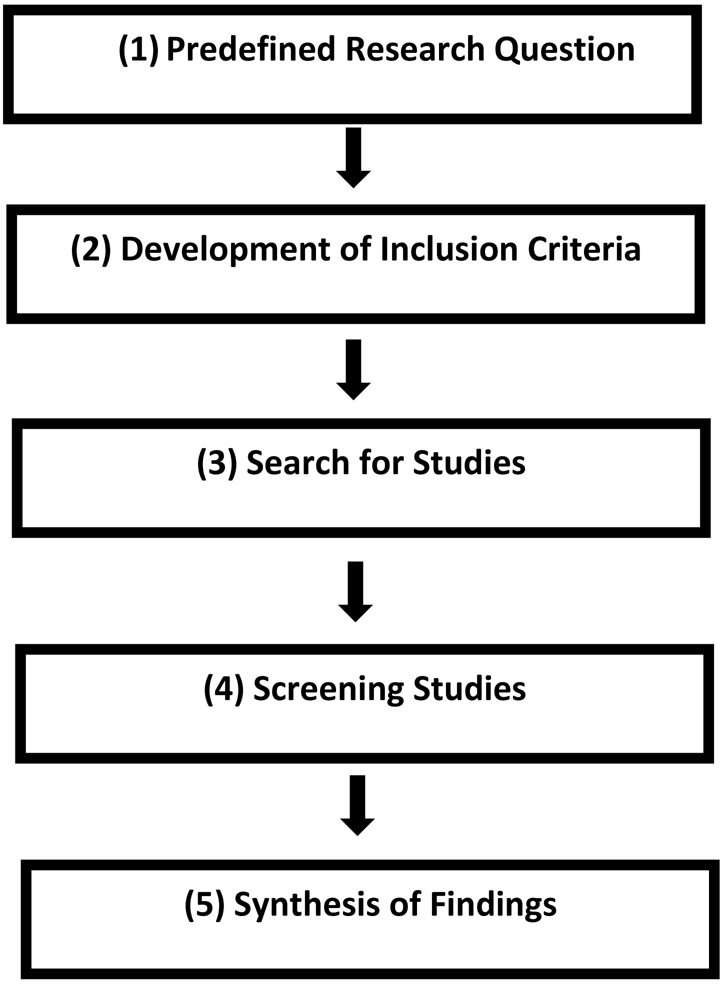
The specific method under ‘qualitative synthesis’ known as metasynthesis is adopted as Sandelowski and Barroso (2007) explain:

> In qualitative metasynthesis, language is viewed as a structure or artefact of culture that must itself be interpreted. Their validity does not reside in a replication logic, but rather in an interpretative logic, whereby findings are reframed, and in the craftsmanship exhibited in the final product. (p.18)

Numerous systematic reviews have been conducted using meta-analysis and this is carried out with the use of statistics and is usually based on quantitative studies. Related to qualitative research, qualitative synthesis has emerged as it uses “interpretive methods to combine study results of studies addressing the same question within a similar epistemological and ontological framework” (Saini & Shlonsky, 2012, p.179). It is not the same as a meta-analysis because the goal of a meta-analysis is to make conclusions on cause and effect relationships through the establishment of certainty; whilst a qualitative synthesis seeks to explain and enhance the understanding of a particular phenomenon (Walsh & Downe, 2005). Though the findings of this approach is normally taken as findings and not typically used as a literature review due to the explicit requirements of transparency in all parts (Dixon-Woods et al., 2006; Thorne, Jensen, Kearney, Noblit & Sandelowski, 2004), I do not believe it would be trustworthy in this sense, and especially due to the nature of the research questions in this study. However, I do hold that it would to some extent enhance understanding of a phenomenon.

The methods employed in qualitative synthesis vary based on whether the research question is predefined or iterative. Saini and Shlonsky (2012) have elaborated on this point. Some researchers have a set research question prior to carrying out the synthesis, this means that they are more likely to aggregate

FIGURE 3.1
Procedure for Metasynthesis



findings; whilst others refuse to approach the synthesis in this manner as they believe that this will have an effect on the interpretation of the synthesis. Researchers who prefer to remain iterative aim to be inductive and they continue to explore to reach new understandings as in the case of meta-interpretation; in other words, it is a discovery process. Metasynthesis is a method “that attempts to integrate results from a number of different but interrelated qualitative studies” (Saini & Shlonsky, 2012, p.179). The overall procedure for the current metasynthesis is outlined in Figure 3.1. There are four main steps which lead to the selection of studies in a metasynthesis. In order, they are developing a research question, searching for literature according to inclusion/exclusion criteria, and appraising the studies (Erwin, Brotherson & Summers, 2011). The appraisal stage includes the use of specific inclusion criteria and assessment of the quality of the studies. It is after this step that the final sample is selected and the findings synthesised for the metasynthesis. The predefined research question is: What non-canonical accounts could be interpreted from the embedment of everyday words in the findings of selected studies on secondary school chemistry? Further details of the procedures can be found in Appendix 1.

3.6.2 Synthesis of Selected Studies

A total of 942 studies were retrieved after the initial database search dating to 2016. This was reduced to 154 papers following abstract screening. The full text screening led to a final sample of 14 studies, and the details of these studies are chronologically listed in Appendix 1. Three main themes emerged related to usage of verbs, usage of nouns, and connotations specifically related to strength. In the dialogue excerpts, ‘R’ is the researcher and ‘S’ is the student. Another point to note is that the examples given under each theme are not fixed as some cases could be represented under other themes.

3.6.2.1 Everyday Doing of Verbs

The way we use verbs in an everyday sense could result in non-canonical accounts of chemistry if we embed that usage in the context of chemistry.

In covalent bonding, the idea of ‘sharing’ of electrons is highly emphasised to such an extent that students consider it to be a key feature of this type of bonding. Boo (1998) found students misunderstood the nature of the bonding in covalent bonding as they thought that one electron is shared between two atoms, such that one atom donates an electron to the other atom. Boo (1998) believes that these students used their everyday understanding of ‘share’, as in when someone shares something, he/she gives that thing to another person without getting anything back in return. A student in Taber and Garcia-Franco’s (2010) seemed to believe that in order for dissolving to occur, stirring must take place.

> R: How is this process of salt dissolving going to happen?
> S: It will start to dissolve, if you stir it.
> R: If I don’t stir it, you don’t think it is going to dissolve?
> S: I think some of it will.
> R: Why is it?
> S: Because the particles move around more, so they can still dissolve.
> R: So, if I don’t move it, do you think it is going to dissolve?
> S: No. (Taber & Garcia-Franco, 2010, p.117)

In this particular example, salt dissolves into sodium and chlorine ions, and although stirring could make the process occur faster, it is not related to dissolving as defined in chemistry. Students may be used to stirring two substances together, such as chocolate powder with milk, or even seeing their parents stir sugar in their tea. This is what possibly makes that link between stirring and dissolving, however, stirring is not required for dissolving in the context of chemistry.

Forces of attraction exist between atoms and ions. These chemical bonds take in energy from the surroundings when the bond ‘breaks’, and when chemical bonds are ‘made’, energy is released to the surroundings. So essentially, ‘bond making’ releases energy, and the opposite, ‘bond breaking’, requires energy. Boo (1998) found that students thought that ‘making’ bonds requires energy because in an everyday sense, when something is made, energy is needed to make that thing. These students also believed that ‘breaking ‘bonds releases energy since when something is destroyed, in everyday terms, there is a sense of energy being released. In an everyday context, heating an object causes it to expand. One student applied this principle on a submicroscopic level in an example of boiling water by saying:

“the water would evaporate, the particles expand…if you heat water then the particles…like grow bigger” (Garcia Franco & Taber, 2009, p.1937). Scientifically, we understand that upon heat, particles increase in kinetic energy and move faster, but the molecules do not get ‘bigger’. It could be imagined that the student would believe the opposite whereby objects shrink when cold and thus the particles get smaller. In everyday terms, some people burn things to get rid of them. With regards to the mass of wood splint after it has burnt, a student in Hesse and Anderson’s (1992) study said: “…it disintegrates and goes “bye-bye.” It’s gone in the form of ashes or nothing” (p.288), thus not appreciating the concept of conservation of energy.

3.6.2.2 Everyday Descriptive Features of Nouns

In the examples reported here, students use everyday descriptive features of nouns and apply this to the chemistry context. First, accounts of general nouns are given, followed by more specific nouns.

General Nouns

Mayer (2011) reported on a classroom experiment which was designed to counteract any misconceptions held by students with regards to the mass of solids and gases. In the experiment, solid carbon dioxide (dry ice) sublimed (solid to gas) in a closed container. The students weighed the solid at the beginning and at the end, and they found that the mass did not change. This experiment clearly showed them that mass is not related to the state of a substance whether it is a solid or gas. A substance being a solid does not mean it will be greater in mass than a gas, and the opposite is also true with the gas not being lesser in mass than the solid. Even with such evidence one student said in astonishment, “But it’s the same” (Mayer, 2011, p.112). Students could relate a description of lightness when they think of gases and one of heaviness when they consider solids. One student thought that metal atoms were hard and that liquid atoms were soft:

> R: Do you think atoms are hard or soft?
> S: . . . they could be either.
> R: Sometimes hard, sometimes soft?
> S: Yep . . . it depends on what it's making really, whether it's a metal or a liquid.
> R: So we talked about a metal, what would you say?
> S: Probably be hard.
> R: A liquid?
> S: Probably be softer . . . (Harisson & Treagust, 1996, p.524)

She did not realise that such properties of metals or liquids come about due to the forces of attraction between atoms.

Specific Nouns

In a saturated solution, no more solute dissolves in the solvent unless the temperature is increased. During an interview about a system of salt and water, a student described salt crystals, which formed as a result of saturation, as snow.

> S: The salt is at the bottom. The water is on top. The salt has crystallized and that means it has reached its original state.
> […]
> R: Why do you think most of the salt has come down?
> S: The low temperature causes crystals.
> R: Why would low temperature cause crystals?
> S: Less particle movement which cause the stop and it [salt] starts crystallizing.
> […]
> R: Do you think there is anything happening between the two parts?
> S: Between the crystals and the solution. Starting to break apart.
> R: Why do you think it is breaking apart?
> S: Because the temperature is rising here.
> R: How do you think the temperature rises? We have not done anything to it.
> S: I know, but the crystals are probably frozen, I guess. The temperature is lower.
> R: It is because of the freezing nature, the salt has come down?
> S: Right.
> R: When it gains room temperature, it goes back to the other state?
> S: Yeah, like snow. (Ebenezer & Gaskell, 1995, pp.9-10)

The student focussed his explanation on change of temperature and change of state from liquid to solid due to kinetics, even though the temperature did not change. He should have explained this in terms of saturation, but his connection of salt crystals to snow diverted his thoughts towards state changes.

Macroscopic properties of dyes have been used to explain related submicroscopic phenomena as one student explained to the researcher:

> R: Okay. If we put droplets of food colouring in water, what happens to the particles of food colouring just after it is added and over time?
> S: … The food colouring … it sinks right away, but once it gets to the
>
> bottom, it starts to dissipate…and move in between the spaces and bonds…with the water particles. It sort of dyes them….
> R: How does food colouring dye water?
> S: I think, because the food colouring has its own colour and it can colour other things that it touches. That is why if we touch the food colouring we have that colour. It is kind of stuck to our fingers…, but on top of that the food colouring itself diffuses through the water and in between the spaces between the water molecules... (Adadan, Irving & Trundle, 2009, p.1761)

This student not only believed that the dye goes between bonds, but also that dyes colour particles like they stain in an everyday context. This student has not recognised that the dye itself is particulate. A student in Harrison & Treagust's (1996) study thought that electron shells are like egg shells:

> S: That's the, . . .right out there is the shell, and then . . . that's [indicating] the nucleus. .
> R: Shell of what?
> S: The shell of the atom.
> R: What do you think the shell, when I say shell, what do you think of?
> S: Apart from an egg shell, something, er, like a hard coating around the outside. (Harrison & Treagust, 1996, p.524)

In this instance the student admitted that she thought of egg shells. Without understanding the concept of energy levels, these students' understanding would not enable them to progress to develop understanding at higher levels where this knowledge is crucial. Johnson (1998) reported on students not being able to distinguish between particles and grain. This difficulty occurred when students were referring to grains of sugar. Johnson (1998) said that that students' everyday use of particles did not allow them to differentiate its use between the macroscopic and submicroscopic levels.

3.6.2.3 Connotations Related to Strength

Some words have associated connotations which adds a deeper meaning to a word, such as feelings of strength, or negativity. The studies reported here are examples of students applying connotations of strength to the everyday word strong.

A common misconception in the topic of acids is the misunderstanding of the terms 'strong' acid and 'weak' acid. In chemistry, whether an acid is strong or weak is related to what extent it separates into ions. If we consider hydrochloric acid in water, it separates completely into hydrogen ions and chlorine ions and since it has completely ionised, or dissociated into ions, we can say it is a strong acid. On the other hand, ethanoic acid in water only partially dissociates into hydrogen and ethanoate acids and is therefore referred to as a weak acid. Analogous to this context, acetic acid is a weak acid as it is partially ionised, however, due to it being an acid, a student would still believe it is strong:

> R: Would you say acetic acid is a strong or a weak acid? Acetic acid was the one which had the slow reaction.
> S: I would still say it was strong, but not as strong as the other one. So more likely (pause) it was weaker than the other one, but I can't say it was weak. (Ross & Munby, 1991, p.20)

This student is not understanding strong and weak acids in terms of dissociation of ions. The association of strong with acid is deep rooted in the student's thoughts.

In dissolving, substances act on each other, however, some students have assumed connotations of a substance being overpowering, as the following excerpt highlights:

> R: What if I just put water again and salt again, what happens with that?
> S: Well it's kind of like dissolving either into the water, or the water is like eroding it, you could say it's mixing in with the water.
> R: What do you mean by eroding it?
> S: When it hit the water, kind of make the material [pause] melt, they can totally, it was a liquid but it turned to a solid, but when the solid goes back to a liquid, the water kind of erodes it and washes it.
> R: So, the solid is turning into a liquid?
> S: Yeah.
> R: [pause] How do you imagine the salt particles are being broken off?
> S: You pour in the salt, and then it kind of disappears, and then [pause] so, the salt crystal, this bit here, it's where the water slowly dissolving it and making into a liquid and soon it would all be dissolved. [pause]
>
> R: If you think there are particles in the water, would [this] help you to explain this eroding, dissolving, mixing [pause]?
> S: Well, the particles of the salt, when they go into the water, they might react with the particles in the water and the water particles might destroy, you could say, but not really destroy them, they make their way and then this bit mixes in with the water. (Taber & Garcia-Franco, 2010, p.120)

In this example of salt dissolving in water, the water is made out to be the substance in control. The student used words such as 'eroding', 'washes', and at one stage the word 'destroy' was temporarily used. There is no scientific basis for this connotation. A student in Selley's (2000) study thought of water as an army: "[The water] is like an army towards the tablet – the quicker it attacks, the quicker it gets rid of what's in the way" (p.394). A further analysis of the words used to describe the actions of water shows the effect of water through natural disasters such as tsunamis and 'eroding' rocks, and other related terms such as 'destroying', and 'gets rid of'. This worldly experience of the strength of water could have led to such connotations and as a result producing unscientific explanations.

In a response to a computer generated question, a student regarded iron to be powerful:

> Computer: When an iron nail rusts, the atoms of iron are still there but cannot be seen.
> Student: There might be some parts which rust really properly and then it all goes but then there might be tiny little bits left that…still have the power of iron in them. (Brosnan & Reynolds, 2001, p.75)

The student may have thought that since some iron is 'left', it must have been powerful enough to survive rusting. This student further failed to appreciate that rusting was caused by the iron atoms reacting with oxygen, and thus it still exists. Also, Toplis (1998), from his classroom observations, noticed that students thought that acids were stronger than alkalis. It is the everyday usage of these terms that imply strength, as iron is used to imply something strong such as the metaphor of 'iron fists', and acids are associated with causing corrosion and burns which implies strength. Furthermore, a student described magnesium as the "driving force" in a reaction between magnesium and hydrochloric acid "because it is very reactive" (Boo, 1998, p.576).

3.7 FORMULATION OF RESEARCH QUESTIONS

The literature review indicates that research related to Saudi college students who study chemistry in the medium of English as a Foreign Language is relatively under-researched (Shamim et al., 2016), and that studies pertaining specifically to their understanding of non-technical words in chemistry appears non-existent. Based on this identified gap, the overarching research question for this study is: how do Saudi EFL college students understand selected non-technical words from their core chemistry textbook?

Most research on English Language Learners (ELLs) in science has been conducted in elementary schools (Lee, 2005). Past studies on non-technical words included ELLs as participants (Cassels & Johnstone, 1985; Marshall, Gilmour & Lewis, 1991; Farrell & Ventura, 1998; Childs & O'Farrell, 2003; Garza et al., 2017), and even with EFL students (Tao, 1994), but these were not based on chemistry specifically. Chemistry is distinct from the other science disciplines and this can be appreciated by its representation at three levels: macroscopic, submicroscopic, and symbolic levels (see section 3.5.1). More recent research related to non-technical words in chemistry is shifting towards a more diverse range of students, or non-traditional students (Cink & Song, 2016; Rees, Kind & Newton, 2018a), and even exploring non-technical words in languages other than English (Vladusic, Bucat & Ozic, 2016). The participants in Cink and Song's (2016) study had experience, to varying degrees, of studying chemistry in English; in addition, they were situated in USA, a country where English is the official language. As such, they could be described as ESL (English as a Second Language) students; although they have another language as their mother tongue, they are using English in an English-speaking country.

The Saudi EFL students in this study, have never had any chemistry lessons delivered in English prior to joining the college as their high school years in Saudi public schools were in the medium of Arabic, except for English (as a subject). Studying in the college is their first experience of learning chemistry, as well as other subjects, in the medium of English. Moreover, they are in a country where English is used as a foreign language, hence they are EFL students as their mother tongue, Arabic, is the official language of the country. Furthermore, a study focussing on lexis (a central aspect of language) is consistent with the assumptions of constructivism adopted in this study (see section 3.3.4 for a detailed discussion). Therefore, the overarching research question for this study is:

- How do Saudi EFL college students understand selected non-technical words from their core chemistry textbook?

This research question raises several sub-research questions. Firstly, non-technical words would need to be identified from the students' chemistry textbook, hence:

- What non-technical words are there in the Saudi EFL college students' core chemistry textbook?

The various methods used to analyse textbooks (see section 3.4.4), especially corpus analysis, highlights the importance of looking beyond the meaning of a non-technical word itself, and looking at how meaning is made with non-technical words in relation to surrounding words through collocations and connotations. The metasynthesis (see section 3.6) demonstrated that the way that we use verbs and describe nouns in our daily lives could potentially be applied in a scientific context and be interpreted as a non-canonical account of science.

After identifying potential non-technical words, a number of factors would need be taken into consideration. Non-technical words by their definition have an everyday and chemistry meaning, and when the everyday usage is embedded in the context of chemistry it can be problematic in terms of grasping the chemistry 'concept' which may or may not influence students' conceptions of the target concept. Due to this, the research question for this is:

- To what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry?

These students are EFL students. Their first language is Arabic, and English is used as a foreign language. Issues pertaining to familiarity of the usage of the identified words would be of interest; as they are not bilinguals. In addition, they need to translate words, so in effect, their first language is in use. As such, this raises the following questions:

- How familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words?
- What is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?

CHAPTER FOUR
RESEARCH METHODOLOGY

4.1 INTRODUCTION

This chapter justifies the overall methodology for this study which is case study research, and details the research design and associated methods employed to collect the data. A mixed methods sequential design was incorporated in this study which utilises a corpus based method to identify potential non-technical words in the textbook used in this case study, and this was followed up with semi-structured interviews with the participants of this study. The chapter also discusses ethical, validity and reliability issues pertaining to this study.

4.2 CASE STUDY RESEARCH

A methodology is “the activity or business of choosing, reflecting upon, evaluating, and justifying the methods you use” (Wellington, 2000, p.22). Therefore, in this sense, the methodology for the current study is case study research. Case study as a methodology is appropriate for this study; exploring and describing a case in which L1 Arabic students construct personal knowledge when learning chemistry in English. Even though the current methodology does not contradict with the assumptions of constructivism adopted in this study, it is worthwhile noting that:

> Constructivism as a referent for Science Education is seen here as an ontological commitment (that what is studied, student learning of science, can be understood in terms of the active 'construction' of knowledge), *but not necessarily* as an epistemological commitment (that research findings themselves are constructed rather than discovered). Undoubtedly the authors of 'constructivist' science education research would take a variety of positions here. (Taber, 2006, p.133)

The next sections elaborate on the framing of the case in the present thesis and the underlying philosophical assumptions for this research, as it uses both qualitative and quantitative data to address the research questions.

4.2.1 Defining Case Study Research

A "case study is the study of the particularity and complexity of a single case, coming to understand its activity with important circumstances" (Stake, 1995, p.xi). Yin (2009) provides a two-fold definition for case studies:

> 1. A case study is an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident.
> 2. The case study enquiry copes with the technically distinctive situation…relies on multiple sources of evidence…benefit(ing) from the prior development of theoretical propositions to guide data collection and analysis. (p.18)

Even though different standpoints with respect to what a case is rests on "the enduring gulf between quantitative and qualitative social science" (Ragin, 1992, p.3), and that Stake is seen as a constructivist and Yin as a postpositivist (Boblin, Ireland, Kirkpatrick & Robertson, 2013), the common attribute of a case study is that it focusses on the 'particularity' and 'distinctive' nature of the case. It is a "social phenomena specific to time and place" (Ragin, 1992, p.2). Therefore, this attribute of case study research is suitable for the present study which is premised on constructivism as a theory of learning which acknowledges and gives recognition to learners' conceptual structures exhibiting both commonalities and idiosyncratic features (Taber, 2013).

Stake (1994) categorises case studies into three kinds: intrinsic, instrumental, and collective. The intrinsic case study is not for the purpose of 'theory building,' but because the researcher has a particular interest in the case itself, "for example, this particular child" (Stake, 1994, p.237). The concern for an instrumental case study is focused on the issue, rather than the case itself. The case is used, or chosen, to enhance our understanding of the issue itself. The collective case study uses a number of cases (as opposed to a single case) whereby similarities, and/or dissimilarities, between the cases collectively enhance our understanding of the phenomenon. Though Yin (2009) recommends using a multiple-case study as he believes that it is “more powerful than…a single case…alone” (p.61), he also acknowledges that it is not always ideal and is dependent upon the focus of the study. Yin (2009) provides several rationales for conducting single case studies, and this includes conducting single case studies to better understand other similar cases, or that the case involves a particular unique participant and as such multiple cases would not be possible. Similarly, Stake (2006) points out that a “single case is meaningful, to some extent, in terms of other cases” (p.4). The way we comprehend other cases is by knowing known single cases, and thus even with multiple case study research, there is still great interest in the single case.

One of the main criticisms of case studies is the issue of generalisability, primarily due to the particularity of a case, however, it can be argued that “formal generalization is overvalued as a source of scientific development, whereas “the force of example is underestimated” (Flyvbjerg, 2006, p.228). Despite this, this issue would continue to be seen by some as a shortcoming of case study research, whilst as a strength for those in favour of case study research as the importance given to the particularity is a dominant feature of this kind of research:

> The real business of case study is particularization, not generalisation. We take a particular case and come to know it well, not primarily as to how it is different from others but what it is, what it does. There is emphasis on uniqueness, and implies knowledge of others that the case is different from, but the first emphasis is on understanding the case itself. (Stake, 1995, p.8)

Instead of focussing on generalizability, the researcher can provide a rich descriptive account of the case to help the reader “make judgments about the applicability” of the case (Meyer, 2001, p.348).

4.2.2 The Case

“Binding the case will ensure that your study remains reasonable in scope” (Baxter & Jack, 2008, pp.546-547). In defining the case, a decision needs to be made with respect to “what constitutes the ‘bounded system’. This is a single unit of analysis – a class, institution, project, or programme” (Simons, 2009, p.29). Essentially, the case itself, or the ‘unit of analysis’ (an individual, entity, event etc.), is linked to the primary research question (Yin, 2009, p.29). The case in this study is Saudi EFL college students’ understanding of selected non-technical words from their course chemistry textbook. Furthermore, a case study is a “study of a singularity conducted in depth in natural settings” (Bassey, 1999, p.47). A description of the case setting is given in section 2.6 and this characterises its uniqueness. The case has a natural setting with unique aspects such as its location, background of the students, the program of study and the teachers of the programs. The participants in this study are from amongst the sample of students who belong to this case as they study a particular chemistry program in this particular institution.

The case described here is a single case amongst others (Stake, 2006). Other similar institutions in Saudi Arabia may differ in many ways including and not limited to the English course instructional hours, though as mainstream English books are widespread in the kingdom, following CEFR levels, the content is not expected to be very different. Some institutions have non-native speakers of English teaching these programs. Whilst this institution follows an IGCSE chemistry textbook with their syllabus taught in English by teachers who do not know Arabic, other preparatory year chemistry programs may have their own in-house curriculum, and teachers there may be Arabic-English bilingual speakers. The students in the present study have studied in Arabic medium public schools, whereas other preparatory programs may have students who have studied in English medium international schools.

4.2.3 Philosophical Assumptions

All research comes with underlying philosophical assumptions that guide the research process in terms of the decisions made and conclusions reached. Paradigms differ in terms of ontology and epistemology. Ontology is about the nature of reality and epistemology is about the nature and validity of knowledge (Wellington, 2000); epistemology is that which pertains to knowledge, truth and verification (Pring, 2004). Positivists hold the ontological assumption that reality exists independently of us and that there can only be one truth (Wellington, 2000). Researchers with a positivist ontology tend to focus on collecting quantitative data in an attempt to make generalisations about reality. Interpretivists believe ontologically that reality is dependent on one's perspective of it; it is socially constructed, and so there are multiple truths (Lichtman, 2013). Interpretivists generally collect data qualitatively, and try to give a detailed thick description of the events without necessarily focusing on making generalisations (Lichtman, 2013).

Case study researchers, coming from a range of disciplines, have approached the field with different philosophical positions:

> Central to these variations is the underpinning ontological and epistemological orientations of those involved in the evolution of case study research. Researchers who have contributed to the development of case study research come from diverse disciplines and their philosophical underpinnings have created variety and diversity in approaches used. (Harrison, Birks, Franklin & Mills, 2017, pp.1-2)

So, for example, “philosophically, case study research can be orientated from a realist or positivist perspective…and can be apprehended, studied and measured, through to a relativist or interpretivist perspective. (Mills, Harrison, Franklin & Birks, 2017, p.7). Literature related to the methodology of case study research is “not vast, and is actually very heterogeneous…researchers cite the already well-known texts; newer publications refer to older ones” (Swanborn, 2010, p.11). Merriam, Stake, and Yin are core references in case study research, yet their writing exhibit differences in philosophical assumptions. Some claim that Yin is a positivist, and that Merriam and Stake are constructivists (Yazan, 2015). Brown (2008) sees them on a continuum with Yin’s work in line with positivist rhetoric, Stake with constructivism, and Merriam in the middle as she takes a pragmatic approach. Even so, none of them restrict case study research to one form of data. Case study research does not lend itself to a specific research design, nor is it comprised of one data form (qualitative or quantitative) as this is determined by whether or not “they facilitate an understanding of the particular case, what kind of inferences you can make from the data and how these are valued by different audiences for different purposes” (Simons, 2009, p.5). “Any set of methods that will help to develop understanding can be used, case study is a bridge that spans the research paradigms” (Luck, Jackson & Usher, 2006, p.105).

The present study utilises mixed methods as both qualitative and quantitative data are required to address the research questions. Johnson, Onwuegbuzie and Turner (2007) asked 31 leaders in the field of mixed methods research about their definition of mixed methods and defined it as:

> …the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection,

> analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration. (p.123)

It is this particular characteristic of mixed methods that advocates view as a strength and critics regard as a weakness, arguing that mixed methods research is no different to positivism (Howe, 2004; Giddings, 2006; Lichtman, 2013). Giddings (2006) claims that mixed methods research rarely comes from a subjectivist's view of the world, and that the qualitative segment is just 'fitted' into the 'descriptive' design. Symonds and Gorard (2008) argue that at times you can combine data from observations and interviews, and this could in some cases be better than using a combination of numerical data. Despite these criticisms, researchers within mixed methods research believe that by being restricted to one form of data, their research questions cannot be answered and has thus emerged due to its practical nature:

> Mixed methods research is "practical" in the sense that the researcher is free to use all methods possible to address a research problem… "practical" because individuals tend to solve problems using both number and word, combine inductive and deductive thinking…a preferred mode for understanding the world. (Creswell & Plano Clark, 2011, p.13)

Mixed methods research has been orientated by four worldviews known as postpositivism, constructivism, participatory, and pragmatism with each worldview differing in terms of ontology, epistemology, axiology and methodology (Creswell & Plano Clark, 2011). Ontological and epistemological beliefs within the postpositivist and constructivist (interpretivist) camps has preceded. Participatory researchers hold the ontological assumption of there being a political reality and that collaboration with participants has an effect on a researcher's epistemological, axiological, and methodological beliefs; whereas pragmatism holds an ontological position of singular or multiple realities, and the strong focus on practicality allows for the accommodation of both qualitative and quantitative epistemological, axiological, and methodological views

(Creswell & Plano Clark, 2011). Creswell and Plano Clark (2011) conclude that from the aforementioned traditions, mixed methods researchers have taken four stances with respect to their philosophical assumptions: stance 1, one best world view; stance 2, multiple world views; stance 3, multiple world views related to the mixed methods design; and stance 4, a worldview dependent on the scholarly community (see Denscombe, 2008). The researcher's position with respect to the present study is more inclined with Johnson and Onwuegbuzie's (2004) stance of there being one best world view by adopting pragmatism, however, with the acknowledgement of this view being an imperfect one. They believe that the philosophical assumptions in pragmatism is compatible with mixed methods research as it takes on the strengths of qualitative research, such as induction and discovery, and the strengths of quantitative research, including deduction and prediction, in a combined manner to best answer the research question.

4.3 OVERALL RESEARCH DESIGN

The overarching research question seeks to explain how Saudi EFL college students understand non-technical terms from their core chemistry textbook. This requires firstly to identify potential non-technical words in chemistry, and then to explain how these words are understood by Saudi EFL students. In essence, this is a two-step process, with one stage building into the other, and as such, a mixed methods sequential design is adopted for this case study. The two phases in this study seek to answer the overarching research question through several sub-questions. The first phase in the present study addresses the following research sub-question in the form of a corpus analysis:

- **RQA:** What non-technical words are there in the Saudi EFL college students' core chemistry textbook?

This builds into the second phase which involves semi-structured interviews to address the following research sub-questions:

- **RQB:** How familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words?
- **RQC:** To what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry?
- **RQD:** What is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?

Creswell and Plano Clark (2011) point to four areas that need to be determined when formulating a design in mixed methods research: the level of interaction between quantitative and qualitative strands, the priority of the quantitative and qualitative strands, the timing of the quantitative and qualitative strands, and where and how to mix the quantitative and qualitative strands. With all the possible decisions, there are many combinations of designs that could be made. There are several designs that are well established in mixed methods research: the convergent parallel design, the explanatory sequential design, the exploratory sequential design, the embedded design, the transformative design, and the multiphase design. Each one uses a combination of choices from within the four key decision-making areas (Creswell & Plano Clark, 2011). In a convergent parallel design, both the qualitative and quantitative strands are collected and analysed independently and concurrently with respect to the stage of the research; and the final interpretation draws together aspects which converge and diverge from the two data sets. Essentially, the convergent design gives equal importance to both strands, and thus mixing usually takes place after the analysis of both strands. In embedded designs, either qualitative data and analysis embeds within a quantitative strand, or vice-versa, to strengthen the overall strand. Transformative and multiphase designs could use any of the previously mentioned designs, but the former is for the purpose of promoting social justice, and the latter is for longitudinal studies which could span for a number of years.

Sequential designs could either begin with a qualitative strand building into a quantitative strand which is known as the exploratory sequential design, or a quantitative strand building into a qualitative strand, known as the explanatory sequential design (Creswell & Plano Clark, 2011). The present study adopts the explanatory sequential design which “implies collecting and analysing first quantitative and then qualitative data in two consecutive phases within one study” (Ivankova, Creswell & Stick, 2006, p.4). At the interface between the two strands, specific quantitative results warrant additional explanation and thus guiding the development of the qualitative strand. Subsequently, the qualitative data is collected and analysed in anticipation that it adds further insight into the quantitative data. For instance, Buck, Cook, Quigley, Eastwood & Lucas (2009) conducted a sequential explanatory mixed methods study to explore the position of African American girls from low socioeconomic status in terms of their attitudes toward science. They administered a 25-item questionnaire as part of the first phase, the quantitative strand, and created a profile to identify four kinds of students. This followed with the second phase where they conducted small group interviews (3/4 participants) consisting of each of the four profiled students.

FIGURE 4.1
Overall Research Design

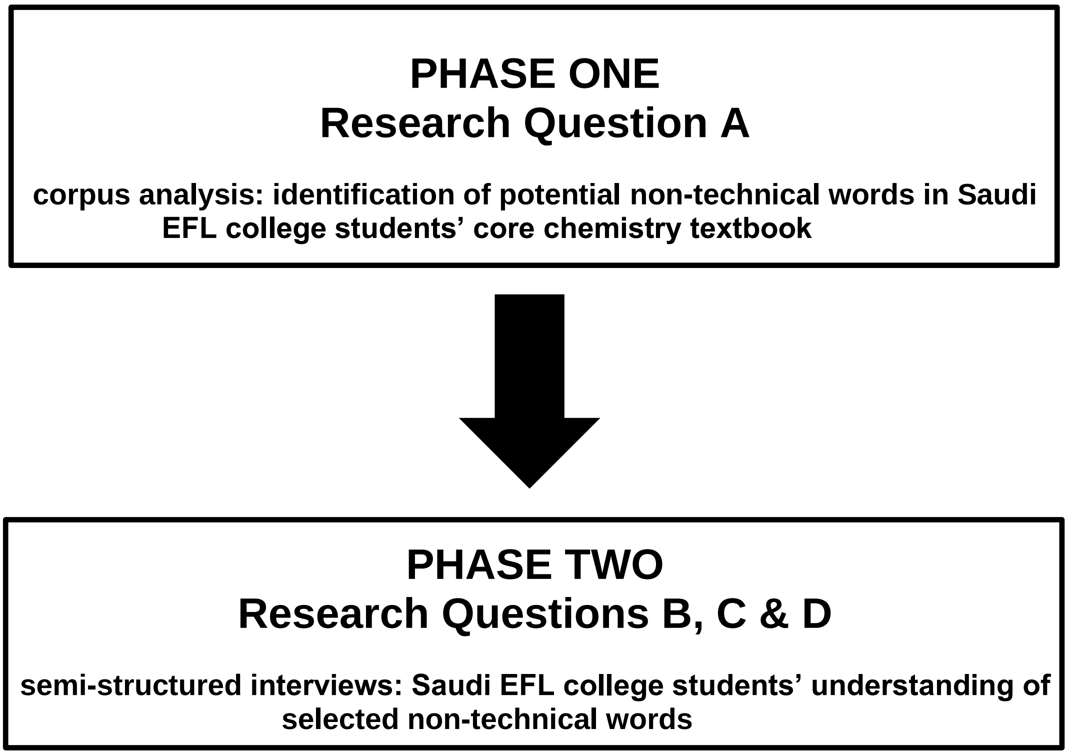


Figure 4.1 depicts the two phases of this explanatory sequential design. In order to identify potential non-technical words, a corpus analysis of the Saudi EFL students' chemistry textbook was carried out. One of the major characteristics of the corpus approach is that "we take the quantitative results generated from the corpus and the analyze them qualitatively" as intuition from an "expert user" of a language plays an important role (Bennett, 2010, p.7). "Functional interpretations of quantitative patterns" are given rather than simply reporting quantitative findings (Biber, Conrad & Reppen, 1998, p.5). As for the follow up second phase, interviewing was the main method employed to collect data qualitatively. The emphasis of the study does not necessarily need to be on the first phase. The priority can be given "to the qualitative data collection and analysis despite (it) being the second phase of the research process" as it should be "influenced by the purpose of the study" (Ivankova, Creswell & Stick, 2006, p.10). In this study the priority is given to the second phase as the

purpose is to better understand how Saudi EFL college students understand non-technical words, rather than a study focussing purely on non-technical words from a chemistry textbook. The next two sections expand on these two phases further.

4.4 PHASE ONE: CORPUS ANALYSIS

This section outlines the methods to address RQA (What non-technical words are there in the Saudi EFL college students' chemistry textbook?). The discussion begins with an overview of corpus linguistics - a method where the results are generated quantitatively (Bennett, 2010). This is followed by outlining significant aspects of corpus analysis, namely: collocation, colligation, semantic prosody and keyword analysis. The relevancy of these aspects is more evident in Chapter Five where they are referred to in the analysis, and this section discusses key issues and debates surrounding them. The research question requires an analysis of the Saudi EFL students' core textbook which is one IGCSE chemistry textbook, or corpus, for non-technical words. The methods available in corpus linguistics allow for the analysis of collocations from statistically selected keywords. A description of the procedures and the construction of the corpora follow.

4.4.1 Corpus Linguistics

Corpus linguistics assists in the study of large machine readable texts (corpora) in order to explore a theory (corpus-based), or even develop theories from the corpus itself (corpus-driven). This is achieved with the use of concordance programs that allow the researcher to analyse words in their context with the aid of statistical tools. This section highlights the dichotomy between corpus-driven and corpus-based research followed by the role of statistics, and the development of concordancers and English corpus linguistics.

Corpus linguistic researchers are largely classified as either corpus-based or corpus-driven researchers (Tognini-Bonelli, 2001). Corpus-driven researchers believe that the corpus itself has theoretical status, such that there is no distinction between the data (corpus) and the theory which arises as a result of the corpus. In contrast, corpus-based researchers, apply theories which were found independent of the corpus, and test these theories using the corpus. Baker (2006) explains the difference as one of deduction and induction:

> …[corpus-based] uses a corpus as source of examples, to check researcher intuition or to examine the frequency and/or plausibility of the language contained within a smaller data set. A corpus-driven analysis proceeds in a more inductive way – the corpus itself is the data and the patterns in it are noted as a way of expressing regularities (and exceptions) in language. (p.16)

So corpus-based can be viewed as top-down research and corpus-driven as bottom-up. Examples of corpus-based research include applying theories such as critical discourse analysis (Baker et al., 2008) or conceptual metaphor theory (Deignan, 2005) to the corpora. However, the distinction between corpus-based and corpus-driven is not always clear. McEnery and Hardie (2012) explain that a researcher could approach the corpus with a particular theory to be tested, but finds that the corpus is not in line with that particular theory. This would result in the corpus refining the theory, and hence the research now appears to lie between corpus-based and corpus-driven.

“Empiricism lies at the core of corpus linguistics, so its frequent recourse to statistical analysis is not surprising” (McEnery & Hardie, 2012, p.490). It is very common to find the use of descriptive analysis in corpus studies whereby statistics is used to describe the data rather than test for significance. One such way is by using frequency counts. In frequency counts, the target word is calculated as a simple percentage against the total number of running words. This will show how frequent the word is against all the other words in the corpus, and this can also be carried out with collocations. Studies which use significant tests for inferential statistics have commonly done so for purposes of keyword analysis and collocations. When calculating keywords, the software compares the corpus against a reference corpus to calculate if a particular word occurs more frequently than that of the reference corpus. With collocations, software such as Wordsmith Tools calculates how frequent the node (word under study) appears with other words concurrently (Scott, 1996). Software programs have made it easy for linguistics who are not proficient in statistics as these complex calculations are performed instantly.

One of the most powerful tools used for analysis in corpus linguistics is a concordancer. This tool makes it possible to search for specific words in a corpus and all the entries appear as a list showing both the words which come before and after the target word. Concordancers are not limited to words as searches could be made for phrases, idioms, or any part of a word such as prefixes. Moreover, as some corpora are annotated, for example with speech tags, a search can be conducted according to the desired speech tag like nouns or auxiliary verbs. Such searches would be almost impossible to do without the use of a concordancer due to the amount of time this tool reduces in searching through a corpus. The idea of concordance dates back to the 13th century when it was conducted by hand as Hugh of St Cher compiled a concordance for a Latin Bible in 1230; while acknowledgment of the first machine readable concordance is given to Roberto Busa in 1951 (McEnery & Hardie, 2012). In the early years of concordance, usage of it was carried out at specific sites, but in the era where personal computers became readily available, access to concordancers was made easier due to relevant software such as the Kaye concordancer (Kaye, 1990). The invention of Unicode made the task for concordance software writers easier as they no longer needed to adapt their packages for different writing scripts. Several popular concordance software programs were also developed during this time such as Wordsmith (Scott, 1996) and Xaira. Software of this generation is similar in terms of the tools available which were essentially generating concordances, producing frequency lists and keyword analysis, and showing collocations. More recent corpus software has shifted towards making programs available on the Internet, such as the BNCweb (British National Corpus – Web) (Hoffman, Evert, Smith, Lee & Prytz, 2008). This way the user no longer needs to update their software, or computer, as this is done by the software. Development in concordance software will continue to be challenging as updating corpus tools requires a combined knowledge of both corpus linguistics and computer programming.

The Survey of English Usage (SEU) was one of the first corpora in use for modern day English and assisted in the development of other corpora such as the British National Corpus (BNC) and American National Corpus (Ide & Reppen, 2004). Many leading UK universities have produced other well established corpora and have significantly developed corpus linguistics. Researchers at University College London (UCL) constructed the International Corpus of English (ICE) which consists of a variety of Englishes such as Indian and Australian English (Greenbaum, 1996). Researchers in Lancaster University have played a significant role in the annotation aspect of corpus linguistics, for instance, the development of part-of-speech tags (POS) (Garside, Leech & McEnery, 1997). Due to their collaborative work with computer scientists, the lengthy process of POS tags for large corpora was possible to do on a large scale as they were easily able to tag words as nouns, verbs and so on with the assistance of a computer rather than doing it manually. John Sinclair contributed much towards the development of the ‘lexical grammar’ approach whereby the meaning of a word and its grammar are strongly connected (Sinclair, 1991). Sinclair gave great emphasis to collocations in corpus linguistics and it led to a new dictionary being published by Collins in addition to a monitor corpus named Bank of English which is in continuous growth (Hanks, 2009).

University of Nottingham has contributed much to the development of studies which focus on the grammatical differences between speech and writing, and this assisted in the development of the Multi-Modal Corpus (McEnery & Hardie, 2012). Leech (1998) listed several differences between speech and writing other than the obvious visual and aural difference. For example, he said that speech takes place in a shared context which can be noted by the high usage of personal pronouns; it avoids elaboration as the lexical density is kept minimal; and speech occurs in real time. But of course this dichotomy between speech and writing is not the only variation that exists as texts could vary with respect to genre. American researcher Douglas Biber in his proposal of the multi-dimensional approach took on a more comprehensive approach by looking at a vast range of linguistics features to differentiate between texts. One of his findings was that texts which have many past tense verbs also have many third person pronouns (McEnery & Hardie, 2012). The important point to note is that variations amongst corpora are quite complex and care needs to be taken when deducing meaning from them.

4.4.2 Collocation

In corpus linguistics, the study of collocations is at the root of many studies. Researchers search for common co-occurrences between words and attempt to gain understanding into the implications of the collocation. The word span of a collocation could range from as few as two words (Harris, 2006), to as many as eight words (Mahlberg, 2007), or no more than a sentence Greenbaum (1974). The use of collocations dates back to the eighteenth century with Alexander Cruden's concordance of the bible (Kennedy, 1998), although, its use in contemporary corpus linguistics is attributed to John Firth (1957). Firth and those that followed him such as the prominent corpus linguistic researcher Sinclair, strongly believe that meaning comes about due to how a word collocates with other words rather than through the meaning of individual words. For this reason, they have placed central importance on the use of collocations in analysing corpora. Prior to the development of modern technology, collocations were studied by researchers' intuition as Greenbaum (1974) justifies:

> …collocation is more than a statistical matter: it has a psycho- logical correlate, and I have suggested that earlier by talking about expectancy. We know that items are collocated just as we know that one sequence of items is part of our language and another is not. Both constitute knowledge that speakers have of their language. Of course it would be surprising if there are instances where people disagree on collocations: they sometimes disagree on whether certain sequences are part of language. And just as we recognize degrees of acceptability (some sequences seem more obviously all right than others), so we can recognize degrees collocation (some cooccurrences seem more frequent than others). We therefore consult our own knowledge of the language, particularly obvious cases of collocation… (p.83)

Identifying collocations using pure intuition may work for 'obvious cases', however, language is not static and therefore we cannot always rely on our intuition. For this reason, statistical significant tests can be employed to identify highly probable collocations as these tests would make calculations for the frequency of the co-occurrence of words (Krishnamurthy, 2000). Kilgarriff (2005) provided experimental evidence to demonstrate that such significant tests cannot be used as language is non-random, yet, statistical tests assume randomness. To highlight this, a simple comparison of the log-likelihood measure and the mutual information measure in the British National Corpus reveals inconsistent results as the top collocates for cheese did not match, with the former test listing bread, cream and grated, and the latter listing “feta, ricotta, parmesan and mozzarella” (McEnery & Hardie, 2012, p.128). Stubbs (2001) provides a typology for data in this respect where the corpus itself is referred to as first order data, followed by the concordance program as second order, and the third order being data derived from statistical analyses. He stresses that intuition has priority over third order data as infrequent collocations could be missed out. In either case, whether relying on statistical analyses or not, the end result would be the use of intuition in determining whether or not the collocation is in reality a real collocation. It seems that a combination of statistical analyses and the use of intuition would ensure identification of relevant collocations.

4.4.3 Colligation

The manner in which meaning is construed from a collocation differs amongst the community of corpus researchers from a number of aspects. One of the well-established branches is that of colligation, and it was coined by Firth (1957). It is viewed as a type of collocation, especially if we view lexis and grammar to be indistinguishable to the extent that they are dependent on each other (Hunston, 2001). Even so, colligation lies closer to grammar than lexis and can thus lead to a better understanding of grammar. By analysing common grammatical patterns in a given text, polysemous words can be better understood as the differences between the senses for a particular word become more evident. Hunston (2001) found that the word ‘downside’ appears 856 times in the Bank of English corpus and the most frequent meaning is ‘disadvantage’, but it is also used for financial explanations. Statistically frequent collocations to both the left and right of ‘downside’ were found to be: the + downside (456 occurrences), the + downside + of (154 occurrences), on + the + downside (105 occurrences), and the + downside + is + that (61 occurrences). Taking the example of On + the + downside, 47 occurrences were related to a financial meaning and the remaining 58 had a meaning connected to disadvantage. From the 58 occurrences, 44 of them appeared in the beginning of a sentence with a capital letter of which 24 initiated a new paragraph. All these 24 instances showed a pattern of positive evaluation, followed by a new paragraph (indicated by <p>) which had a negative evaluation, as shown in these examples:

> The gearbox is smooth, the clutch and power steering delightfully light. <p> *On the downside*, the car retains its predecessor’s limited rear legroom and the cabin’s slightly cramped feel.
>
> “The political correctness lobby has made people stop and think a lot more about what they say and its implications.” <p> *On the downside*, “some people are obsessed with PC to the point that it’s not clear whether their obsession is not a joke.”
>
> The focus will fall on family matters, with many Librans intent on creating a cosy and contented atmosphere in the home. <p> *On the downside*, there could be concerns about a partner’s well-being or restrictions due to lack of cash. (Hunston, 2001, p.17)

It was through colligation that such a finding could be established as it is indicative of a phrase’s preference and associated meaning. As another example, the word ‘seem’ has several meanings, but when the pattern of can + seem is used, the word is often followed by something negative:

the toe followed by a tap, say — can seem beyond you. It's a bit…
alone The first days at home can seem rather daunting without the…
hoice of complementary therapies can seem bewildering, so here is…
In an orchestral context they can seem rather drab but in…
rate of 10 per cent a month, it can seem unwieldy and unmanageable.
released from it. As people they can seem unapproachable. Think…
a fortnight or month. This can seem like an eternity if you are feel…
(Hunston, 2001, p.23)

In these examples, after can + seem, negative words like daunting, drab and unapproachable also exemplify this negative prosody.

4.4.4 Semantic Prosody

A well-established branch of collocation studies within corpus linguistics is that of semantic prosody as proposed by Louw (1993). In this branch of collocational study, researchers explore the possibilities of connotations due to co-occurrence of words. It is the frequency of the collocation found in the concordances, as opposed to intuition, that leads to judging if a particular lemma has a positive or negative connotation. A lemma is "a group of word forms that are related by being inflectional forms of the same base word" (McEnery & Hardie, 2012, p.245). Lemmas are deemed to be favourable or unfavourable, not necessarily due to the inherent meaning of the item, but because of their usage within a given context. A particular word occurs in such contexts as a language user has set mental rules which serve as a criterion as to how a word should collocate (Partington, 2004). Partington (2004) explored prosodies associated with the terms 'happen' and 'set in', and other words synonymously related to them like 'occur', 'come about' and 'take place'. He used two corpora, one was constructed from academic texts and the other was a corpus of newspaper texts. It was the frequency of examples that led him to conclude whether or not a word has a favourable or unfavourable prosody attached to it. With the word 'happened', 24 of the 50 examples were unfavourable prosodies as in the example: **"**She then went to bed feeling more relaxed, but after a while felt unwell and was soon sick. This happened several times during the night." (Partington, 2004, p.136). Whereas with the words 'come about', there was little evidence from which one could conclude that there is a favourable or unfavourable inclination.

The distinction between 'semantic prosody' and 'semantic preference' remains problematic, as the latter also is related to the study of semantic collocations, though, McEnery and Hardie (2012) clarify:

> …semantic preference links the node to some word in its context drawn from a particular semantic field, whereas semantic prosody links the node to some expression of attitude or evaluation which may not be a single word, but may be given in the wide context. (p.138)

This implies that semantic preference is limited to the study of collocations, whereas semantic prosody is much broader and related to attitude and evaluation. There is no doubt that there is some overlap between the two, and so the issue lies in whether semantic prosody is a subset of semantic preference, or vice versa. Partington (2004) believes that semantic preference is not as broad as semantic prosody, and the former builds into the latter, as he succinctly clarifies:

> …semantic preference is a "narrower" phenomenon – relating the node item to another item from a particular semantic set – than prosody which can affect wider stretches of text…the former, preference, contributes powerfully to building the latter, prosody; conversely, the latter dictates the general environment which constrains the preferential choices of the node item. (p.151)

This can be illustrated with the word 'undergo'. Stubbs (2001) found that it frequently collocates to the right in the semantic field of medicine (e.g. treatment) and tests (e.g. examinations), and it collocates to the left with words which belong to the semantic field of involuntariness (e.g. forced to). These semantic field collocations lead to an overall negative prosody for the word undergo as it is undesirable to do actions without choice and to go through treatment. In the case of ‘undergo’, it is its semantic preference that led to concluding its unfavourable prosody.

In essence, semantic prosody is exclusively a collocation study of connotations, and does have its limitations. Semantic prosody is a subjective matter as when judging whether or not a collocation is positive or negative, or attaching some kind of attitude to the meaning associated with the collocation rests on an observer’s view of the collocation and thus lacks consensual value. Furthermore, critics of semantic prosody argue that Louw’s idea of such collocations causing words to change meaning in other contexts cannot be proved by using corpora from contemporary English (Whitsitt, 2005). A discovery of a semantic prosody does not indicate universal usage, as in other contexts the potential semantic prosody may not carry the same meaning. Hunston (2007) also acknowledges this criticism, and elaborates on this issue. She took the example of the word ‘cause’ from the Bank of English corpus:

> 1 a real downer of a word, likely to cause a lot of confusion. After
> 2 until I told her. What I did has caused a rift between me and my friend’
> 3 nd. His decision to oppose the war caused amazement in the ranks…
> 4 quality in the borough”. The award caused anger among anti-racist
> 5 of new media outlets and choice, causing audience fragmentation. To
> 6 een suffering from a kidney stone, caused by excess build-up of urine.
> 7 s chronic unemployment problem is caused by featherbedding workers
> 8 de, Isle of Wight, last June which caused damage estimated at
> 9 in some carrots could cause dizziness and vomiting, but said
> 10 control fairly rapidly. Hepatitis causes inflammation of the liver…
>
> (Hunston, 2007, p.251)

In these examples, ‘cause’ collocates with something undesirable such as ‘confusion’ (line 1), ‘kidney stone’ (line 6), ‘damage’ (line 8) and ‘inflammation’ (line 10). From this, one could be tempted to conclude that collocations of ‘cause’ are associated with negative undesirable experiences. Though, when Hunston (2004) extracted several examples from the journal New Scientist, the supposedly undesirable association of cause was not found:

1. They [researchers] also searched for a second group of molecules called desensitisation proteins, which temporarily stop the receptor cells from responding to an odour. These proteins cause a smell to become less strong if we continue to sniff at it. The keys to the researchers' success were antibodies which recognise …
2. When mounted a few micrometres above a chip, the probe and circuit form a capacitor. Any AC signal flowing beneath the probe causes a displacement current to flow through this capacitor. The value of this current changes depending on the amplitude and phase of the AC signal, enabling the signal to be imaged.
3. If signals are seen, how will we be certain that they are caused by dark matter particles? One way of finding out would be …
4. Whatever their views about the causes of the more mysterious amphibian declines, herpetologists agree about one thing: the chief practical problem is distinguishing genuine, long-term changes in population trends from fluctuations caused by short-term variations in weather.
5. The astronomers found that a part of the absorption spectrum called the Lyman alpha line … had been red-shifted by a factor of 3.390 so that it appeared at visible wavelengths. They knew that this Lyman alpha line was caused by a galaxy because it matched the equivalent line in a faint, visible galaxy near to the quasar. (Hunston, 2007, p.252)

The examples from New Scientist are neither desirable nor undesirable as they are simply providing factual information, such as desensitisation proteins causing a smell to become less strong (line 1). From this comparison, we can affirm that collocations of cause cannot be attributed to something which is undesirable unrestrictedly, as in part, it depends on the corpus from which we are drawing are conclusions from. Hunston (2007) suggests that this could indicate that when cause is used with humans, it is associated with negativity, but not in cases where it is used with inanimate objects, as in the examples from New Scientist. In other words, such deductions of collocations can serve as an indication of what the norm is. On the other hand, some semantic prosodies have strong predictability:

wood' (VSB 168) - and abundant to the point of extravagance (VSB 167).
s supposed to be puritanical to the point of ingenuousness, is obviously v
Rushdie, for one). Convoluted to the point of dislocation - there are stori
Willie's subjects are laconic to the point of silence; there are interviews
in these years was hermetic to the point of solipsism — a stance of icy
labourer and sus-picious to the point of paranoia. <p> By extraordinar
to its old self, precious to the point of self-parody, a magnet for

professional manner was strict to the point of severity. She brought crystal
(Hunston, 2007, p.261)

She explains that ‘to the point of’ links a ‘less saturated evaluative item’ to one which is more saturated (Hunston, 2007). For instance, the fourth example has the word ‘laconic’, and it is linked to silence, as in one who says not only a few words, but almost no words.

So when weighing out the nature of the semantic prosody, it can be dealt with by differentiating between explanatory and predictive uses of semantic prosody, as caution needs to be taken when making claims for generalised usage of semantic prosodies. Whether studying collocations specifically for semantic prosody or colligation, it is clear that the objective is to find the preferences of words and deduce the meaning they construe due to their preferences and the evidence of any claim relies upon the frequency of such occurrences.

4.4.5 Keyword Analysis

When there is a significant difference between the frequency of a word in a study corpus compared to that of a reference corpus, then such a word would be considered as a keyword; and words which have a similar percentage between the study corpus and the reference corpus are therefore not keywords. This is not to be confused with ‘key word’ (with a space between the words) which is a general word for a word under study, rather such words should be named as KWIC (key words in context) (McEnery & Hardie, 2012). Scott (1997) explains that “the important point to grasp is that the notion underlying it [keywords] is one of outstandingness. In other words, if a word occurs outstandingly frequently…it will be the key” (p.236).

Simple frequency lists are not as useful as keywords when analysing words which are representative of a given text. One reason is that in simple frequency lists, the high ranked words are often not of interest to the researcher as they may be too common to be distinguished as a keyword; also, variants of words which are from the same lemma are not counted as one (Baron, Rayson & Archer, 2009). Keywords are somewhat different to collocations as collocations are limited to concordance lines, whereas keywords can potentially find associations through whole texts. Scott (1997) analysed keywords in featured stories which appeared between 1992 and 1994 in the Guardian. The Guardian was also used as a reference corpus containing approximately 70 million words. The keywords were then used by referring back to the files which contained the concerned keywords, and a further keyword analysis was taken with these particular files. The word 'women' was one of the keywords found in the initial analysis of the complete sample corpus. This word appeared in 258 files, and so these files were analysed for keywords. For example, the word 'mother' appeared in 19 of the 258 files. The list contained words which related to traditional roles of women, as in the word mother, though there were other words such as 'work' and 'rights' which shows the changing role of women in society.

It can be appreciated that such findings are not likely to be revealed through collocations as the analysis is limited to a few words span to the left and right of the concerned word. Whereas in this analysis, the keyword shows association to other words through whole texts, whether that be a distance of a sentence, or one or several paragraphs. The researcher can continue to clump words together that frequently appear in the same text and from this, plausible explanations can be deduced from these grouped words. Moreover, such clumping can also serve as an indication of words which may be synonymous to another due to the frequent co-occurrence of words in whole texts. It may seem that the list of the keywords is largely dependent on the reference corpus used, as not all corpora are the same. This may be true to a certain extent, especially with corpora which focuses on a particular subject. However, studies have found that with respect to general English corpora, such as the BNC and Bank of English corpus, similar keywords would still be extracted from the study corpus no matter what reputable reference corpus is used (see for examples: Berber-Sardinha, 2000; Goh, 2011). As texts vary in nature, it is the keywords contained within them that give them their uniqueness, and so it is probable that such keywords would be identified against any large general English reference corpora.

Keyword analysis in itself does provide great insights into the nature of the studied corpus; though, much more could be learnt about the corpus by combining this analysis with collocation analysis. Baker (2006) made corpora based on a parliamentary debate about fox-hunting. One file was made that contained transcripts of those who were against such hunting practices, and a second file contained transcripts of the opposing party. He began by comparing the two files with one another in order to extract the keywords from each side of the debate. One of the surprising findings from the keyword analysis was that the word ‘criminal’ was used by the pro-hunters 38 times, whereas the anti-hunters only used this word twice. One would expect the opposite to be the case, and any further analysis through the use of keyword analysis would not provide greater insights into this matter. Therefore, Baker (2006) resorted to concordancing to look at the associated collocations of the word criminal (see Table 4.1).

The concordances show that the word criminal is being used in the sense of making the banning of fox-hunting as a discriminatory act which is unfair to people in general and not just to those who are supportive of fox-hunting. Baker (2006) referred to the BNC to see if there were any prosodies attached to the words which collocated with the node criminal. From this search, it was found that the lemma ‘impose’ (see lines 9 and 10 in Table 4.1) collocated with negative words such as ‘impose restrictions’. This finding provided a deeper understanding as the pro-hunters collocated the node criminal with impose to show their disapproval of making fox-hunters appear as criminals. It was the keyword analysis that narrowed down the words which would be of particular interest for further study, but it was the study of collocations that allowed the findings to be better understood.

TABLE 4.1

Concordance Lines for Criminal

1	ack Benches. The Bill will turn into a	criminal	offence an activity now lawfully enjoyed by a
2	be particularly wrong to invoke the	criminal	law against people in my constituency who t
3	be found so to do. It is the use of the	criminal	law that would most appeal me. I shall not have
4	eman to say that the invocation of the	criminal	law in these circumstances is somehow akin t
5	Mr. Garnier: We are extending the	criminal	law. Does my hon. Friend think it in the least
6	he reason we do not normally use the	criminal	law in areas of this kind. Of course, we use t
7	sued by the new authority would be a	criminal	act attracting a fine of up to £5,000. The auth
8	his view, it should not be part of the	criminal	law. My hon. Friend the Member for North
9	ny law that we might pass. Imposing	criminal	sanctions on anybody is a serious matter. The
10	like to address the issue of imposing	criminal	sanctions on people who transgress any law t

Note: From Baker (2006, p.3).

4.4.6 Data Analysis Procedures

This section outlines the procedures for collecting and analysing the data in the corpus phase of this study. The previous few sections explored key issues which have informed the decisions that needed to be made when preparing and analysing the corpus. Firstly, the present study is corpus-based and not corpus-driven primarily due to the corpora being constructed for the purpose of identifying non-technical words in chemistry. This focal point was not derived from the corpus itself and therefore cannot be considered as corpus-driven. Secondly, the non-technical words were identified from a keyword list as opposed to a frequency word list as keyword lists are more representative of a corpus (see section 4.4.5). Like many of the studies cited in this corpus section of the thesis, a well-known corpus software, WordSmith Tools, was used. This software program was also chosen because of its accessibility and suitability in terms of having all the necessary tools to conduct the analysis for this study. The identified non-technical words were analysed in the concordances for collocational and colligational patterns (see sections 4.4.2 & 4.4.3), as well as for any possible semantic prosody (see section 4.4.4). For instance, the prosodic nature of the everyday use of a given non-technical word was imposed on the concordances in the corpus to see if such connotations were plausible.

4.4.6.1 Description of the Textbook

The students' core chemistry book is an IGCSE chemistry textbook published by Cambridge University Press and endorsed by Cambridge International Examinations (Harwood & Lodge, 2014). This is the same book that the students used for their chemistry course. This textbook is the fourth edition, and even at the time of writing, there was no fifth edition published. It is widely available in Saudi Arabia in many of the well-known bookshops such as Jarir Bookstore and Obeikan. The textbook consists of twelve main chapters, each of which is divided into further subsections (Table 4.2 provides further details regarding the subtopics in each chapter). This is a comprehensive textbook as it covers the whole IGCSE chemistry syllabus and within each chapter, other than the main body of text, there are several features. Each chapter contains questions related to the reading text in general, and the end of chapter questions are taken from IGCSE chemistry past paper questions. The textbook also contains numerous pictures, diagrams and study tips to assist students studying the large amount of text. Additionally, as this is a chemistry textbook, there are references to practical activities which require the accompanying CD-ROM since worksheets are needed for these experiments. Towards the end of the book there is a glossary of key terms with definitions.

TABLE 4.2
Chemistry Textbook Topics & Subtopics

Chemistry Topic	Related Subtopics
Planet Earth	**Nature cycles and resources** **The atmosphere** **Seas and rivers** **The Earth's crust**
The nature of matter	**The states of matter** **Separating and purifying substances** **Atoms and molecules** **The structure of an atom** **Electron arrangements in atoms**
Elements and compounds	**The periodic table - classifying the elements** **Trends in groups** **Trends across a period** **Chemical bonding in elements and compounds** **The chemical formulae of elements and compounds** **Metals, alloys and crystals**
Chemical reactions	**Chemical reactions** **Equations for chemical reactions** **Types of chemical reaction** **A closer look at reactions, particularly redox reactions** **Electrolysis** **A closer look at electrode reactions**
Acids, bases and salts	**What is an acid?** **Acid and alkali solutions** **Metal oxides and non - metal oxides** **Acid reactions in everyday life** **Alkalis and bases** **Characteristic reactions of acids** **Acids and alkalis in chemical analysis** **Salts** **Preparing soluble salts** **Preparing insoluble salts** **Strong and weak acids and alkalis**
Quantitative chemistry	**Chemical analysis and formulae** **The mole and chemical formulae** **The mole and chemical equations**

	Calculations involving gases **Moles and solution chemistry**
How far? How fast?	**Energy changes in chemical reactions** **Rates of reaction** **Catalysts** **Photochemical reactions** **Reversible reactions and chemical equilibria**
Patterns and properties of metals	**The alkali metals** **Aluminium** **The transition elements** **The reactivity of metals** **Electrical cells and energy**
Industrial inorganic chemistry	**The extraction of metals by carbon reduction** **The extraction of metals by electrolysis** **Ammonia and fertilisers** **Sulfur and sulphuric acid** **The chlor-alkali industry** **Limestone** **The economics of the chemical industry**
Organic chemistry	**The unique properties of carbon** **Alkanes** **Alkenes** **Hydrocarbon structure and isomerism** **Chemical reaction of alkanes** **Chemical reactions of alkenes** **Alcohols** **The reaction of ethanol** **Organic acids and esters**
Petrochemicals and polymers	**Petroleum** **Alternative fuels and energy sources** **Addition polymerisation** **Condensation polymerisation**
Chemical analysis and investigation	**Inorganic analysis** **Organic analysis** **Experimental design and investigation** **Practical examinations**

Note: Adapted from Harwood and Lodge (2014, pp. iii-iv)

4.4.6.2 Construction of the Corpora

Twelve corpora were made from the text of the students’ core chemistry textbook. In the process of preparing the raw text, I decided to exclude certain features which I judged as not being part of the core text as these parts did not explain the actual science. For example, certain features within the chapters were considered as instructional for the purpose of guiding the reader to other supplementary material on the course CD. I had to also exclude text which could not be considered as sentences, and this includes the text under the figures. As the keyword analysis was based on non-technical words, I also excluded any chemical equations (shown with chemical symbols). In essence, any text which was considered to be diverging from the main coherent scientific explanatory part of the text was omitted and this extended to the end of chapter questions and appendices.

A decision was made as to the preference of having one chemistry corpus for the whole textbook, or to have a corpus which represented each chapter of the textbook. As can be seen in Table 4.2 the content of each chapter varies considerably, though, no doubt there is some overlap too in some areas. Industrial chemistry, chapter 9, is not the same as the topic of Acids, Bases and Salts, chapter 5. The former contains information which is specialised for specific industrial processes such as the production of iron in a blast furnace, and the latter has information about more general acid – base reactions. There is inevitably some overlap in the chemistry learnt in earlier chapters with those that come later, for instance, the concept of alkanes and alkenes in chapter 10, Organic Chemistry, would contain information from chapter 3, Elements and Compounds, since the concept of covalent bonding in chapter 3 is pertinent to chapter 10. Therefore, I decided to have a corpus for each chapter rather than one chemistry corpus for all chapters as each chapter should be considered separately due to its distinct chemical knowledge. This led to the construction of 12 separate hand typed plain text files (one for each chapter) for analysis purposes.

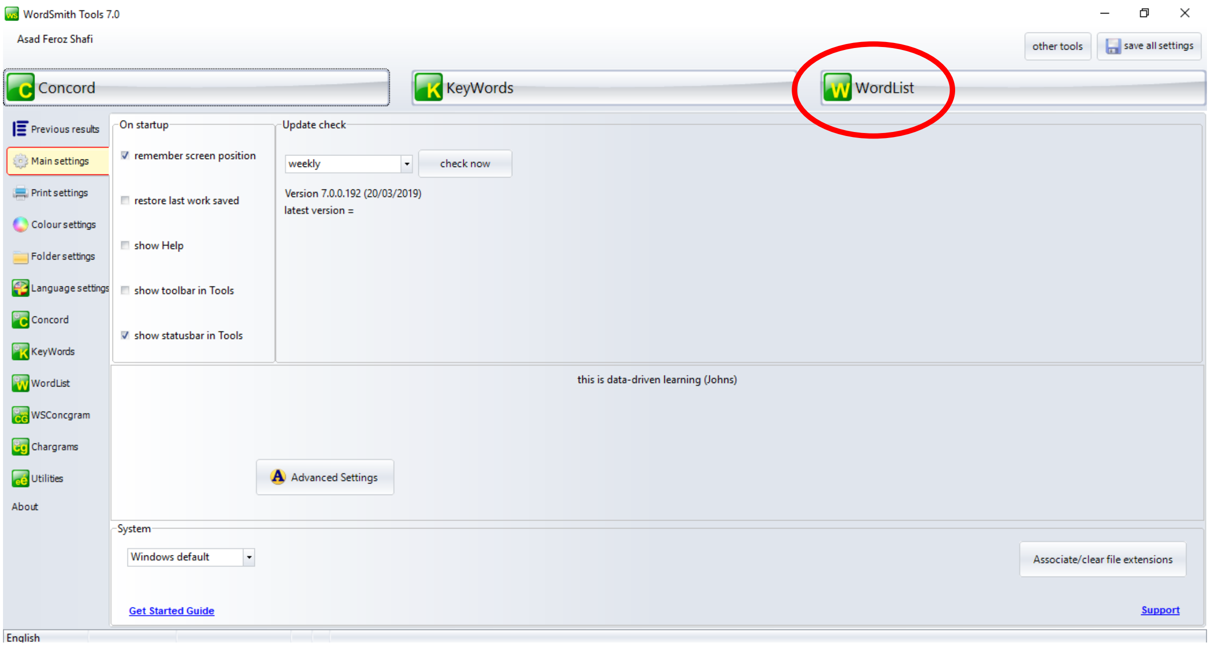
4.4.6.3 Production of Keyword Lists

After the preparation of the 12 plain text files for the chemistry corpus, two main stages were followed which led to the production of 12 keyword lists (see Figure 4.2 for screenshots of these steps). The first step requires the raw text data to be converted into a frequency word list. In the second step, the frequency word list is compared with a frequency word list from a reference corpus. The condition for selecting a reference corpus in the WordSmith program is that the study corpus must be smaller than the reference corpus. Wordsmith compares the frequent words from the corpus with that of the reference corpus and informs the user about the words that are found to have a significant difference in terms of its uniqueness. The British National Corpus, provided by the software company, WordSmith Tools, was used as the reference corpus. Regardless, some studies show that using other reputable general English reference corpora makes little difference to the final keyword list (see section 4.4.5). In essence, a corpus which is representative of the Saudi EFL college students' chemistry textbook was compared to a general English corpus, British National Corpus, in order to find keywords, which are words that appear in the study corpus at a higher frequency than the reference corpus.

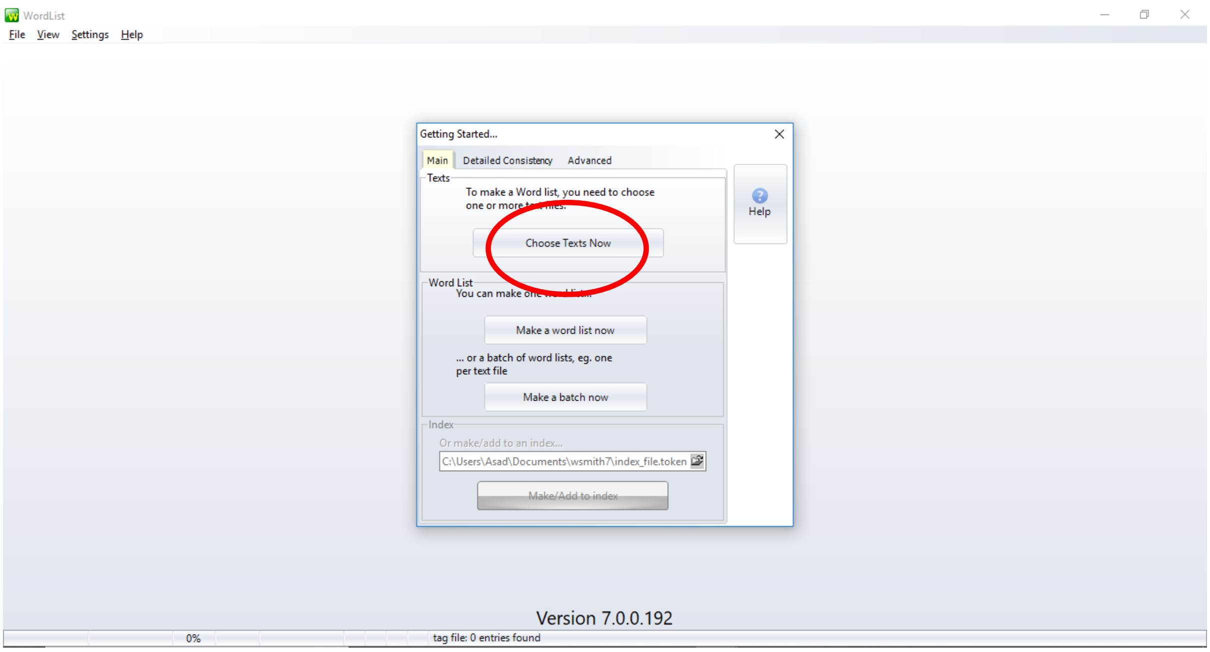
In a corpus there are many high frequency words compared to low frequency words and thus the distribution is skewed. For this reason, log-likelihood tests, rather than chi-square tests, are used to determine the probability of the instance being significant as "the chi-square test presupposes a so-called normal distribution of the data" whereas "the log-likelihood test…is now preferred by some corpus linguists as it makes no assumption of a normal distribution" (McEnery & Hardie, 2012, pp.51-52). Scott (2015) suggests using the minimum p-value ($p < 0.0000001$) to produce the keywords list as the purpose of a keyword list is to narrow down words which would be of interest. Therefore, for the present study, the default, and recommended, settings for the production of keywords on WordSmith Tools was used. This procedure was repeated for each textbook chapter, effectively producing 12 Keyword Lists (Appendix 2).

FIGURE 4.2
Screenshots of Production of Word Lists Using WordSmith

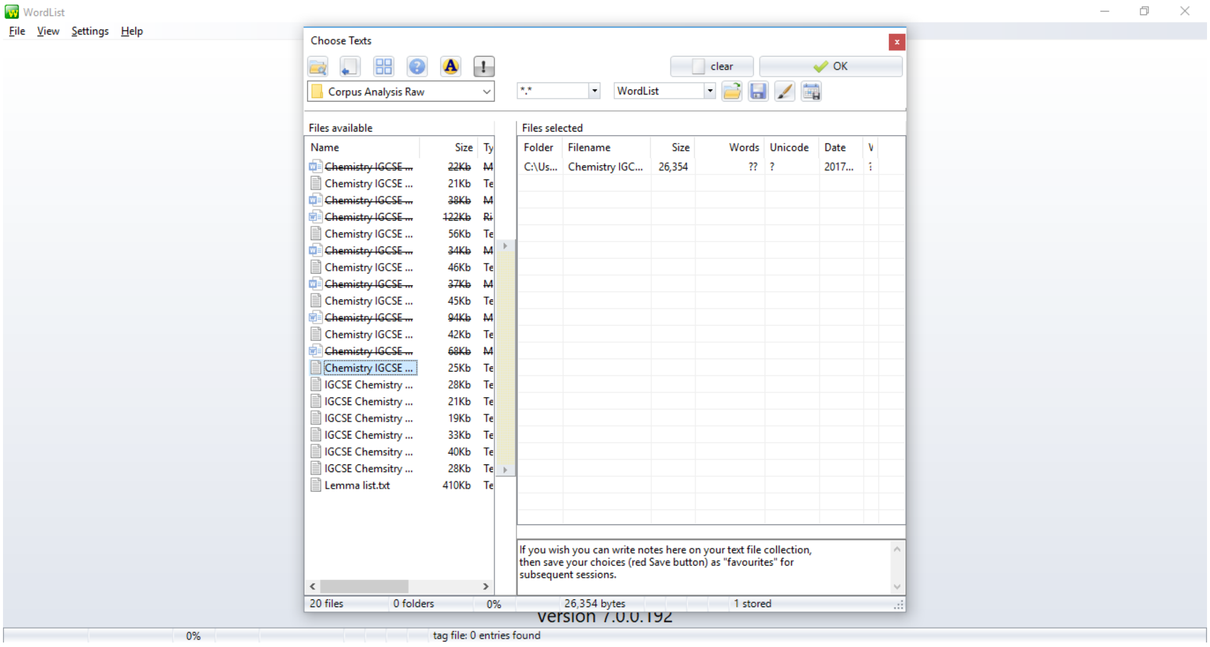
Step 1A: select ‘WordList’



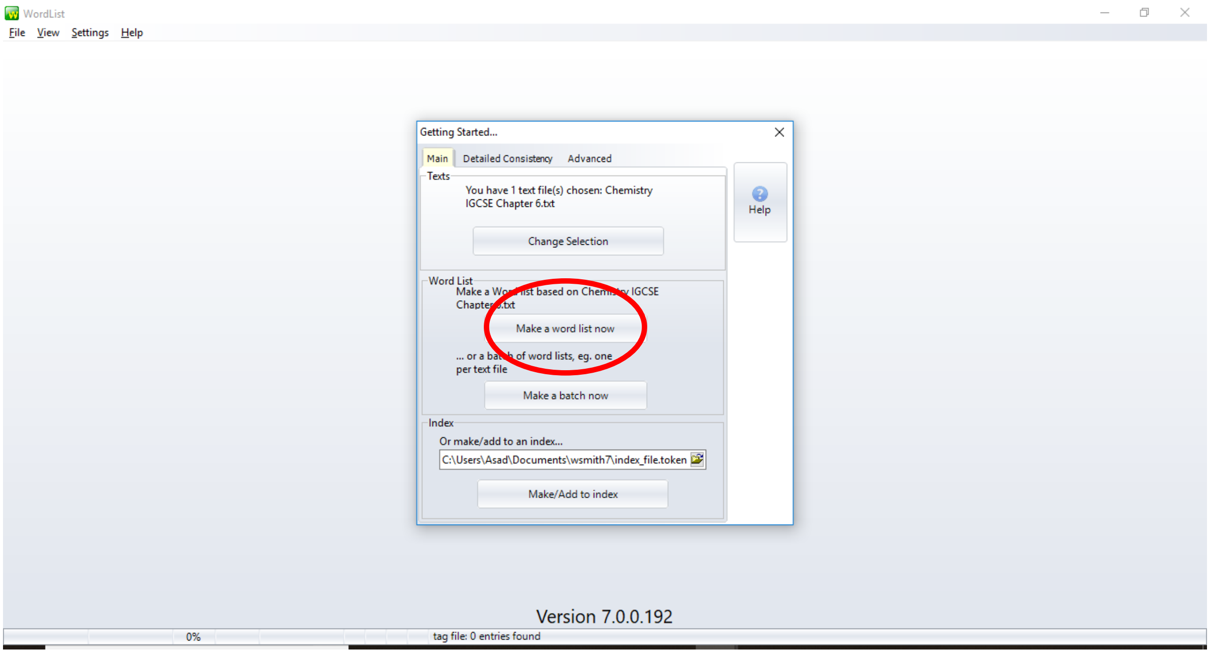
Step 1B: select File, New, then ‘choose texts now’



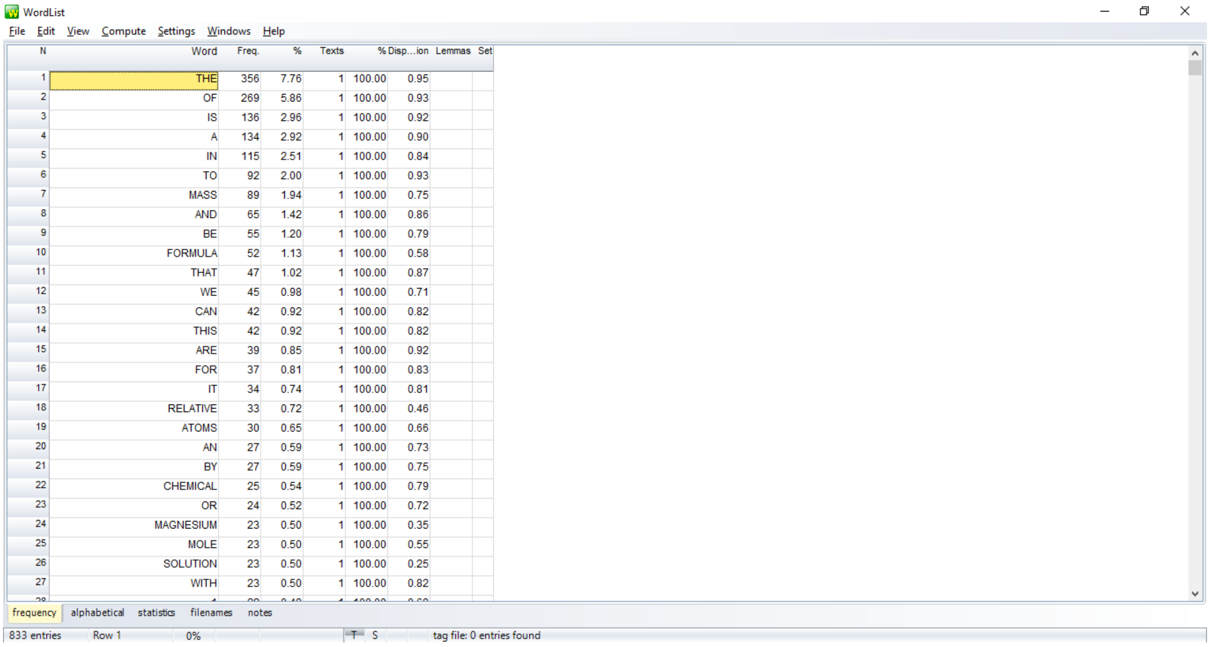
Step 1C: choose Raw Text File and drag over, then click OK



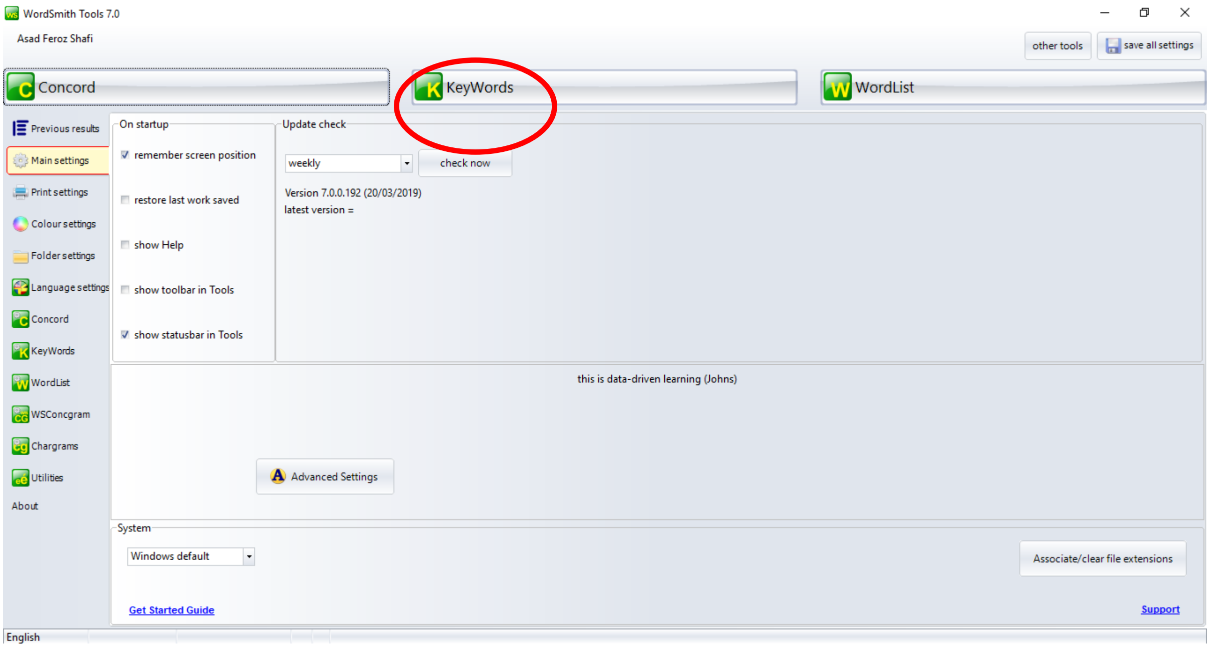
Step 1D: select 'Make a word list now'



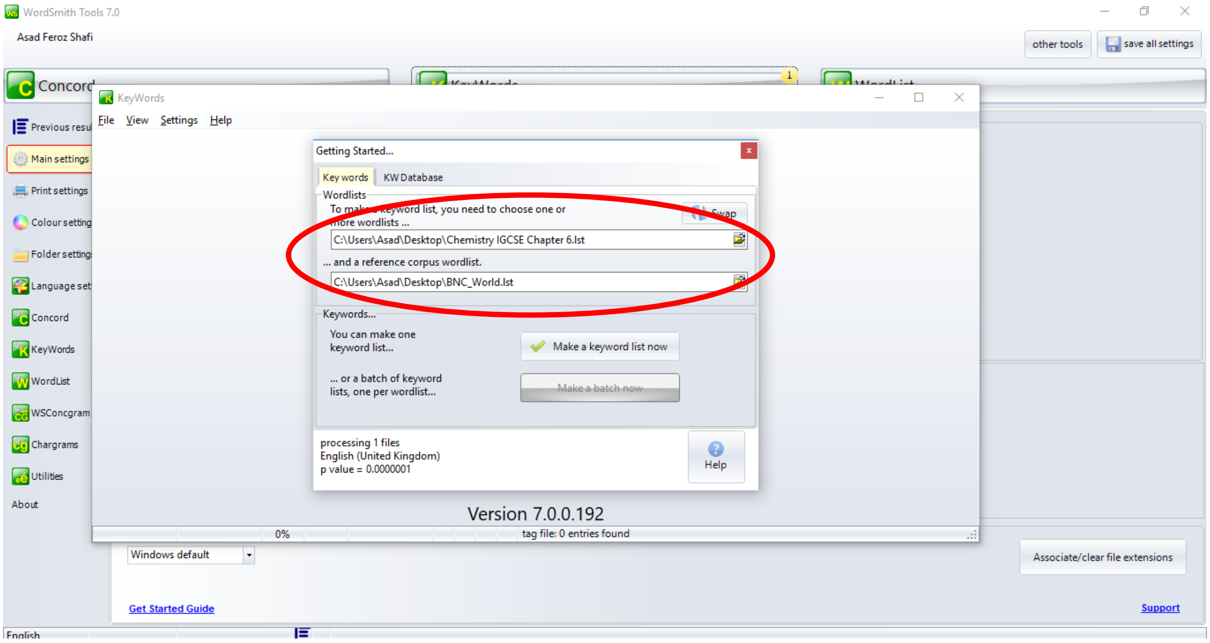
Step 1E: save ‘WorldList’ file



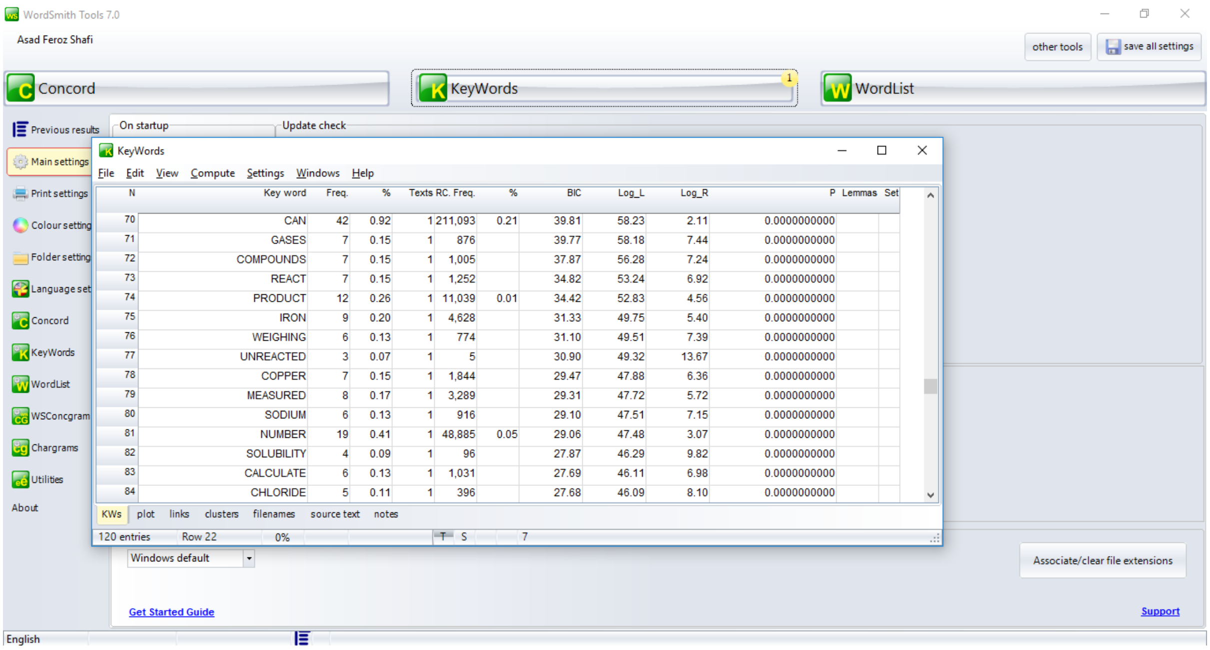
Step 2A: select ‘KeyWords’



Step 2B: choose 'WordList' file and reference corpus, then select 'Make a keyword list now'



Step 2C: save 'KeyWord' file

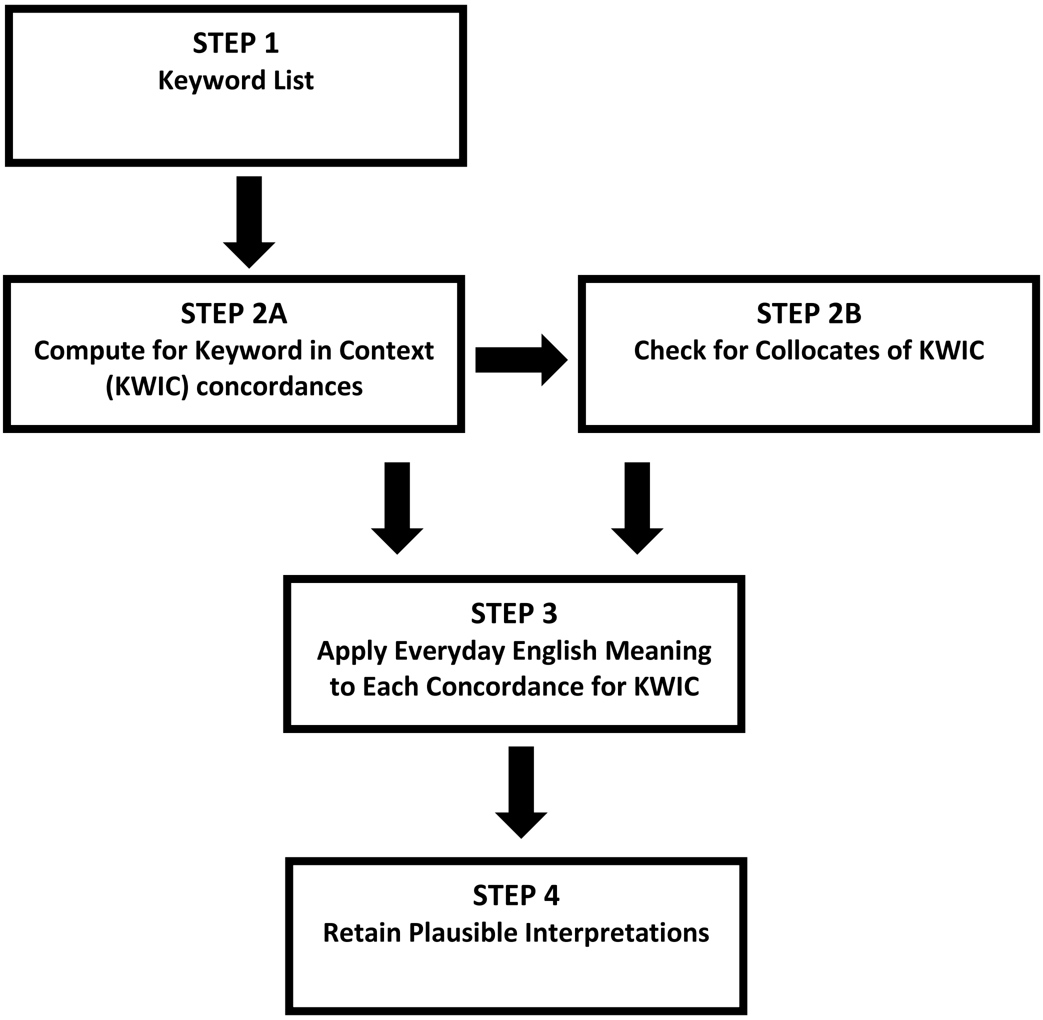


4.4.6.4 Analysis of Keywords

The process of identifying potential non-technical words was carried out in four steps (see Figure 4.3). After opening the keyword list file (step 1), each keyword in context (KWIC) was analysed one at a time by computing the KWIC for concordances (step 2A). WordSmith Tools allows the user to locate the concordance in the original text, and this helped in cases where the KWIC had to be read in its broader context. For those words which held an everyday meaning in addition to a scientific meaning, then the everyday usage of the word (as found in a dictionary) was applied to the concordance (Step 3). If the applied everyday usage of the KWIC was plausible, then the related concordances were saved on a Microsoft Word file with a description of how the non-technical everyday meaning could be incorrectly applied to the chemistry context (step 4).

Potential colligational patterns and collocations of the KWIC were also searched for. WordSmith Tools has an option to check if the KWIC has any significant collocations (step 2B). If any were found, the everyday meaning of the collocate was imposed on the concordances (step 3), and any plausible interpretations were recorded (step 4). Collocations in this context refers to one, or even two words, associated with the keyword; whereas colligational patterns are based on the preferred position of the keyword, such as being a head noun or an adjective. Despite this, it was made clear in the preceded discussion on collocations that collocation is a broad term and colligation can be considered as a type of collocation. In this study, the collocational analysis was done broadly and so it even included searching for potential cases of semantic prosody. In all circumstances, it was the research question that led the analysis.

FIGURE 4.3
Four-Step Process for Identifying Potential Non-technical Words



The classification process was carried out by referring to a general dictionary as this ensured that the word held meanings in both a science and a day-to-day context as the study is concerned with non-technical words. Oxford Dictionaries was used as a reference to check the meaning of the KWIC in its everyday sense, and this meaning was applied to each concordance (step 3). Oxford Dictionaries itself is derived from a corpus, the Oxford English Corpus, which consists of a 2.3 billion word bank. This dictionary removes the need to refer back to the BNC for the purpose of checking how a particular word is used in context. Another advantage is that the dictionary lists the senses in order so the user can be informed about a word's most common usage. Menon and Mukundan (2010) used a specialised science dictionary to deduce the scientific meaning of non-technical words in their corpus study of several general science textbooks. However, the present study is a corpus made from a single chemistry textbook, and therefore the textbook itself acted as a reference for scientific definitions. Figure 4.4 shows screenshots of how all four steps (outlined in Fig. 4.3) of the process was applied in the analysis of one of the KWIC (fossils).

FIGURE 4.4
Application of Four-Step Process for 'Fossils'

<u>Step 1:</u> Chapter 1 Keyword List has 77 entries of which 'Fossils' is one

File Edit View Compute Settings Windows Help

N	Key word	Freq.	%	Texts	RC. Freq.	%	BIC	Log_L	Log_R	P	Lemmas	Set
1	CARBON	40	1.06	1	2,465		385.52	403.94	8.74	0.0000000000		
2	DIOXIDE	35	0.92	1	1,397		365.07	383.49	9.36	0.0000000000		
3	GASES	25	0.66	1	876		261.92	280.34	9.55	0.0000000000		
4	HYDROGEN	19	0.50	1	1,189		172.88	191.29	8.71	0.0000000000		
5	WATER	34	0.90	1	34,134	0.03	138.13	156.54	4.71	0.0000000000		
6	NITROGEN	15	0.40	1	881		134.49	152.90	8.80	0.0000000000		
7	OXYGEN	17	0.45	1	1,883		133.51	151.92	7.89	0.0000000000		
8	EARTH	22	0.58	1	8,402		124.32	142.74	6.10	0.0000000000		
9	1	7	0.18	1	0		124.05	142.46	139.92	0.0000000000		
10	FUEL	18	0.48	1	4,190		115.96	134.38	6.82	0.0000000000		
11	FUELS	12	0.32	1	577		108.65	127.07	9.09	0.0000000000		
12	FIGURE	23	0.61	1	17,214	0.02	100.53	118.95	5.13	0.0000000000		
13	RENEWABLE	10	0.26	1	337		94.49	112.90	9.61	0.0000000000		
14	CRUST	11	0.29	1	660		93.25	111.66	8.77	0.0000000000		
15	FOSSIL	11	0.29	1	893		86.66	105.08	8.34	0.0000000000		
16	ENERGY	19	0.50	1	12,098	0.01	85.82	104.24	5.37	0.0000000000		
17	SULFUR	6	0.16	1	7		85.75	104.17	14.46	0.0000000000		
18	AIR	21	0.55	1	18,415	0.02	83.75	102.16	4.90	0.0000000000		
19	IS	113	2.98	1	974,293	0.98	81.51	99.93	1.61	0.0000000000		
20	LIMESTONE	10	0.26	1	805		77.28	95.69	8.35	0.0000000000		
21	METHANE	8	0.21	1	332		68.62	87.04	9.31	0.0000000000		
22	RESOURCES	16	0.42	1	10,445	0.01	68.59	87.00	5.33	0.0000000000		
23	USED	28	0.74	1	65,980	0.07	65.62	84.04	3.48	0.0000000000		
24	2011	4	0.11	1	0		62.99	81.41	139.11	0.0000000000		
25	ATMOSPHERE	12	0.32	1	4,751		58.59	77.01	6.05	0.0000000000		
26	ORES	6	0.16	1	96		58.07	76.48	10.68	0.0000000000		
27	ARE	64	1.69	1	458,368	0.46	54.81	73.23	1.87	0.0000000000		

KWs plot links clusters filenames source text notes

Step 2A: computing concordances for 'Fossils' led to 11 concordance lines

File Edit View Compute Settings Windows Help

N	Concordance	Set	Tag
1	carbon dioxide Fossilised plants and animals form **fossil** fuels (coal, oil and gas); these produce	...L	
2	example, metallic and non-metallic minerals and **fossil** fuels. They were formed over millions of years	...L	
3	low quality, making the process of extraction costly. **Fossil** fuels are another concern. New deposits of	...L	
4	helps save energy, which comes mainly from **fossil** fuels. Fossil fuels are a bigger problem. We	...L	
5	save energy, which comes mainly from fossil fuels. **Fossil** fuels are a bigger problem. We will always	...L	
6	main source of 'problem' gases is the burning of **fossil** fuels. Most countries produce electricity by	...L	
7	the forests increase the problem. Burning less **fossil** fuel and planting more trees would help to	...L	
8	the method of making lime industrially. The major **fossil** fuels are coal, petroleum (or crude oil) and	...L	
9	many other useful substances. For more detail of **fossil** fuels and their uses see chapter 11. If these	...L	
10	resource. In 2007, it was estimated that the **fossil** fuel supplies we currently know about would	...L	
11	little energy is obtained from sources other than **fossil** fuels, with the figure for coal showing a	...L	

Step 2B: 1 collocation found (Fossil Fuel) with 9 entries

File Edit View Compute Settings Windows Help

N	Word	Set	Texts	Total	Total Left	Total Right	L5	L4	L3	L2	L1	Centre	R1	R2	R3	R4	R5
1	FOSSIL		1	13	1	1				1		11		1			
2	FUELS		1	11	1	10					1		9		1		

Step 3: Oxford Dictionaries meaning/usage was applied

DICTIONARY fossil

NOUN

1 The remains or impression of a prehistoric plant or animal embedded in rock and preserved in petrified form.

'sites rich in fossils'

[as modifier] *'a fossil fish'*

− More example sentences

'Most geologists are familiar with the occurrence of plant compression fossils in bedded sedimentary rocks.'

'Other marine trace fossils, together with marine bivalves, have been described from the unit as a whole.'

'Very few dinosaur fossils are actually found near this boundary.'

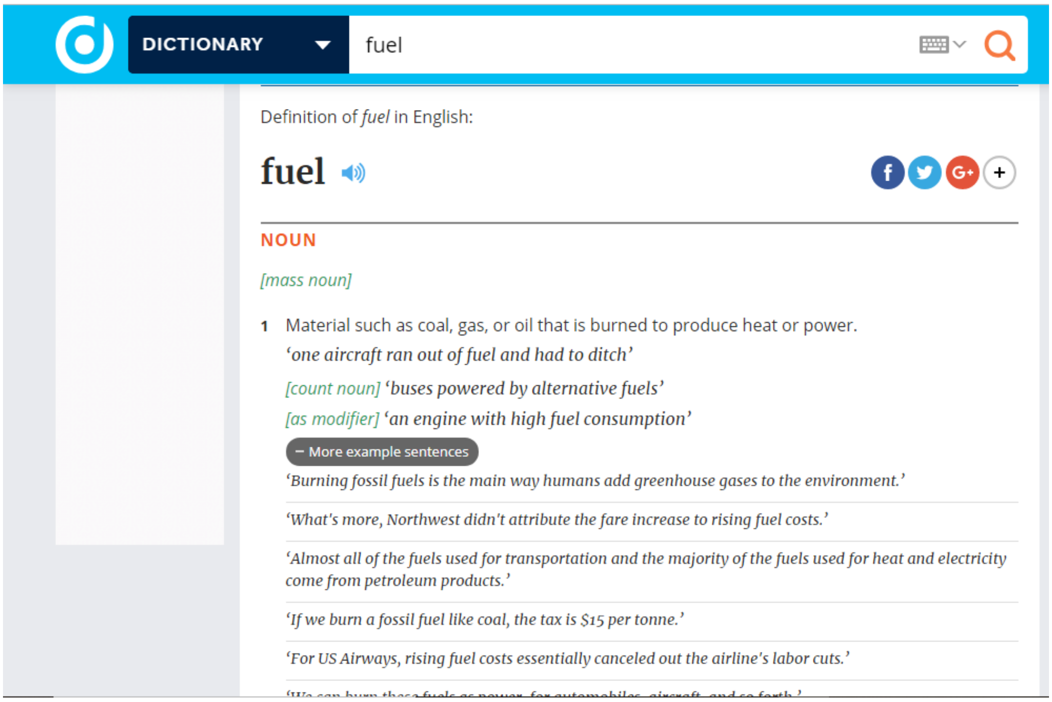
'Then we use the dating of a recently discovered hominid fossil as a calibration point.'

'Shallow marine invertebrate fossils occur throughout the formation, but are mainly concentrated in four broad intervals.'

'Two years ago, scientists described 5-million-year-old albatross fossils representing five different species.'

'All of these sites have yielded remarkably preserved Cambrian fossils, in large part due to rapid burial.'

'The oldest true vertebrate fossils date back 530 million years.'



<u>Step 4:</u> interpretation was found to be plausible, therefore retained

KeyWord List 1: Fossil

File Edit View Compute Settings Windows Help

N	Concordance	Set	Tag
1	carbon dioxide Fossilised plants and animals form **fossil** fuels (coal, oil and gas); these produce	...L	
2	example, metallic and non-metallic minerals and **fossil** fuels. They were formed over millions of years	...L	
3	low quality, making the process of extraction costly. **Fossil** fuels are another concern. New deposits of	...L	
4	helps save energy, which comes mainly from **fossil** fuels. Fossil fuels are a bigger problem. We	...L	
5	save energy, which comes mainly from fossil fuels. **Fossil** fuels are a bigger problem. We will always	...L	
6	main source of 'problem' gases is the burning of **fossil** fuels. Most countries produce electricity by	...L	
7	the forests increase the problem. Burning less **fossil** fuel and planting more trees would help to	...L	
8	the method of making lime industrially. The major **fossil** fuels are coal, petroleum (or crude oil) and	...L	
9	many other useful substances. For more detail of **fossil** fuels and their uses see chapter 11. If these	...L	
10	resource. In 2007, it was estimated that the **fossil** fuel supplies we currently know about would	...L	
11	little energy is obtained from sources other than **fossil** fuels, with the figure for coal showing a	...L	

<u>Chemistry Definition:</u> 'Fossil Fuel' – fuels such as coal, oil and natural gas, formed underground over geological periods of time from the remains of plants and animals.

<u>Oxford Dictionaries:</u> 'Fossil' common usage different, 'Fossil Fuel' only two examples

<u>Concordance (C):</u> In negative context: C3 – 'another concern', C5 – 'bigger problem', C6 – 'main source of problem'

<u>Oxford Dictionaries:</u> 'Fossil' no connotation, 'Fossil Fuel' only two negative examples

<u>Interpretation:</u> negative connotation seems rare in everyday usage, but surrounding negative words in concordances may exhibit fossil fuels as a bad thing, though only the burning of it is bad.

The number of concordance lines that needed to be analysed for each KWIC varied. For example, the wordlist for chapter 2 alone consisted of 175 keywords. One of the keywords, 'liquid', appeared 68 times, and the associated ‘liquids’ appeared 21 times. This meant I had to analyse 89 concordances of liquid against the everyday meaning/usage. In addition to this, some words had multiple senses (meanings), so this had to be kept in mind when carrying out the analysis. There were also 98 significant collocates. These collocates were then also referred back to the everyday meaning and again compared with the meaning found in the concordance. Through the analysis, as expected, some keywords appeared in multiple keyword lists.

When reporting on the potential non-technical words, I took care not to report on non-technical words where the embedment of the everyday meaning in the scientific context is not meaningful. As an example, matter, masses, and solution are words from the keywords list that hold both a meaning in the everyday context and in the context of chemistry (see Table 4.3). However, it would be virtually impossible to apply their everyday meaning in the context of chemistry. For instance, the dictionary meaning of matter (first two senses) is no different to the meaning in the chemistry context (Oxford Dictionaries, 2017), but sense three (‘The reason for distress or a problem’, e.g. ‘what’s the matter?’) is clearly different from concordance lines 1 and 2 (Table 4.3). Despite this difference, all 15 concordances of matter are used in such a way that by applying the sense three meaning into to the chemistry context, it would lead to a meaningless sentence. The everyday meanings of masses (e.g. ‘It has been made for the masses.’), and solution (e.g. ‘what’s the solution?’) (Oxford Dictionaries, 2017) are similar to some extent in that they do not appear to be problematic when embedding their everyday meaning in the context of chemistry.

TABLE 4.3
Selected Concordance Lines for 'Matter', 'Masses' & Solution

No.	Concordance
1	er There are many different kinds of matter. The word is used to cover all the s
2	main points of the kinetic model All matter is made up of very small particles
3	be weighed on a balance. However, the mass of one atom can be compared wit
4	ts. Carbon is given a relative atomic mass of exactly 12, which can be written
5	carbon is chosen as the standard. The masses of atoms of all other elements
6	so explains why most relative atomic masses are not whole numbers. But, to ma
7	and done safely. The concentrated solution is allowed to cool slowly. The
8	such as ethanol, ethanoic acid solution and propanone are common. Organic s

4.4.7 Corpus Analysis: Validity & Reliability

Validity relates "to the degree to which a method, a test or a research tool actually measures what it is supposed to measure," whilst reliability is linked to 'replicability' in that the extent to which the research could be replicated across a range of settings and give the same results (Wellington, 2000, p.30). Whilst there are differences in terms of how validity and reliability are defined in quantitative and qualitative research, there is "some common ground" (Cohen, Manion & Morrison, 2011, p.183). Though qualitative researchers tend not to refer to reliability, validity in both qualitative and quantitative approaches "serves the purpose of checking on the quality of the data, the results, and the interpretation" (Creswell & Plano Clark, 2011, p.210). There are many types of validity. Internal and external validity is addressed in both qualitative and quantitative research (Cohen, Manion & Morrison, 2011). Internal validity "seeks to demonstrate that the explanation of a particular event, issue or set of data which a piece of research provides can actually be sustained by the data" (Cohen, Manion & Morrison, 2011, p.183). External validity concerns the extent to which the results of the study "can be generalised to the wider population, cases, settings, times or situations" (Cohen, Manion & Morrison, 2011, p.185).

The balance and representativeness of a given corpora is "rarely attain(ed)" and is a matter "of degree" (McEnery & Hardie, 2012, p.10). The corpora in this study is believed to be representative of the chemical language used in the Saudi EFL participants' chemistry course since it is produced by detailed analysis of their core chemistry textbook (see section 4.4.6 for analytical methods), but we cannot claim it is representative of all preparatory year courses as other colleges may use different material. The corpus analysis was taken in two main steps. First the results were generated quantitatively, and then analysed qualitatively. This study has provided details of the procedures involved in constructing the corpus, including the recommended settings from WordSmith Tools, and the reference corpus (BNC), to produce the keywords. The analysis of the keywords, which is qualitative in nature, relies on the researcher interpreting the concordances (Biber, Conrad & Reppen, 1998). Inevitably, this part of the analysis would have some bearing on the validity and reliability of the claims made. The purpose of the corpus analysis was to identify non-technical words, and by definition, a non-technical word has an everyday meaning, and a meaning in chemistry. By using definitions from Oxford Dictionaries to convey the everyday meaning, and the core chemistry textbook for scientific meanings, the subjective nature of interpretations was reduced. These interpretations were not purely founded upon what I believe the everyday or chemistry meaning to be, but referenced to a published resource. The process involved applying the everyday dictionary meaning to the chemistry context, though beyond this point, it is interpretive, but "the only way we can judge whether our perceptions match reality is to appeal to our perceptions…we are caught in a circular trap" (Wellington, 2000, p.31).

Despite this, an extra safe-guard known as inter-rater agreement was adopted for this study:

> Inter-rater agreement, which is an estimate of how reliable and consistent a coding is, should be reported in studies working with a

> judgement variable. This is a variable that involves categorization or evaluation of cases (e.g. concordance lines) by the analyst that might bring an element of subjectivity into the study. (Brezina, 2018, p.87)

In a typical inter-rater agreement, the second coder independently analyses all the concordances and draws his/her own interpretations. Due to the technical nature of operating WordSmith Tools, and secondly the time intensive process, it was not possible to find a second coder to meet these requirements. However, a qualified and experienced chemistry teacher read the interpretations given for each identified non-technical word with the aim of deducing whether the interpretation being drawn is plausible or not in terms of the embedment of the everyday meaning being meaningful in the chemistry context. In cases of disagreement between the researcher, and the reader, the non-technical word was removed. Appendix 3 lists all the potential non-technical words suggested for this study, totalling 60, and descriptions of the disagreed non-technical words are also found within this appendix. Two non-technical words (colourless and bubbles) were mentioned by the textbook authors, so these were not reviewed by the second-rater. Therefore, 44 cases were agreed, whilst 14 were disagreed upon by the second-rater. A calculation for "raw agreement…a metric, often expressed as a percentage…provides the proportion of agreement cases in all cases" (Brezina, 2018, p.89). Thus:
[44 (cases of agreement) / 58 (total no. of cases)] x 100 = 76% (2 s.f.) agreement. Brezina (2018) explains that ideally 80% raw agreement should be aimed for, though the focus should be on evaluating the nature of the disagreement. Appendix 3, in the description of disagreed non-technical words, provides an explanation for the second-rater's disagreement.

4.5 PHASE TWO: SEMI-STRUCTURED INTERVIEWS

This section outlines the methods to address the following research sub questions:

- **(RQB)** How familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words?
- **(RQC)** To what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry?
- **(RQD)** What is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?

The section begins with a discussion on the interview preliminary work (selection of non-technical words and recruitment of participants), followed by details of the interviews with eleven Saudi EFL college students (all male), and data from documentary evidence.

4.5.1 Selection of Non-Technical Words

The management team at the vocational college selected the following non-technical words from the corpus analysis: arrangement, base, boiling, collisions, gain & lose, impurities, making & breaking, and strong & weak. Chapter Five explains in detail why these words are considered to be non-technical words, and the potential challenges students may face if they apply the everyday meaning of these words in the context of chemistry.

A total of 46 potential non-technical words were identified in the corpus analysis of the students' IGCSE chemistry textbook. It would no doubt be impractical to probe students' understanding of all these words. As the first phase of this sequential design was completed, including the analysis of these non-technical words, the non-technical words were ready for selection. The full list of the 46 non-technical words, alongside the findings in Chapter Five, were given to the gatekeeper who worked alongside the chemistry teachers to select words that would be of interest to them, and those that have been taught in class already. As each interview was planned to last for one hour, I suggested that they select no more than ten words, as even at this point the pilot interview would have determined a suitable number. I had no direct contact with the head of science during the research process, though, a member of the senior management team, the gatekeeper, acted as an intermediary between the researcher (myself) and the science department.

The final agreement included a total of 11 non-technical words. The senior manager confirmed that the science department selected words based on three reasons. First, that the words were covered in class, thus no new material was presented to the students in the interview according to the chemistry syllabus. Secondly, they included both familiar (e.g. strong) and unfamiliar (e.g. impurities) non-technical words. Thirdly, they selected words from a range of chemistry topics. The students were first informed about these selected non-technical words in the interview, and not prior, in order to avoid students giving memorised rote-learned responses (Ausubel, 2000).

4.5.2 Recruitment & Sample of Participants

The participants in this study, eleven in total, are from Saudi Arabia, all of whom are male, aged 19-22, and were at the time of interviewing studying in the first year of the Foundation Year program at the vocational college. In their particular year group, they represent a population of approximately 20% of the students.

4.5.2.1 The Recruitment Process

Selecting the participants for this study was restricted greatly by access, as “the business of sampling, generalizability and access…are completely interwoven”

(Wellington, 2000, p.61). Having built a relationship with several institutions' administrative staff in Riyadh, I was able to approach the management team of one vocational college in-person and presented the information consent forms (see Appendices 9 & 10). They offered to recruit the participants on my behalf and handled the recruitment of participants. They made announcements primarily through direct emails to the students, messages on noticeboards outside the students' classrooms, and word-of-mouth to recruit potential participants for this research. This resulted in a number of students approaching them and agreeing to give consent to participate on a voluntary basis.

The recommended number of participants for a case study research varies typically between one and ten (Stake, 1995; Yin, 2009). In qualitative research there are "no hard rules" with regards to the sample size as the "goal…is to describe and interpret rather than to generalize" (Lichtman, 2013). Even though a request was made for ten Saudi EFL college students, in addition to a student for a pilot interview, the college could only confirm on the day if any of the consenting students would be available for the interview. This is because, according to the gatekeeper, firstly the participants took part in the study purely on a voluntary basis. Secondly, they had a very busy schedule, and thirdly, as the research took place towards the end of the semester, attendance was expected to be low.

4.5.2.2 The Sample

There are number of strategies available for sampling, and this differs for qualitative and quantitative studies. Quantitative researchers often use probabilistic sampling as large numbers of individuals are used to represent a given population, but in case study research, this logic is not applied as the cases are studied in depth (Yin, 2009). In qualitative research, researchers typically use purposive sampling where "researchers intentionally select (or recruit) participants who have experienced the central phenomena or the key concept being explored" (Creswell & Plano Clark, 2011, p.173). Patton (1990) states:

> The logic and power of purposeful sampling lies in selecting *information-rich cases* for study in depth. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the term *purposeful* sampling. (p.169)

There are a few variations of this type of sampling, including maximum variation sampling, typical case sampling, and critical case sampling (Wellington, 2000). Maximum variation sampling involves selecting participants who are representative of extreme cases of the phenomenon. Typical case sampling, as the name suggests, involves selecting cases that are believed to be typical representatives of the phenomena. Whilst critical cases involve participants who have distinct features or characteristics.

Despite the number of variations, Patton (1990) stresses that the underlying principle to purposeful sampling (or purposive sampling) is that the selection should be based on information-rich cases, where "one can learn a great deal about matters of importance" (p.181). The sample and research phenomena are concerned with Saudi EFL college students' understanding of non-technical words in chemistry. The participants belong to the natural boundaries of this case study as, for example, they are studying a particular chemistry course within a specific institution, and are thus key members of the case setting when taking the research question into consideration. In this sense, it is believed that the selected participants from this particular case study setting would provide the necessary information to enhance our understanding of the research question. The sampling strategy for this case was purposive in that the sample was sought directly from the group of students within the boundaries of the case. However, it was also, to an extent, a convenience sample in that the students within the case self-selected to participate. Thus, they do not represent the complete range of students in terms of varied levels of English proficiency or educational experience of learning chemistry. Therefore, the sampling strategy employed was a mix of purposive and convenience sampling.

4.5.3 Interviews

There are several sources of evidence that can be used in case study research, however, interviews are "one of the most important sources of case study information" (Yin, 2009, p.106). Interviews are a 'matter of degree', at one end there is the 'structured' interview which is like a verbal questionnaire, and at the other end of the spectrum is the 'unstructured interview' where the interviewee takes control to some extent as the interview is completely flexible (Wellington, 2000). The present study involves semi-structured interviews which "is defined as an interview with the purpose of obtaining descriptions of the life world of the interviewee in order to interpret the meaning of the described phenomena" (Kvale & Brinkmann, 2009, p.3). At the time of interviewing the students were in the last two weeks of the semester (weeks 14 and 15), and had completed most of the syllabus; including the topics concerning the selected non-technical words. Within the two weeks of data collection at the college, all eleven students were interviewed. The next few sections outline the procedures for: piloting the interview to make the final interview schedule; recording and transcribing the data; and analysing the data.

4.5.3.1 Pilot Interview

The combination of the research questions and the findings from the first phase of this study, in addition to the pilot interview, contributed to the final interview schedule (Appendix 4) and associated material (Appendix 5). Only minor refinements were made to the originally planned interview schedule, and details of the finalised interview schedule are presented in section 4.5.3.2.

A pilot interview was conducted with the first Saudi EFL college student. Piloting interviews are very valuable as it allows the researcher to identify potential pitfalls or shortcomings in the interview schedule, also other practical issues such as the appropriateness of the interview venue (Wellington, 2000). It "should be routine" to pilot the interview and try out the questions (Stake, 1995, p.65), and "the skills of interviewing are learned by practicing the interview" (Kvale & Brinkmann, 2009, p.17). There were numerous reasons for conducting a pilot interview in this study. I wanted to see to what extent I could engage with the student in a discussion about his understanding of non-technical words in chemistry, as the students were not native speakers of English. "In a foreign culture, an interviewer needs time to establish familiarity with the new culture…extralinguistic features of communication may also give rise to misunderstandings" (Kvale & Brinkmann, 2009, p.144). Having taught at some institutions with similar aged EFL Saudi students, I had some understanding of their culture. Also, I wanted to know if the interview contained too many, or too few, non-technical words. CEFR A2 learners of English are not expected to produce language fluently, so there was a concern with respect to the time spent on each word.

Overall, the number of non-technical words was deemed to be sufficient for the one-hour interview. In the pilot study, there was an initial problem with finding a suitable venue for the interview which took approximately 15 minutes of the interview time. The student had to go to his class, and therefore he was not able to complete the full hour. Even though there were eleven non-technical words chosen for this study, some of the selected non-technical words were introduced as pairs in the same context, namely strong/weak, gain/lose, and making/breaking, so this saved time in the interview. The pilot interview made me realise the importance of probing. I found myself repeating the same point many times before being persuaded that what the student said is his stance and was not influenced by me. I found that the flexible nature of semi-structured interviews allowed enough flexibility to elicit sufficient information from the student.

The pilot student did not come with any resources, and he wanted access to an electronic dictionary. Fortunately, the venue for the interview, which was an office, had a computer with an internet connection. The student said that normally he would use the dictionary on his phone. Therefore, the same level of access was made available to all the other participating students. Students were told that they could bring whatever resources they wish to the interview. This included any of their class notes, chemistry textbook, electronic devices. When asked about how the everyday meaning of the word is used in Arabic, the pilot student was not able to focus on the word, but when he was asked to write the example in Arabic on paper, and then translate what he wrote into English, he was able to focus better. So, this addition was adopted for all the students in this study.

I found during the pilot interview that it was important to have reference page numbers ready related to all the specific non-technical words. Despite the pilot student being familiar with the words, he was not able to explain the science, so by directing him to the textbook reading passage, it encouraged further dialogue. Though, this led to other complications, as for instance, the reading passage related to the non-technical word ‘impurities’ was in the context of the extraction of iron in a blast furnace. I had to unpack the text as there were some words that needed to be clarified. This naturally led to having to explain the science whilst paraphrasing, or summarising, the text in the core IGCSE chemistry textbook, and this could have influenced the participant's response. “The knowledge resources that are drawn upon, and the answer that the student generates, depend on features of the interview context” (Sherin, Krakowski & Lee, 2012, pp.169-170). As this interview was not based on the students' memory of scientific concepts, and rather on the understanding of non-technical words in context, I felt it was acceptable to intervene, especially if the student asked for clarification. This had implications on the ordering of questions, as constantly referring to the textbook reading passage could lead to fatigue. Therefore, non-technical words related to dense reading passages were spread between those words which only required looking at a schematic diagram, or interpreting a chemical equation, of the instance.

4.5.3.2 Interview Schedule

The semi-structured interview was conducted in two main parts with the first part exploring the students' familiarity of the non-technical words, and the second with probing students' understanding of these words within related chemistry concepts (see Appendix 4 for interview schedule, and Appendix 5 for related interview material). This two-step process was completed for one non-technical word, before introducing the next non-technical word.

The first part addressed the following research sub-question: how familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words? Students were asked first if they were familiar with the word, and then the interview progressed into how they use these words. Students were asked how they would use the equivalent Arabic word, and at times, as some of the words were unfamiliar to begin with, they would resort to an English-Arabic dictionary, and then proceeded with their own examples. The examples given by the students were noted by the researcher and incorporated into the second part of the probing. The second part was designed to address the sub-research question: to what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry? The third sub-research question (what is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?) was addressed mainly in the second part as during the interview I had to draw on the information given in the first part to develop a discussion in the second part.

In order to probe students' ideas about non-technical words in the context of chemistry a technique known as interview-about-instances was used. Osborne and Gilbert (1979) developed the interview-about-instances technique as "a practical way of investigating a student's concept of a word" (p.86). This technique "involves giving interviewees separately a number of instances and non-instances of a particular concept, usually in line-drawing format, and basing an interview around these" (Brass, Gunstone & Fensham, 2003, p.249). The interviewer pursues "courses of fruitful dialogue as they (arise) and (seek) out opportunities for gaining an in-depth understanding of students' conceptions" (Mills, Tomas & Lewthwaite, 2017, p.300).

The accompanied scenarios for the non-technical words were situated in the context of the findings from the corpus analysis. For example, boiling was identified as non-technical as in everyday English it is used in the sense of 'heat' whereas in chemistry boiling with its collocation 'point' (boiling point) refers to a specific temperature at which a liquid boils. The students were asked for their opinion about the boiling point of oxygen being -183^0 c. Thus probing the students ideas about the possibility of a boiling point existing at very cold temperatures. PowerPoint slides were used to introduce some of the scenarios, followed by material related to their textbook (Appendix 5).

4.5.3.3 Recording and Transcription

All the interviews were recorded using a digital voice recorder, and soon after transferred to a password protected-computer kept in a secure location, with the original recording on the voice recorder deleted at this point. “Transcription is understood as the graphic representation of selected aspects of the behaviour of individuals engaged in a conversation” (Kowal & O’Connell, 2004, p.248).

> There is always a transformation…a reduction, a loss and thus an impact on validity…Recording and the process of transcription and of representation…are a process of work, of building, or of creating…it is not that one view is right and the other wrong, it is rather the question of how the researcher and the reader engages with the interviewing process from its inception to the traces that remain. (Schostak, 2006, p.68)

There are many features that could be transcribed beyond standard orthography such as gestures, but only those features that would be analysed should be included (Kowal & O’Connell, 2004). Thus, all the interviews were transcribed verbatim, whilst acknowledging that transcribing is an interpretive process (Kvale & Brinkmann, 2009). In terms of specific features for the participants of this study, the transcription included some Arabic words as the participants drew on their mother tongue. These were transliterated, and where necessary, these words were translated within a parenthesis to acknowledge that it is the researcher’s translation, though it should be noted that the researcher’s proficiency in Arabic is basic, and utilised Google Translate where possible. It was not possible to take the recordings to a professional translator due to data protection matters. A sample of a completed transcription of one participant’s interview data can be found in Appendix 6.

4.5.3.4 Data Analysis

Analysing data is "about process, and interpretation…there is a process you follow and interpretations to be made from that process" (Lichtman, 2013, p.245). There is no agreed upon process as "no particular tradition, whether humanistic or positivistic, has a monopoly on text analysis" (Ryan & Bernard, 2000, p.780), and no qualitative researcher "can claim final authority on coding's utility or the "best " way to analyze qualitative data" (Saldana, 2013, p.2). There are several ways to analyse an interview transcript, and the quality in the analysis depends upon "the craftsmanship of the researcher, his or her knowledge of the research topic, sensitivity to the medium he or she is working with – language, and mastery tools for analysis" (Kvale & Brinkmann, 2009, p.196).

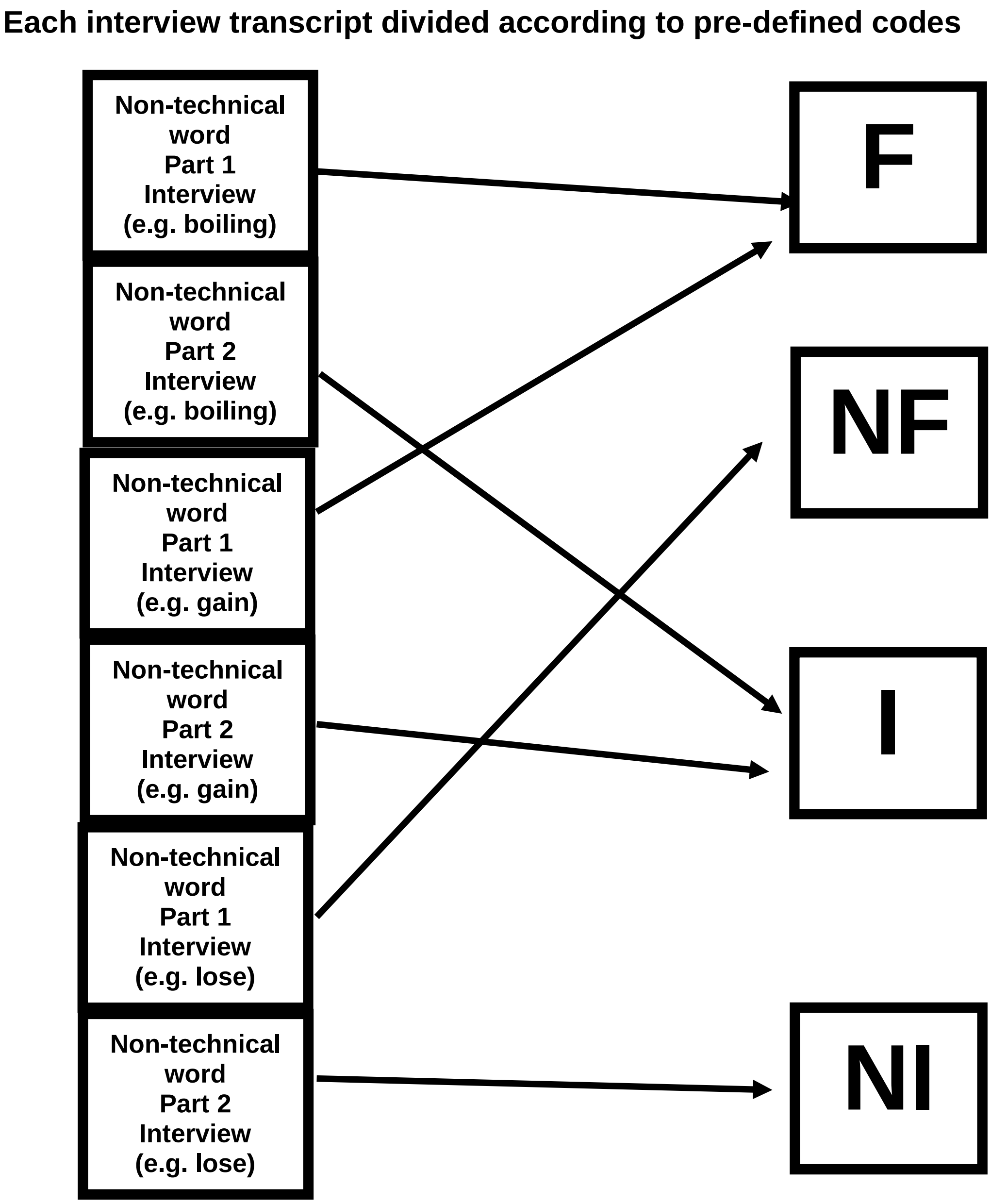
Broadly speaking, qualitative analysis involves two primary steps, the first is coding, and the second is making sense of the relationship between these codes. Coding is an analysis in itself, whereby codes are assigned "units of meaning to the descriptive or inferential information compiled during a study…attached to "chunks" of varying size – words, phrases, sentences, or whole paragraphs" (Miles & Huberman, 1994, p.56). Kvale and Brinkmann (2009) explain that coding can be concept-driven or data-driven. They elaborate that concept-driven coding requires pre-defined codes, which could be established through the literature, and data-driven coding produces codes at the time of analysis. In essence, the analysis can start with deductive procedures, but ends with an inductive approach. Hybrid approaches that begin with deduction, by applying pre-defined codes, make it easier for the researcher to analyse qualitative data without losing the value of developing themes from the data inductively (Fereday & Muir-Cochrane, 2006; Kumarassamy & Koh, 2019).

The interview transcripts were analysed as separate transcripts first, and then made comparisons between the transcripts as naturally the coding of the second participant's data may lead to recoding the first participant's coding (Saldana, 2013, p.22). Moreover, the current study used both deductive and inductive approaches to examine the interview transcripts. Appendix 6 shows the application of the predefined codes, and Appendix 7 shows how the codes are organised under one category for a theme. The following pre-defined codes were developed based on the research questions for the qualitative phase of the sequential study: non-technical word familiar (F), non-technical word not familiar (NF), chemistry concept influenced by non-technical word (I), chemistry concept not influenced by non-technical word (NI). The interview schedule was designed in a way that each non-technical word would first be introduced with questions regarding its familiarity (Part 1 – P1), and then followed by questions regarding its use in chemistry with a related scenario (Part 2 – P2). This interview structure allowed the separation of these two parts for each participant's interview transcript which for now will be named P1 (Part 1) and P2 (Part 2). P1 was assigned 'F' or 'NF' codes. The 'F' code meant that the student demonstrated that he had some understanding of the meaning of the word, and 'NF' meant the opposite and would normally be indicated by the student's need to access a dictionary. P2 was assigned 'I' or 'NI' codes. The 'I' code meant that there appeared to be some relationship with the student's response to the scenario and the everyday meaning of the non-technical word, and 'NI' meant that there was no indication of there being a relationship, possibly, but not necessarily, due to the student giving a reasonable scientific explanation.

Each segment of the transcript related to P1, code 'F', was grouped together, and the same was done with P1 'NF', P2 'I', and P2 'NI' (see Fig.4.5).

At this point, inductive analysis presumed with preliminary descriptions being given when comparing for example all the excerpts related to P1 'F', P1 'NF' and so forth. The data for P1 'F' and P1 'NF' were compared after individual analysis, and similarly P2 'I' and P2 'NI'. After this, comparisons were made between P1 and P2. Due to the nature of the interview, there were parts of the interview data from P1 that were also in P2. The semi-structured interview allowed flexibility in the sense that when the student was being probed during the P2 scenario, part of this involved bringing in the participant's example sentence from P1 to verify if he would apply the everyday meaning in the chemistry context. So, in effect, P2 contained this element of P1 in the interview. This whole process was executed for one individual interview transcript and was carried out in the same way for each of the eleven transcripts. After this process, systematically, the coded transcripts were compared to each other to find any commonalities or differences between participants. This involved a continuous process of refining the codes. The findings of this outcome are presented in Chapter Five as the codes are organised under thirteen categories, and the categories under three broad themes.

Figure 4.5
Interview Data Analysis



4.5.4 Documentary Evidence

"Documents such as…an achievement test report can be key repositories or measures for the case…Quite often, documents serve as substitutes for records of activity that the researcher could not observe directly" (Stake, 1995, p.68). Documents are useful as time is saved in interviews as certain factual information is made readily available, and they are "helpful in counteracting the biases of the interviews" (Meyer, 2001, p.339). The syllabi for both the English and chemistry courses in the Foundation Year mainly outlines the objectives of the program and the breakdown of the assessment methods and weightings on each exam. Though these documents are available to the public, especially prospective students, they are not added to the appendices as they contain the institution's details including a large emblem in the background of each document. These documents contributed to the background information for the case setting.

4.5.5 Interviews: Validity & Reliability

Validity and reliability are "vital concepts in surveys and experiments – but not in case study research," and instead the concept of trustworthiness is more appropriate (Bassey, 1999, p.74). Lincoln and Guba (1985) suggest using the terms credibility and transferability as more appropriate terms for internal and external validity; dependability instead of reliability; and confirmability for objectivity. In the present study credibility was established through the use of thick descriptions using numerous students' quotes and peer debriefing. Though it is appreciated that member checking is an effective validation strategy, it was not possible in this study due to limited access to the participants. Yin (2009) explains that real triangulation occurs when "the events or facts of the case study have been supported by more than a single source of evidence" (p.116). The semi-structured interviews were the primary source of data collection for the case, however, the other documents which includes mainly the course syllabi for both the English and chemistry courses support the findings in the sense of knowing how the students study their program, and this adds to the overall depth of the case.

Peer debriefing involves "exposing oneself to a disinterested peer…for the purpose of exploring aspects of the inquiry that might otherwise remain only implicit within the inquirer's mind" (Lincoln & Guba, 1985, p.308). The findings also include real quotations (thick descriptions) from the participants, not translations. As in the corpus analysis, the same chemist read through the findings in Chapter 6 and mainly focussed on the interpretations drawn for canonical and non-canonical accounts of chemistry. Due to the chemist's limited time, it was not possible for him to code the transcripts. Instead, this was achieved in one sitting with the researcher referring to parts of the transcript to verify claims as the chemist raised questions. This resulted in an increase in the number of quotations in the chapter to satisfy the reader that fair claims were being made about the data. In terms of transferability, the study has attempted to provide a reasonably 'thick description' detailing the context of the study. It is also hoped that the details provided in this section with regards to the data collection and analysis procedures, raw data such as an interview transcript, is sufficient as an 'audit trail' to establish dependability and confirmability.

4.6 ETHICS

Ethics is important in any research and the "this factor is multiplied in educational research where people are studying people" (Wellington, 2000, p.54). Ethics is related to "moral principles, rules, or standards governing a person or profession" (Lichtman, 2013, p.51). The corpus based analysis involved an analysis of one published IGCSE chemistry textbook, and the case study required access to prospective Saudi EFL students in a vocational college. Both the supervisor and a member of the ethics approval committee were consulted prior to extracting the text and they confirmed via email that no approval was required as nothing was being breached by conducting the present corpus analysis of one IGCSE chemistry textbook. However, approval was required from the ethics committee for conducting the interviews in this case study. Therefore, I sought to obtain approval from the university by submitting the university's ethical clearance form, after several modifications, it was accepted (see Appendix 8).

The gatekeepers, or the institute in this study, should be informed regarding "the purpose, methods and intended possible uses of the research, what their participation in the research entails and what risks, if any, are involved" (Economic and Social Research Council, ESRC, 2010, p.2). The gatekeeper in particular in this research was the institute's senior management team. The final consent rests with the students, depending on how competent the student is about what it means to participate in the research (Wiles, Heath, Crow & Charles, 2005). The participants in this study were all adults, aged 19 and over, and were more than capable of making an informed decision. I provided interested participants, and the management team of the institute, with a combined information and consent form. There was a separate form tailored for the management team (see Appendix 9), and another for the Saudi EFL students (see Appendix 10). The student version of the form was written in Arabic and the document translations were carried out by a licensed company in Saudi Arabia, and thus it is assumed that there were no significant changes to the original meaning. A bilingual member of the management team went through the information and consent forms with the students. The participants gave their consent to be interviewed individually and for the data to be analysed and presented anonymously in this thesis.

Students may feel that the research is linked to their class work (Wiles *et al*., 2005), however, it was made very clear in the consent form that their participation is voluntary. Moreover, this was emphasised by the senior management team. Students may also feel that they have to complete the interview, especially as they agreed, or they may feel shy to say that the interview is too long. At the start of the interview, and at several points within the interview, the students were asked if they were happy to continue. Throughout this study, I ensured that the institute and the participants remained anonymous, and strict confidentiality was upheld. All participant names used in this study are pseudonyms. Even though no such instances occurred, I acknowledged that confidentiality cannot be kept unrestrictedly, as for instance, a situation could occur where harm is being caused, or that harm could be prevented, in which case the researcher has a duty to notify the authorities (Wellington, 2000).

4.7 CHAPTER SUMMARY

The overall methodology adopted for this study is case study research. In order to address the research questions a sequential explanatory design was found to be the most appropriate design as the first phase of the study builds into the second phase. The first phase involved a corpus based study to identify potential non-technical words from the participants' core chemistry textbook. This chapter detailed the procedures to construct the corpora using WordSmith Tools which is a corpus software tool. A step-by-step outline of the production of keyword lists is given, and this includes details regarding the analyses of aspects pertaining to collocations, colligation patterns and potential semantic prosodies. The second phase consisted of eleven semi-structured interviews focussing on investigating the participants' understanding of a selection of the identified non-technical words from the first phase. For both phases of the study, issues pertaining to data collection and analysis procedures are outlined as well addressing ethical and validation matters.

CHAPTER FIVE

PHASE 1 FINDINGS: CORPUS STUDY

5.1 INTRODUCTION

This section reports the findings of the corpus-based study which seeks to identify potential non-technical words in the Saudi EFL college participants' core chemistry textbook and is concerned with research question RQA (What non-technical words are there in the Saudi EFL college students' chemistry textbook?). The findings and analysis of this corpus-based study has been divided according to the corpora which was made from each chapter of the IGCSE chemistry textbook (Harwood & Lodge, 2014), and the procedure for data analysis can be found in section 4.4.6.4. The title of the section headings (5.2 – 5.13) are the same as the textbook chapter headings and the words presented under these sections are in alphabetical order. As the sections progress, no keyword is repeated within the same context so as to avoid any unnecessary repetition, though it is recommended to refer to the full list of keywords in the appendices (Appendix 2) to see if the keyword appears in other textbook chapters. Keywords are only repeated in cases where the context is considerably different to what has already been mentioned. Note that the subheadings refer to the everyday word which occasionally is not a keyword, but a collocation of it.

Table 5.1 provides information on the number of words in total in each corpus (tokens), the number of distinct (or unique) words in that corpus (types), and the number of keywords. There are a few points to note regarding this data. The totals for the tokens are not reflective of the actual chapter in the textbook as I discussed earlier in section 4.4.6.2 that unsuitable material was omitted.

Also, not all the corpora are similar in size as the largest is 9733 tokens and the smallest is 3378 tokens which is a significant difference, and the same difference is noticed for types and keywords.

Table 5.1
Number of Tokens, Types & Keywords for the Study's Corpora

Corpus	Tokens	Types	Keywords
Planet Earth	3756	936	77
The nature of matter	9733	1494	174
Elements and compounds	7865	1167	149
Chemical reactions	7946	1177	164
Acids, bases and salts	7365	1116	160
Quantitative chemistry	4570	754	113
How far? How fast?	6830	1191	136
Patterns and properties of metals	4690	952	111
Industrial inorganic chemistry	5585	1210	127
Organic chemistry	4600	1022	112
Petrochemicals and polymers	3501	936	96
Chemical analysis and investigation	3378	857	78

The concordance lines in this section attempt to primarily highlight significant collocations, and to a certain extent, inform the reader of the various contexts in which the keyword is used. Where the concordance line appears limited, contextual information is provided in the main text of this chapter. When the position of the collocates is denoted by an alphanumerical code, it means the position relative to the keyword; so L1 would mean one position to the left of the keyword. Oxford Dictionaries (2017) was used as the main dictionary, and where appropriate reference was made to the sense of the keyword to highlight how common the meaning is for words that have more than one meaning. Section 5.13, corresponding to chapter 12 of the chemistry textbook, has been reported in a different manner due to the nature of this chapter and details of this can be found therein.

5.2 PLANET EARTH

Air and Gases

A gas is most commonly known as "an air-like fluid substance which expands freely to fill any space available, irrespective of its quantity" (e.g. "poisonous gases") (Oxford Dictionaries, 2017). In the chapter on Planet Earth, gas collocates three times with the word acidic at position L1 (see concordances 1 – 3, Table 5.2). Acidic is an adjective meaning "having the properties of an acid, or containing acid; having a pH below 7" (e.g. "When this compound is dissolved in water, an acidic solution of hydrogen cyanide, also known as prussic acid, is produced.") (Oxford Dictionaries, 2017). An acid is commonly known as a liquid, and therefore things which are acidic are normally solutions, which is clearly different to gases and this could cause problems in terms of students understanding the real physical state of acidic gases.

Table 5.2
Selected Concordance Lines for 'Gas' and 'Air'

No.	Concordance
1	on, however, is to prevent the acidic gases from being released in the first pla
2	ul. In many countries, though, acidic gases from power stations are still a seri
3	urnaces. In these devices, the acidic gases are passed through an alkaline subst
4	a liquid (liquefies). Then the liquid air is allowed to warm up again. The vari
5	the fractional distillation of liquid air, and that the separated gases have th

A similar problem exists with the collocation 'liquid air', though there are only two instances of this collocation (see concordance lines 4 & 5, Table 5.2). In this case students may find it difficult to understand air as a mixture of gases, and misunderstand air to be in a gas state, unrestrictedly. This meaning which results in conflating gas and air can be found in the definition of a gas as the Oxford Dictionaries (2017) defines gases as "air-like". Despite the dictionary definition, such distinctions do not fit well with what is known of gas and air in chemistry due to their meaning which requires a submicroscopic understanding of these terms.

Energy and Power

Out of a total of 19 concordances, there were eight adjective + noun structures of energy, with energy as the head noun. Two of these adjectives were quantifiers (little and more), and the other six adjectives described energy with an extended meaning related to type (see Table 5.3).

Table 5.3
Selected Concordance Lines for 'Energy'

No.	Concordance
1	droelectric power (6.4%) and nuclear energy (4.9%) do make a contribution, altho
2	ion, although the figure for nuclear energy has fallen in this time. In 2011, on
3	gy to the Earth. The amount of solar energy falling on the Earth's surface is im
4	e efficient way of changing chemical energy into electrical energy by using a fu
5	ging chemical energy into electrical energy by using a fuel cell. A hydrogen fue
6	ce that hydrogen is one possible new energy source that is currently under devel

In science, energy is not made up of anything else nor are there variations of energy. It exists in different forms such as sound energy and electrical energy, but essentially they are all energy as there is no differentiation in this respect. Everyday usage of energy pertains mainly to "strength" for the body (e.g. "What I was about to do would require a lot of energy…") (Oxford Dictionaries, 2017). Without scientific knowledge of energy, students will likely understand that there are different types of energy and this would be simply added to their everyday understanding of energy and development of a belief that there are different kinds of energy.

Power was also found to be used in the same way (see Table 5.4). In these examples there are adjective + power structures with several adjectives such as wind, solar, and nuclear. Power in science is related to the transfer of energy, and though on the outset the structure allows students to understand that the source (for example electricity) is providing power, appreciation may not be given to the transfer of energy in this process and consequently the understanding of energy being energy.

Table 5.4
Selected Concordance Lines for 'Power'

No.	Concordance
1	use of our renewable resources. Wind power, solar power and water power from ri
2	between 2006 and 2011. Hydroelectric power (6.4%) and nuclear energy (4.9%) do
3	solar power, wind power and wave power combined. Clearly change is necessary
4	heap surplus electricity from nuclear power may make electrolysis more economica
5	based on the production of electrical power using the combustion reaction for hy

Fossils

Fossils are "the remains or impression of a prehistoric plant or animal embedded in rock and preserved in petrified form" (Oxford Dictionaries, 2017). Fossil appeared eleven times of which nine of them collocated with 'fuels', as in fossil fuels, forming a compound noun (see Table 5.5). There seems to be a negative connotation associated with fossil fuels because it is made out to be bad for the environment as other words within a few words span such as 'concern' and 'problem' make this negativity evident. This may have an effect on students' everyday usage in terms of prosody, as they may think of fossils as bad for the environment, when in actuality it is the burning of fossil fuels that is harmful. This could be a case of semantic prosody transferring from the context of chemistry to a student's everyday understanding of the word. Though the example sentences for 'fossil' in Oxford Dictionaries (2017) did not show any sort of prosody (Table 5.6, 1-3), its collocation 'fossil fuel' had 2 out of 20 examples in a negative context (Table 5.6, 4-5).

Table 5.5
Selected Concordance Lines for 'Fossils'

No.	Concordance
1	ng the process of extraction costly. Fossil fuels are another concern. New depos
2	hich comes mainly from fossil fuels. Fossil fuels are a bigger problem. We will
3	of 'problem' gases is the burning of fossil fuels. Most countries produce electr
4	s increase the problem. Burning less fossil fuel and planting more trees would h

Table 5.6
Example Sentences of Fossil and Fossil Fuels

No.	Example Sentences
1	There is an abundance of shelly animal fossils.
2	The oldest true vertebrate fossils date back 530 million years.
3	Very few dinosaur fossils are actually found near this boundary.
4	Burning fossil fuels is the main way humans add greenhouse gases to the environment.
5	If we burn a fossil fuel like coal, the tax is $15 per tonne.

Renewable

Renewable is an adjective meaning "capable of being renewed" (e.g. "We are on renewable contracts.") (Oxford Dictionaries, 2007). 'Resources' collocated with renewable seven out of the ten instances at position R1 (see Table 5.7). In chemistry, a renewable resource is a source "of energy and other resources which cannot run out or which can be made faster than our current rate of use" such as solar energy and wind (Harwood & Lodge, 2014, p.343). In its everyday meaning, the thing which needs to be renewed can run out or expire. With insurance for example, the policy can expire and would require one to renew his/her car insurance. Whereas, for instance, wind energy, it is renewable because by definition it does not run out.

Table 5.7
Selected Concordance Lines for 'Renewable'

No.	Concordance
1	solution is to make more use of our renewable resources. Wind power, solar power
2	is the way in which our potentially renewable resources are being affected by ov
3	d on our short human timescale. Non-renewable resources are those that exist in

5.3 THE NATURE OF MATTER

Boiling

Boiling can be both a noun and an adjective. As a noun it means “the action of bringing a liquid to the temperature at which it bubbles and turns to vapour” (e.g. “Reheat the sauce to just below boiling point.”) (Oxford Dictionaries, 2017). When used as an adjective, it also carries the same meaning, but informally it means “extremely hot” (e.g. “Saturday is forecast to be boiling and sunny.”) (Oxford Dictionaries, 2017). In chemistry, to some extent, the meaning of boiling is the formal meaning and it is most commonly used as an adjective with ‘point(s)’ appearing at position R1, 32 out of the 34 concordances (see Table 5.8). The remaining 2 concordances were its noun form.

Table 5.8
Selected Concordance Lines for ‘Boiling’

No.	Concordance
1	g the pressure, without cooling. The boiling point of a liquid can change if the
2	ure changes. The value given for the boiling point is usually stated at the pres
3	(Figure 2.5, overleaf). Evaporation, boiling and condensation. If a liquid is lef
4	the liquid. This process is known as boiling. It takes place at a specific tempe

Despite the strong relationship between the formal meaning and its textbook meaning, the informal meaning does pose some issues. When something is boiling in its informal sense, you would expect high temperatures, but in chemistry, boiling means more than just the temperature. It is the “condition under which gas bubbles are able to form within a liquid [and] escape from the body of liquid” (Harwood & Lodge, 2014, p.337). A boiling point is “the temperature at which a liquid boils when the pressure of the gas created above the liquid equals atmospheric pressure” (Harwood & Lodge, 2014, p.337). In other words, the temperature at which boiling occurs is not limited to being high, but rather, governed by the process. The prosody of boiling occurring at hot temperatures cannot be applied in the context of chemistry. Boiling collocated with low and lowest several times, whereby in two instances ethanol was used as an example of a substance with a low boiling point of 78^{o}C (see concordance lines 1 & 2, Table 5.9).

Table 5.9

Selected Collocations 'Boiling'

No.	Concordance
1	le liquid. Ethanol, with a boiling point of 78 °C, is more v
2	y and has a relatively low boiling point. Ethanol (b.p. 78 °
3	The boiling point of the liquid is usually very much lower
4	he mixture with the lowest boiling point (the most volatile)
5	the liquid with the lowest boiling point that distils over f

Other compounds cited in this textbook chapter have boiling points in the negative such as carbon dioxide (-78^{o}C) and oxygen (-183^{o}C). Such examples could be difficult to accept as it is far in meaning from the informal use of boiling. The terms melting and freezing could also be problematic for the same reason, however, there were no significant collocations with melting for any term associated with low, nor the term high with freezing. Although, similar to boiling, there were three cited examples of compounds having low melting points: oxygen (-219^{o}C), nitrogen (-210^{o}C), and ethanol (-117^{o}C). Students may not appreciate the predominance of the process of boiling over the temperature at which a substance boils.

Liquid

Liquid as a noun means "a substance that flows freely but is of constant volume, having a consistency like that of water or oil" (e.g. "Drink plenty of liquids.") (Oxford Dictionaries, 2017). When used as an adjective, it carries the meaning of "consistency" but also includes "having the translucence of water; clear" (e.g. "Look into those liquid dark eyes.") (Oxford Dictionaries, 2017). There seems to be a strong correlation of liquids with that of water in its common use. There were 68 entries for liquid and 21 for liquids in the keyword list. No conclusions could be drawn from the statistically significant collocations that would suggest inconsistent use of liquid with that of its everyday meaning, except in one instance. The word volatile was highlighted as a significant collocate with 5 instances of it occurring at position L1 and one at R3 (see Table 5.10). If liquids are to be related to water, then a property such as volatility does not reflect the property of water, as it is not volatile. Further, though there was only one instance of the word liquid directly modifying another liquid at position L1, as in 'liquid bromine', the properties of bromine could be mistakenly taken as similar to water.

Table 5.10
Selected Concordance Lines for 'Liquid'

No.	Concordance
1	anol (b.p. 78 °C) is a more volatile liquid than water (b.p. 100°C). The reverse
2	er volatility than water. A volatile liquid is one which evaporates easily and h
3	han that of the dissolved solid. The liquid is more volatile than the dissolved
4	ional distillation the most volatile liquid in the mixture distils over first an
5	iling point — it is quite a volatile liquid. Ethanol, with a boiling point of 78
6	ls over first and the least volatile liquid boils over last. For example, ethano

The keyword 'liquid' also collocates with the word solid 22 times and with gas 14 times (see Table 5.11). In all these cases, liquid is something different from solids and gases, as it is considered as one of the three states of matter. However, there were a few cases of when liquid is used as a modifier (adjective) for nouns which are certainly unrelated to not only water, but the term liquid itself (see Table 5.12). The word liquid modifies nouns that are solids (metals and iron), and a gas (air) at room temperature. It is the everyday usage of metals, irons and air that give them their prosody of only existing in such states.

Table 5.11
Selected Collocations of 'liquid' with 'Solid' and 'Gas'

No.	Concordance
1	these particles differs in a solid, liquid or gas, how changing physical state
2	a particular substance is a solid, a liquid or a gas at room temperature. These
3	y is needed to change a solid into a liquid, or a liquid into a gas. During the

Table 5.12
Selected Concordance of 'Liquid' as Modifier

No.	Concordance
1	lutions. They are made by mixing the liquid metals together (dissolving one meta
2	forms a separate layer on top of the liquid iron. The two can then be 'tapped' o
3	he diffusion of gases A few drops of liquid bromine are put into a gas jar and t
4	(page 276), the different gases from liquid air (page 7). Study tip In fractiona

Organic

Organic is an adjective with a number of meanings including "produced or involving production without the use of chemical fertilizers, pesticides, or other artificial chemicals" (e.g. "organic farming") (Oxford Dictionaries, 2017). In chemistry, it is defined as a "branch of chemistry concerned with compounds of carbon found originally in living organisms" (Harwood & Lodge, 2014, p.342). The everyday prosody attached to organic is that being free from chemicals, yet, as expected in chemistry, it is directly related to chemicals. There were six instances of organic in this chemistry chapter, and solvent collocates in five of these concordances (see Table 5.13)

Table 5.13
Selected Concordance Lines for 'Organic'

No.	Concordance
1	re used in chromatography. Water and organic solvents (carbon-containing solve
2	d solution and propanone are common. Organic solvents are useful because they
3	that are insoluble in water. When an organic solvent is used, the process is car
4	nt. Most of these other solvents are organic liquids, such as ethanol, propanone
5	propanone and trichloroethane. These organic solvents are important because th

The solvents being referred to as organic are chemicals such as ethanol and trichloroethane. It could be difficult for students to understand how chemicals could be organic, especially as these substances are made industrially. Further, ‘organic farming’ is for the purpose of eating healthily, yet, these chemicals are harmful. Organic in chemistry is almost opposite to its everyday sense.

Particle

Particle is a noun meaning “a minute portion of matter” (e.g. “tiny particles of dust”) (Oxford Dictionaries, 2017). From this first sense in the dictionary, we can understand particles as something which is a smaller part of a whole. So in the example given, a particle of dust is still dust, but just a part of the whole dust. Particles appeared 50 times in this textbook chapter, and there was one instance of the word particle (no ‘s’ for plural form). In many of the concordances, such as those below, ‘particles’ is used in line with the dictionary definition (see Table 5.14).

Table 5.14
Selected Concordance Lines for ‘Particle’

No.	Concordance
1	One phase is broken up into small particles, droplets, or bubbles, within the main
2	this type of mixture is a suspension of fine particles of a solid in a liquid, such as
3	achieves a separation — especially if the particles of solid are large enough. On
4	howed random motion of dust particles in suspension in water or smoke particles
5	involved. But the spreading of the solute particles throughout the liquid is an exa

In these concordances, the particles are a small part of a whole thing, as in ‘dust particles’ and ‘solute particles’. On the other hand, there are several instances where this meaning is not used according to its everyday definition. The word atom collocates with ‘particles’ 5 times at positions L5, L4, R3 and R4, and twice with ‘molecules’ at L4 and R5 (see Table 5.15). These concordances show that the word particle is used synonymously with the words atoms and molecules; in essence, they are defined as particles in all these concordances. The textbook definition of an atom is: “the smallest particle of an element that can take part in a chemical reaction” (Harwood & Lodge, 2014, p.336). This in itself is different from the everyday definition and example, as the smaller part of the whole is not given a specific name. The 'tiny particles of dust' is no more than a dust particle; yet, a particle of an element is defined specifically as an atom and not an 'element particle'. As for molecules, it is defined as "a group of atoms held together by covalent bonds" (Harwood & Lodge. 2014, p.341). This means that some students may think that technically an atom is a particle of a molecule. Particles also collocated with 'subatomic' (see concordance line 3, Table 5.15), though concordance 6 in the same table shows particles being referred to as protons, neutrons, and electrons.

This varied use of the word particles can be a cause of much confusion as in the macroscopic level of chemistry particles have no specific name, but when the submicroscopic level is being explained, particles have defined names, and in a sense, the concept of whole and a portion of this whole becomes unclear. The word particle can be used for both the macroscopic and the submicroscopic levels, but that which is defined as a particle in the submicroscopic level would cease to have the same meaning in the macroscopic level. We could not say 'dust electrons' or 'dust protons', as such things do not exist in chemistry.

Table 5.15
Selected Collocations of 'Particles' with 'atoms' and 'molecules'

No.	Concordance
1	size and mass, atoms are the smallest particles that take part in a chemical re
2	substances contain different types of particles — such as atoms or molecules)
3	atoms consisted of three subatomic particles — protons, neutrons and electron
4	matter was infinitely divided into very small particles known as atoms. These
5	molecules to explain the particles making up compounds such as water, carbon
6	three subatomic particles — protons, neutrons and electrons. These particles

Physical

Physical is an adjective meaning that which relates "to things perceived through the senses as opposed to the mind"; it is something which is "tangible or concrete” (e.g. “less physical sports such as bowls”, “the physical world”) (Oxford Dictionaries, 2017). We can see from the senses that physical refers to something tangible which is evident in the real world as we see it. However, in many cases, the word physical is used to explain things which are not tangible in the real world. There were 19 instances of physical in this chemistry textbook chapter, and ‘properties’ collocated with physical at position R1 in five of these concordances (see Table 5.16). A further analysis of what is actually mentioned about physical properties revealed that these properties were not concrete properties. They are in fact abstract properties. As an example, the first concordance is referring to submicroscopic arrangements in lattices (in completion: ‘to explain their different overall physical properties. The highly structured, ordered microscopic arrangements (lattices) in solids can produce the regular crystal structures seen in this state’); the concordances which mention isotopes are referring to properties related to masses of atoms.

Table 5.16
Selected Concordance Lines for ‘Physical’

No.	Concordance
1	to explain their different overall physical properties. The highly structured,
2	in some way on a difference in the physical properties of the substances in the
3	rified. Some suitable difference in physical properties needs to be found. Usual
4	cts with other atoms. However, some physical properties of the isotopes are diff

In chemistry, ‘physical change’ is used as an antonym to ‘chemical change’, rather than the everyday antonyms physical and mental. A chemical change is one where a new substance is formed and this in many cases is observed by an actual change as identified by sense, such as a change in colour. This is closer in meaning to the everyday meaning of physical and so the meaning of physical differs in the context of chemistry macroscopically.

Space

From the meanings of the noun space is: “continuous area or expanse which is free, available, or unoccupied” (e.g. [The] “table took up much of the space.”; “He reversed out of the parking space.”) (Oxford Dictionaries, 2017). When we use space in the everyday sense we refer to it to define a place which can be designated for something. There are several examples from the 10 instances of space which are used in this way (see Table 5.17).

Table 5.17
Selected Concordance Lines for ‘Space’

No.	Concordance
1	roperties in common: they each occupy space (they have volume) and they have
2	2.26). Gases diffuse to fill all the space available to them. Diffusion is impo
3	loric particles spreading to fill the space available to the molecules. Key defi

In these concordances of space, something is going to occupy the space. However, the meaning of space in chemistry is more literal in the sense that space is nothing – it is literally empty. All 10 concordances of space are referring to a submicroscopic context, where the general meaning is not entirely applicable. So although the general meaning can be applied to some degree, the idea of complete emptiness may be incomprehensible for a student as it requires thinking which is beyond their daily experiences of space.

Substance

Substance is a noun which carries several meanings. From its common meanings are: “a particular kind of matter with uniform properties” (e.g. “a steel tube coated with a waxy substance”); “the real physical matter of which a person or thing consists and which has a tangible, solid presence” (e.g. “Proteins compose much of the actual substance of the body.”); and “an intoxicating, stimulating, or narcotic chemical or drug, especially an illegal one” (e.g. ‘‘He was suspended for using a banned substance.”) (Oxford Dictionaries, 2017). The last aforementioned meaning indicates a negative prosody as it is used in the context of illegal drugs. Substance and substances appeared 93 times in total (see Table 5.18).

Table 5.18
Selected Concordance Lines for 'Substances'

No.	Concordance
1	Pure substances A pure substance consists of only one sub
2	we do not 'handle' pure substances very often. The air we b
3	mperature at which a pure substance turns to a liquid is cal
4	ge takes place, how pure substances have precise melting and
5	can be used to purify a substance from a mixture, how pure
6	check for the purity of a substance. If the sample is pure,
7	only one substance. There is nothing else in it: it has no contaminating impurities

One of the strongest collocates is 'pure', whereby it collocates with substance(s) 23 times; other similar words such as purify and purity also collocated five and three times respectively. The collocation is so frequent that it would appear that substances must be pure in its natural state, and that any impurities found within it are problematic. It could also suggest that pure substances are not common, and so it must be emphasised. This prosodic characteristic of substance being pure does not match with the negative prosody of substance as a "narcotic chemical or drug" as defined in the Oxford Dictionaries (2017).

There are also several collocations of pure substance with compound and related examples of chemical compounds (see Table 4.19). Since the dictionary senses indicate that a substance is a single thing coupled with the collocation of pure substances, it may be hard for students to accept that compounds are also substances as they are made of more than one type of element. For a student, this would be believable in the macroscopic world, but not in the submicroscopic world. Compounds, such as water, are seen as one substance macroscopically, but when viewed submicroscopically pupils may find it difficult to relate to it as a substance as it is made of other elements.

Table 5.19
Selected Collocations of ‘Substance’ with ‘Compounds’

No.	Concordance
1	There are two types of pure substance — elements and compounds
2	compounds — pure substances made from two, or more, elements chemically co
3	compound breaks down to form two or more substances, is known as decomposit
4	broken down into simpler substances. Thus, lead (II) bromide, which is a white po
5	how pure chemical substances can be either elements or compounds

5.4 ELEMENTS AND COMPOUNDS

Arrangement

An arrangement is “a thing that has been arranged in a neat or attractive way” (Oxford Dictionaries, 2017). This term appeared 18 times in this textbook chapter with the term ‘electron’ collocating at position L1 in 14 of these appearances (see Table 5.20). In this context, electrons are being described in terms of their position within atoms. The understanding at this level (as Key Stage five is considerably different) is that electrons orbit shells, with the inner shell having two electrons and latter ones having a maximum of eight. Though, with the word arrangement, it may be assumed that electrons have been allotted fixed positions within these shells. The everyday connotation of arranged items being neat, orderly and fixed does not reflect the real arrangement of electrons in a shell. The word stable, which collocates at L2 five times and at L1 three times, could further emphasise the electrons being static (see concordance lines 1 & 2, Table 5.20). The symbolic aspect, through 2D electron images, also contributes to the reaffirmation of the everyday connotation in the chemistry context. The idea of a thing orbiting and being arranged may not make sense to students due to their everyday experience.

Table 5.20
Selected Concordance Lines for 'Arrangement'

No.	Concordance
1	hey achieve a more stable electron arrangement, usually that of the nearest nobl
2	formed have a more stable electron arrangement, usually that of the noble gas ne
3	lear relationship between electron arrangement and position in the Periodic Tabl

Gain and Lose

Ionic bonding is described in terms of gaining or losing electrons (see Table 5.21). Metals lose the electrons in their outer shell to form positive ions and non-metals gain electrons to form negative ions. The metal and non-metal form a bond with these opposite electrostatic charges. To lose is to "be deprived of or cease to have or retain (something)" (e.g. "I've lost my appetite.") (Oxford Dictionaries, 2017). Gaining is to "obtain or secure (something wanted or desirable)" (e.g. "We gained entry to the car in five seconds.") (Oxford Dictionaries, 2017). On the one hand, lose has a negative connotation and is undesirable; gain, on the other hand, has a desirable and positive connotation. If these connotations are applied in the context of ionic bonding it appears that it is an undesirable affect whereby metals lose electrons, and that non-metals are somewhat in a better position than their metal counterparts as they are gaining electrons in the process. In terms of chemistry, there is no such connotation and we cannot say that one atom is better off than the other. Such connotations could lead to mistakenly thinking that non-metals are stronger than metals in ionic bonding.

Table 5.21
Selected Concordance Lines for 'Gain' & 'Lose'

No.	Concordance
1	trons and the Group I elements lose electrons to reach a noble-gas electron arra
2	trons. Metal atoms more easily lose electrons than gain them. So, they become
3	ositive ions because they have lost electrons but the number of protons in the n
4	Generally, atoms of non-metals gain electrons to become negative ions. Again in
5	ive charge because they have gained electrons to make a stable structure. Ex

React

In chemistry, when Group I metals react with water, they in fact react with each other to form a metal-hydroxide and hydrogen gas is given off. An ionic bond exists between the positive metal ion and the negative hydroxide. Similarly, halogens form ionic bonds with metals. Both reagents contribute to the reaction, and we cannot consider one reagent as overpowering the other one. In Table 5.22, concordance line 1, the subject of the sentence is 'Group I metals' and the object in the sentence is water. With this word order, students may assume that Group I metals are more powerful than water. This potential misconception in this matter is due to colligation. Had the sentence been written with water as the subject, 'water reacts with Group I metals', it would seem as if water is more powerful. The same could be said for concordance line 3 (Table 5.22), as it appears as though the halogens are more powerful, or even more reactive, than metals.

Table 5.22
Selected Concordance Lines for 'React'

No.	Concordance
1	go down the group. All Group I metals react with water to form hydrogen and an
2	own as the alkali metals because they react vigorously with water to produce hyd
3	halides. The halogens themselves can react directly with metals to form metal h

Simple and Giant

Simple molecular substances are "substances made up of individual molecules held together by covalent bonds: there are only weak forces between the molecules" (Harwood & Lodge, 2014, p.344). Due to the weak forces between molecules they tend to have low boiling points. Giant molecular structures, on the other hand, are harder to break apart as all the atoms are interlinked with covalent bonds and not weak attractive forces. The terms appear together in the sense that covalent bonding results in either simple molecular structures or giant covalent structures and could be taken as direct opposites of each other (see Table 5.23). Both implied meanings could result in misunderstanding the nature of molecules, as the actual science behind the terms may be unappreciated. A simple molecular substance is not in reality related to its simplicity in look, but because of the weak attractive forces between molecules. Furthermore, the term giant may remove the idea of molecules as particulate and thus it could make the molecular structure seem macroscopic.

Table 5.23
Selected Concordance Lines for 'Simple' & 'Molecular'

No.	Concordance
1	gases). Covalent bonding results in simple molecules or giant molecular lattice
2	y covalent bonding, which results in simple molecules or giant molecular lattice
3	ng produces two types of structure — simple molecules and giant molecular (mac
4	in structure and properties between simple molecular and giant molecular covale

5.5 CHEMICAL REACTIONS

Agent

The word agent appeared nine times in this chapter, with L1 collocates of reducing and oxidising occurring five and four times respectively (see Table 5.24). All nine concordances of this term are related to either its definition or an example of the term. The context in which these words appear are related to redox reactions. In a redox reaction both oxidation and reduction occur. Oxidation could refer to the gain of oxygen, the loss of electrons, or an increase in the oxidation number. On the other hand, reduction could occur due to the loss of oxygen, the gain of electrons, or a decrease in the oxidation number. For instance, when sodium reacts with chlorine, sodium loses an electron, or it can be said that it has been oxidised; whereas, the chlorine atom has gained an electron, or it gets reduced. A reducing agent is a "substance which reduces another substance during a redox reaction" (Harwood & Lodge, 2014, p.343);

and an oxidising agent oxidises another substance. The opposite happens to the agent itself, so oxidising agents themselves get reduced and reducing agents get oxidised. The everyday meaning of an agent is “a person who acts on behalf of another person or group” (Oxford Dictionaries, 2017). This seems quite different to the role of oxidising and reducing agents. In an everyday scenario, a person may purchase an airline ticket through a travel agent, so in essence there are three entities, the purchaser, the travel agent, and the airliner. In a redox reaction, the reducing or redox agent is like the travel agent and airliner in one. It is not only assisting the other substance by providing or removing electrons, but it gets reduced or oxidised itself – in other words, it is not just a mediator between two entities. So the term agent may lead students to falsely believe that oxidising and reducing agents are mere mediators in redox reactions.

Table 5.24
Selected Concordance Lines for ‘Agent’

No.	Concordance
1	e. Carbon is an example of a reducing agent. Key definition reducing agent - an
2	n the process of acting as a reducing agent, that substance will itself be oxidi
3	sing agents. Key definition oxidising agent — a substance that will add oxygen
4	ne, for instance, is a good oxidising agent. It displaces iodine from potassium

Discharged

The everyday meaning of discharge is to “tell (someone) officially that they can or must leave a place or situation” (e.g. “Six of the patients were discharged from the hospital.”) (Oxford Dictionaries, 2017). The term in this chapter had 14 entries, all of which were relating to the topic of electrolysis (see Table 5.25). In electrolysis, an aqueous solution of an ionic compound exists as ions in the solution. The positive ions move to an electrode called the cathode (negative terminal) and the negative ions move to the anode (positive terminal). The ions get discharged, or ‘lose their charge’ (concordance line 2, Table 5.25). This results in the breakdown of an ionic compound. The ions do not ‘leave the place or situation’ as is understood in every day terms. Rather, it remains in the electrolytic cell.

Table 5.25
Selected Concordance Lines for ‘Discharged’

No.	Concordance
1	to the electrodes. They are then discharged at the electrodes. A solid ionic
2	they lose their charge (they are discharged). Figure 4.20 shows this movement.
3	move to the cathode and are discharged. Non-metal ions (except hydrogen),
4	anions and move to the anode to be discharged. When a molten ionic compound

Reduction

There were 19 concordances of reduction, all of which were in the context of redox reactions. A brief explanation of this reaction has been given under the same section (5.5) on ‘Agent’. In a redox reaction, reduction has three definitions. One definition relates to the removal of oxygen; another is to do with the gain of electrons; and the third is linked to the decrease of the oxidation state. The definitions related to the ‘removal’ of oxygen and the ‘decrease’ in oxidation number share the same everyday meaning to reduction. However, the second definition relating to the ‘gain’ of electrons is the opposite of its everyday meaning. In order to appreciate the connection of reduction with ‘gain’ of electrons would require comprehensive knowledge of the term as those substances which decrease their oxidation number are in fact gaining electrons.

5.6 ACIDS, BASES & SALTS

Base

Base (and bases) appeared 32 times in this chapter (see Table 5.26). It has several meanings: “the lowest part or edge of something, especially the part on which it rests or is supported”; “a conceptual structure or entity on which something draws or depends” (e.g. “the town's economic base collapsed”); “a main or important element or ingredient to which other things are added" (e.g. "soaps with a vegetable oil base") (Oxford Dictionaries, 2017). In chemistry it has a specialised meaning relating to neutralising acids which results in the production of salts. Bases are metal hydroxides or metal oxides and they accept protons in neutralisation reactions.

Table 5.26
Selected Concordance Lines for 'Base'

No.	Concordance
1	group within that extended family. A base will neutralise an acid, and in the p
2	neutralisation between an acid and a base produces a salt and water only that a
3	a further definition of an acid and a base in terms of hydrogen ion (proton) tra
4	ainly insoluble in water. Alkalis are bases that dissolve in water, and: feel so

If the everyday properties of bases were to be applied to the context of chemistry, this would certainly lead to some misconceptions. One of the definitions stated above, which is the most common, is related to bases being the 'lowest part'. In an acid-base reaction, one could incorrectly assume that the base would be at the bottom of the solution, or even remain there. The other definition given above is that of something which is dependent upon, or the main thing. This connotation, if falsely transferred in this topic of chemistry, would lead to believing that bases are more important than acids in neutralisation reactions. If base was understood as the example of a 'vegetable base', a student may assume that the base is the main substance, and that the acid is a minor substance added to it. In concordance line 1 (Table 5.26), it is stated as the base neutralising the acid, and this could further reinforce this false connotation. In essence the properties of a base in chemistry is very much different from that of the everyday meaning, and any attempts of transferring these properties would lead to an incorrect understanding of the term.

Salt

The first dictionary sense describes salt as “A white crystalline substance … used for seasoning or preserving food” (Oxford Dictionaries, 2017). A salt in chemistry is produced from a neutralisation reaction between acids and alkalis. Common salt, known as sodium chloride, is the salt which people are familiar with in an everyday context. However, salts in the chemical sense differ vastly in terms of their properties and appearance. Some examples from the textbook include hydrated copper (II) sulfate which is blue and iron (II) sulfate which is green. Students would need to extend their understanding of what a salt is by appreciating how they are produced in chemical reactions.

Strong and Weak

Strong collocated nine times with both ‘acids’ and ‘alkalis’ at positions R1 or R3, and weak collocated in the same way eleven times (see Table 5.27). A strong acid is “is completely ionised when dissolved in water – this produces the highest possible concentration of H^+(aq) ions in a solution” whereas a weak acid partially dissociates into ions in water and producing “a low concentration of H^+(aq) in the solution” (Harwood & Lodge, 2014, p.344). For example, hydrochloric acid is a strong acid because all the hydrogen ions fully dissociate in a solution, whereas ethanoic acid is weak as its hydrogen ions only partially dissociate in water. Therefore, if we were to increase the ratio of ethanoic acid to water, it would not make it a strong acid, it would only increase its concentration. Thus the terms strong and weak cannot be used with their everyday meaning of ‘very intense’ and ‘lacking intensity’ (Oxford Dictionaries, 2017). They are unrelated to concentration and dilution when used as adjectives for acids and alkalis.

Table 5.27
Selected Concordance Lines for 'Strong' & 'Weak'

No.	Concordance
1	completely ionised in solution in water. Weak acids and weak alkalis are partially
2	solution, on the other hand, is a weak alkali because it is only partially dissociated
3	concentration of ions, solutions of strong acids and strong alkalis conduct ele
4	nce in conductivity between weak and strong acids and alkalis shows clearly the

5.7 QUANTITATIVE CHEMISTRY

Relative

The term relative collocated mainly with the words formula, atomic, mass and several times with molecular (see Table 5.28). These chemistry terms are used for calculation purposes in chemistry. In the periodic table, the masses given are not the actual masses of the elements, rather, they are the mass relative to carbon which is measured as 12 atomic mass units. So, if an element is double the mass of carbon, its mass will be 24. The meaning of relative in chemistry and what is known in everyday English is similar in that it is something which is "considered in relation or in proportion to something else" (Oxford Dictionaries, 2017). Though, without the appreciation of masses being relative to carbon, students may assume that these masses are related to other units such as grams which could impede on their understanding of the true nature of atoms.

Table 5.28
Selected Concordance Lines for 'Relative'

No.	Concordance
1	of an element about calculating the relative formula mass as the sum of all the
2	n atoms and one oxygen atom. So its relative formula mass is twice the relative
3	ve atomic mass of hydrogen plus the relative atomic mass of oxygen: Sodium
4	tive atomic mass of sodium plus the relative atomic mass of chlorine: Key defini

Mole

In chemistry moles are used as a counting unit. The mass of one mole is equal to its relative formula mass and it contains 6.02×10^{23} atoms, molecules or formula units (Harwood & Lodge, 2014). For instance, iron has a relative formula mass of 56, and the mass of one mole is 56g. This mass contains 6.02 x 10^{23} iron atoms. Magnesium oxide has a relative formula mass of 40, and the mass of one mole is 40g and this mass contains 6.02 x 10^{23} magnesium oxide molecules. Regardless of mass, the number of atoms or molecules in one mole will always be 6.02 x 10^{23}. In everyday terms, a mole is “a small, often slightly raised blemish on the skin” (Oxford Dictionaries, 2017). Although the context clearly differentiates the meaning of the word there are underlying properties that may be transferred and would lead to alternative conceptions. It may be difficult for a student to comprehend that the same number of atoms or molecules could have different masses as the student may focus on the space taken by the mole. Naturally, if a student was to think of a large facial mole and a smaller mole, he/she would think that the larger facial mole has a greater mass. Similarly, two like sized moles would be thought of as having the same mass. Whereas, in the case of calcium carbonate, the mass of one mole is 100g, and yet the number of molecules in one mole is the same as magnesium carbonate which has a molar mass of 40g. The everyday experience of greater mass correlating with a greater amount does not work in the concept of moles simply because the space that is occupied has no importance in the definition of a mole.

5.8 HOW FAR? HOW FAST?

Activation

Activation collocated with energy 13 times with energy in the R1 position (see Table 5.29). For any reaction to occur, some bonds in the reactants need to be broken in order for the reaction to proceed. This initial energy required is referred to as activation energy which is “the energy required to start a chemical reaction – for a reaction to take place the colliding particles must possess at least this amount of energy" (Harwood & Lodge, 2014, p.336). Reactions continue because as new bonds are formed, energy is released. The meaning is not much different to the everyday meaning of activation as "the action or process of making something active or operative" (e.g. "The constant activation of the vibrating alert is running the batteries down.") (Oxford Dictionaries, 2017). Though, students may believe that this activation energy was the reason for the reaction to continue and that the products formed are a direct result of the activation energy. Sometimes the status of words can only really be fully understood by the actions that follow it. In this case, without appreciating that the reactants themselves have stored energy, the energy needed for activation would not be correctly understood as its role in the reaction would be falsely understood.

Table 5.29
Selected Concordance Lines for 'Activation'

No.	Concordance
1	That is why all reactions have an activation energy. All reactions require some
2	exothermic reactions have a higher activation energy; for example, the burning
3	combined energy greater than this activation energy, otherwise they will not re
4	break the bonds. This reduces the activation energy of the reaction and makes s

Collision

The word collision and its associated word form appeared 27 times in total (see Table 5.30). In order for a reaction to progress successfully there has to be frequent collisions between the reactants. It is these collisions between particles that lead to products being formed as a result of the bonds in reactants breaking and new bonds being formed. Taking some examples of the word collision from Oxford Dictionaries (2017) (see Table 5.31) it becomes apparent that the word has a negative connotation attached to it. All the example sentences relate to some unfortunate event, such as an accident involving people or vehicles. On the other hand, in chemistry, students may think that a collision is something desirable. This false connotation (chemistry is neutral) could be drawn as shown in the concordances on collisions (Table 5.30) such as ‘makes sure that more collisions’ (concordance 2) and ‘the more often they collide the more chance’ (concordance 4). Though it seems difficult to draw any negative connotations of collisions from these concordances, students could potentially apply the everyday negative connotation and think that it is not desirable in chemical reactions.

Table 5.30
Selected Concordance Lines for ‘Collision’

No.	Concordance
1	ing faster. Again, this means that collisions will occur more often, giving more
2	reaction and makes sure that more collisions are likely to give products. The r
3	This increases the chances that a collision will result in bonds in the reactants
4	ccur more often. The more often they collide the more chance the particles have

Table 5.31
Selected Example Sentences of ‘Collision’

No.	Example Sentences
1	A mid-air collision between two aircraft…
2	His car was in collision with a lorry.
3	If they could be aided by some automation advising them on how they might resolve potential collisions…
4	Controversy arose over a collision between Peter and the United goalie…

Equilibrium

In its everyday use, when something is in equilibrium, there is “balance” (also a synonym of equilibrium), as an example, “I stumbled over a rock and recovered my equilibrium” (Oxford Dictionaries, 2017). This person recovered his/her balance as though movement has ceased. The term equilibrium had 26 concordances (see Table 5.32). The context in which equilibrium is mentioned is related to a particular type of reaction where the chemical reaction can proceed both in a forward and reverse direction. In the Haber process, nitrogen reacts with hydrogen to produce ammonia (forward direction), at the same time ammonia breaks down to produce nitrogen and hydrogen (reverse direction). When the rate of the forward reaction equals the rate of the reverse reaction, it is then in equilibrium. The everyday meaning of equilibrium is in harmony with the meaning in the chemistry context. Though, if a student was to understand equilibrium to be as both sides of the reaction being balanced and that there is no actual movement occurring, then this would be incorrect. In these reactions, the reactants are turning into products at the same rate as the products are turning back into reactants. So the overall number of molecules on either side of the chemical equation is ‘balanced’, but this does not negate there being any movement as such.

Table 5.32
Selected Concordance Lines for ‘Equilibrium’

No.	Concordance
1	shortens the time taken to reach equilibrium by increasing the rates of both
2	The equilibrium concentrations (the equilibrium position) for a particular reaction
3	It does increase the rate at which equilibrium is reached. Because of its import
4	Le Chatelier can be applied to this equilibrium too. The reaction to produce sulfur

Making and Breaking

In a chemical reaction, bonds are broken in reactants and new bonds are made to form new products. As stated in concordance 2 (Table 5.33), the making of chemical bonds releases energy, and the opposite is true for the breaking of chemical bonds as this requires energy. It is understandable from everyday experience that breaking something requires energy, but it may be hard to comprehend that making bonds releases energy. When you make something, such as a drink, it requires energy as you have to do something for that thing to be made – you are putting energy in, and not taking it out. The concept of making as used in the macroscopic world is not coinciding with what happens submicroscopically.

Table 5.33
Selected Concordance Lines for ‘Making’ & ‘Breaking’

No.	Concordance
1	requiring energy, while the making of bonds is an exothermic process releasing e
2	gives out energy. Making chemical bonds gives out energy to the surroundings
3	The right-hand side involves bond making and gives out energy: The heat
4	it is a useful fuel. Making and breaking bonds experiments have been carried out

Reverse

In this section (5.8), under the term ‘equilibrium’, I have already scientifically explained the concept of reversible reactions as they can proceed in a forward, or reverse direction. Taking the same example of ammonia, students may not appreciate that the product of the forward reaction (ammonia) breaks down when it goes in the reverse direction. The absence of the submicroscopic explanation may lead them to think that it just goes back to the original products and that no reaction is happening for it to actually go in the reverse direction, just as a vehicle could reverse without any changes being made to the vehicle itself. It is the everyday experience of reverse that may lead to overlooking this point.

Table 5.34
Selected Concordance Lines for ‘Reverse’

No.	Concordance
1	er the same conditions — this is the reverse reaction: In the reaction mixture,
2	mic equilibrium that the rate of the reverse reaction is equal to the rate of th
3	ucing ammonia is exothermic, and the reverse reaction is therefore endothermic:
4	er the same conditions — this is the reverse reaction: In the reaction mixture,

5.9 PATTERNS AND PROPERTIES OF METALS

Copper

In the textbook, there were 42 entries for copper (see Table 5.35) with the term often appearing as compounds of the metal. The colours of its compounds vary significantly, for example blue or green in colour, and this is unlike pure copper which is “a red-brown metal” (Oxford Dictionaries, 2017). This could become especially challenging when students observe experiments and are expected to make predictions. They would need to understand that the properties of its compounds are different from the inherent nature of copper itself.

Table 5.35

Selected Concordance Lines for ‘Copper’

No.	Concordance
1	ome coated in a green layer of basic copper(II) carbonate (Figure 8.9) when expo
2	stic blue-green colour. Solutions of copper salts also give a blue gelatinous pr
3	ive a blue gelatinous precipitate of copper(II) hydroxide if sodium hydroxide is

Displace

One of the definitions of displace is to “move (something) from its proper or usual position” (e.g. “He seems to have displaced some vertebrae.”) (Oxford Dictionaries, 2017). The term displace in the context of chemistry (see Table 5.36) occurs under the topic of displacement reactions. A displacement reaction is “a reaction in which a more reactive element displaces a less reactive element from a solution of its salt” (Harwood & Lodge, 2014, p.338). As an illustration, in the chemical reaction between zinc and copper (II) sulfate, zinc displaces copper to form products zinc sulfate and copper. This occurs because zinc is more reactive than copper. Taking the everyday sense of moving something from its normal position may make zinc sulfate seem to be perceived as something which is produced unnaturally as it has displaced copper from its ‘usual position’. The reality of what makes some metals more reactive than others is a matter beyond the scope of IGCSE chemistry. It requires understanding at a higher level, such as Advanced-Levels where students learn about how electrons orbit the various shells, so such a conception could prove challenging to dismiss.

Table 5.36
Selected Concordance Lines for ‘Displace’

No.	Concordance
1	still react with steam or acids to displace hydrogen gas. For example: The fact
2	oxide how a more reactive metal can displace a less reactive metal from a solute
3	of copper nitrate solution: Copper displaces silver from solution, so copper is
4	ess zinc sulfate (Figure 8.15) Zinc displaces copper from solution, so zinc is m

5.10 INDUSTRIAL INORGANIC CHEMISTRY

Air

Air is an “invisible gaseous substance…a mixture mainly of oxygen and nitrogen” and is “regarded as necessary for breathing” (e.g. “The doctor told me to get some air.”) (Oxford Dictionaries, 2017). It is as though air is synonymous with oxygen as it is one of the important elements we need from air as we breathe. In this textbook chapter, the term air appeared 14 times, and is used in contexts where the reactions taking place relate to the elements or compounds present in air (see Table 5.37). At times the specific gas in air is mentioned, as in concordances 1 and 2 with reference to carbon dioxide. Sometimes, the specific compound or element in air is not stated, as in concordances 3 and 4, where oxygen is not written. Additionally, concordance lines 3 and 4 also represents air as more than just a harmless gas, but one which can even ‘attack metals’ and can be used to ‘burn carbon’. Students would need to think about air submicroscopically as a mixture of gases and deduce which gas is being referred to in the reaction, as this may not be oxygen all the time as understood in everyday terms or air.

Table 5.37
Selected Concordance Lines for ‘Air’

No.	Concordance
1	Figure 9.19). Sulfur is then burned in air to form sulfur dioxide. The main reaction
2	calcium hydroxide reacts with carbon dioxide in the air to form calcium carbonate.
3	prevention. When a metal is attacked by air, water or other surrounding substance
4	of the furnace. The carbon burns in the air blast and the furnace gets very hot.

Impurities

The issue of pure and impure substances is briefly reported on in section 5.3. When something is impure, there is some kind of contamination (synonym of impurity) within the substance, and a contaminated substance is one which is made “impure by exposure to or addition of a poisonous or polluting substance” (e.g. “The site was found to be contaminated by radioactivity.”) (Oxford Dictionaries, 2017). In this textbook chapter, impurities occurred in contexts where chemical reactions involved the extraction of a specific kind of metal (see Table 5.38). Concordance 1 is related to the purification of iron ore, also known as hematite, in which sand is considered to be a major impurity. Carbon is referred to as an impurity in concordance 2 and iron (III) oxide in concordance 3. None of these impurities are considered as contaminates in the day to day world in a general sense, especially when they are compared to the Oxford Dictionary (2017) example of ‘radioactivity’. Yet, in these examples, they are found to be contaminates due to their invaluableness as compared to the desired metal to be extracted. Students would need to understand impurity from this perspective in the extraction process. This example shows how non-technical words have associated synonyms which lead to misunderstandings, rather than the word presented in the chemistry context itself.

Table 5.38
Selected Concordance Lines for ‘Impurities’

No.	Concordance
1	melting point of iron. One of the major impurities in iron ore is sand (silica, SiO_2)
2	contains about 4% carbon, and other impurities. This amount of carbon makes the
3	to 25% of bauxite consists of the impurities iron(III) oxide and sand. The iron
4	iron, limestone is used to remove impurities found in the iron ore as slag (calcium

5.11 ORGANIC CHEMISTRY

Alcohol

Alcohol is commonly known as “the intoxicating constituent of wine, beer, spirits, and other drinks” (Oxford Dictionaries, 2017). In this chapter of the textbook, it has been used in the context of a drink (see concordance 3, Table 5.39), but primarily as a particular functional group known by OH (oxygen and hydrogen) whereby the oxygen bonds to a chain of hydrocarbons (a chain of carbon and hydrogen), for example, methanol and ethanol in concordances 4 and 5 (Table 5.39). What students may understand of alcohol (ethanol) being safe to drink within controlled amounts can no longer apply, as other alcohols such as methanol could cause death – it is not made for consumption by any means. Students are expected to reconceptualise their understanding of something familiar in the macroscopic context, and modify the word’s meaning due to its relation to the submicroscopic realm.

Table 5.39
Selected Concordance Lines for ‘Alcohol’

No.	Concordance
1	that there is an oxygen atom in the alcohol molecule itself. Oxidation Vinegar
2	some long-term damage to the brain. Alcohol is a depressive drug and can be add
3	tional groups, such as that for the alcohols (-OH), later in the chapter. All the
4	tains one carbon atom and is called methanol. Note that the names all have the s
5	hane The industrial method of making ethanol involves the addition reaction that

Branched and Chain

Hydrocarbons, such as alkanes, are a series of carbon atoms bonded together with a maximum of one carbon atom on either side and with an additional two or three hydrogens, but with the carbon atom having no more and no less than four bonds in total. This makes a ‘chain’ of hydrocarbons (see Table 5.40).

Table 5.40
Selected Concordance Lines for ‘Branched’ & ‘Chain’

No.	Concordance
1	the compound is 1,2—dibromoethane. Branched-chain alkanes exist where a hydroca
2	ing points. Hydrocarbons containing branched chains have lower melting points an
3	h to the chain. The carbon atoms in a chain can be linked by single, double or t
4	s are arranged in one 'straight' main chain. However, the atoms do not have to b

This understanding of chain is no different to the everyday meaning of “a sequence of items of the same type forming a line”, but it is different from its first dictionary sense of an actual chain where “a series of metal rings (are) used for fastening or securing something” (Oxford Dictionaries, 2017). This analogy could lead students to believe that hydrocarbons are bonded strongly like a chain is linked together, and that a lot of energy is required to break such a chain. Furthermore, the description of ‘branched-chain’ (see Table 5.40) could also be taken as a false analogy. When a more complex molecule, such as butane (hydrocarbon with four carbon atoms), replaces one of the hydrogens on a hydrocarbon, it is considered as branching from the main hydrocarbon chain. Students may falsely describe the regular hydrogens on a hydrocarbon chain as branching; however, this is not branching as these hydrogens have neither replaced one of the original hydrogens nor are they part of a more complex molecule that is attached to the main hydrocarbon chain. Such descriptive qualities of symbolic items in chemistry could be problematic for the novice chemist.

5.12 PETROCHEMICALS AND POLYMERS

Cracking and Link(age)

This textbook chapter uses the words bond, cracking and link(age) to essentially describe the making and breaking of bonds (see Table 5.41). Cracking is the term used to describe a particular process where large hydrocarbon molecules are broken into smaller molecules. Whereas the term link(age) is used to describe the synthesis of polymers as similar alkenes link together by the double bond breaking between the carbon atoms. These terms are used for these specific processes, and students may not be able to relate these terms to the process of bond making and bond breaking. Students would need submicroscopic knowledge to understand what is being cracked, and how a link is being formed. In other words, they would need to connect the concept of chemical bonds to these processes to fully appreciate the meaning of these words in the context of chemistry. Further to this point, concordance 1 refers to bonds being broken and concordance 2 refers to double bonds opening up. So though the everyday process of opening and breaking are different, they are describing the same process in the context of chemistry. Students would need to be vigilant in terms of understanding words which may be different in meaning, yet express the same chemical process.

Table 5.41
Selected Concordance Lines for ‘Bond’, ‘Link(age)’ & ‘Cracking’

No.	Concordance
1	n reactions (see page 258) where the double bond is broken and other atoms attac
2	single monomer. During addition, the double bonds open up and the molecules join
3	etween the two molecules. Each time a link is made, a water molecule is lost: As
4	When they react together, an amide linkage (or peptide linkage) is formed to p
5	but-1-ene may also be produced. All cracking reactions give an alkane with a sh
6	es to produce synthetic rubber. The cracking reaction can be carried out in the

5.13 CHEMICAL ANALYSIS AND INVESTIGATION

Colourless & Bubbles

This textbook chapter is unlike all the other chapters in the textbook. Firstly, it is a summary of all the experiments that were presented in all the preceding chapters such as testing for saturated and unsaturated hydrocarbons, and flame tests. Secondly, it provides practical tips about how to tackle the IGCSE practical exam paper. For these two reasons, it was expected that little data would be extracted from this corpus as the words here appeared in previous chapters within the same context. Despite this, three relevant points were mentioned, and it would be suitable to point them out in this section. It is important to note that these points were explicitly mentioned by the authors of the textbook, and did not require any form of interpretation from the researcher of the present study.

From the authors' concerns regarding common errors made by students in exams were the words 'colourless' and 'bubbles'. Students are expected to give precise descriptions of experiments in an examination paper. If a student were to write 'clear' instead of 'colourless' for a description of what is observed with a precipitate which re-dissolves, it would not be accepted as a valid answer. Similarly, the description of 'gases given off' instead of 'bubbles' would also not be accepted as it is not an observation as such. Furthermore, the authors stress that observations are not just visual, but they are also numerical. To highlight this issue, they gave a case where the student wrote 'orange' for the observation of the pH value instead of a numerical value.

5.14 CHAPTER SUMMARY

This chapter presents the findings for research question RQA, whereby the Saudi EFL college students' core chemistry textbook was analysed using corpus-based methods to identify potential non-technical words. Twelve corpora were made from this chemistry textbook, with each corpus based on the chapters of this textbook. Keyword lists were produced from the corpus (see Appendix 2). These words were analysed by checking if the everyday meaning is at odds with its scientific meaning, and the plausibility of the embedded everyday meaning resulting in a sentence which could be interpreted as a non-canonical account of chemistry. A total of 46 potential non-technical words are reported in this chapter.

CHAPTER SIX

PHASE 2 FINDINGS: INTERVIEWS

6.1 INTRODUCTION

This chapter addresses the following research questions:

- **(RQB)** How familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words?
- **(RQC)** To what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry?
- **(RQD)** What is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?

This chapter reports on the findings from the semi-structured interviews with the Saudi EFL college students under three broad themes. This includes how they use the selected non-technical words: in terms of their everyday usage; through the application of the everyday meaning to the scientific context which leads to alternative conceptions; and other non-canonical accounts which are not derived from the everyday meaning of these words. The chapter ends with a brief summary of the findings. Pseudo names are used for all the participants of this study. All the examples quoted are the students' original words, and has not been translated by the researcher, and where necessary, transliterated Arabic terms are given. The Arabic form of all the transliterated words can be found in Appendix 11. Where judgments are passed regarding the participants' English proficiency, this relates to their use and appropriacy of lexis, grammatical structures and pronunciation features in relation to what is expected of CEFR A2 students. So for example, where a student is deemed weak in English, he may demonstrate: very slow speech with long pauses, hesitations, limited and very basic usage of vocabulary to make a point, rarely using subordinate clauses, producing grammatical structures which are impeding, in addition to finding difficulties in connecting speech and other pronunciation features such as stress and intonation.

6.2 EVERYDAY USAGE OF NON-TECHNICAL WORDS

This section reports on the Saudi EFL college students' familiarity of the non-technical words. This is covered in three sections: familiarity of non-technical words in general; a comparison of the usage of non-technical words in Arabic and English; and the conflicting usage within Arabic amongst the students. Appendix 11 shows the Arabic forms of all the transliterated Arabic words.

6.2.1 Familiarity of Non-technical Words

The students' familiarity of the non-technical words varied greatly, though there were several words where the students demonstrated that they were able to use the word in an everyday sense in English without referring to an Arabic-English dictionary. These words were: 'lose', 'strong', 'weak', 'make', and to a certain extent, 'gain'. Yusuf and Hammad recognised 'gain' only from their chemistry class and were unable to use it in its vernacular sense, and said, "gain electrons." Badr could not recall the word at all. For almost all the students, the words 'collision' and 'impurities' appeared to be the most unfamiliar. Nine of the students said that they have "never seen" the word impurity. Khalid said the word was familiar though he could not give the meaning. Musa was able to relate to the word, however he had to deduce the meaning. He knew the word pure as he said it means "clean," and from this he assumed that 'impurities' was the opposite, "not clean."

Nasr, Musa and Salman consistently demonstrated that they could use words in an everyday sense in English without the aid of a dictionary. They were able to relate: boiling to “tea” (Nasr) and “cooking” (Musa & Salman); arrangement with “travel plans” (Nasr & Musa), “meetings” (Salman); and base with the lowest part of something like a “computer stand” (Nasr), a “main thing” (Salman), and Musa related this to his future profession by saying, “check the base line for the patient.” Muhannad was also familiar with base from his “Netflix basic account.” This shows that even though these students are in an Arabic speaking country, they are still exposed to English terms in their everyday life. Despite this, the other students’ understanding of the other three non-technical words (boiling, arrangement, and base) were mainly limited to a chemistry context as this was the only situation that they could remember the word. Boiling was often related to other chemistry terms such as “evaporation” or that “liquid goes to gas.” Though Khalid provided chemistry examples for arrangement, “involves with the periodic table,” and base, “the opposite meaning of acid,” they were limited in explanation. Whilst the other students recognised arrangement and base, they were not able to comment further until they used a dictionary. For example, Badr said that he had never seen the word arrangement.

6.2.2 Everyday Usage: English & Arabic

The everyday example Arabic sentences that were given by the students for the equivalent non-technical words showed that there are a lot of similarities in terms of how it is used in Arabic and that of the suggested Oxford Dictionary’s examples in Chapter Five. Yet, there are both minor and major contextual differences too. The students were asked to translate their own Arabic sentences into English, and so the examples provided here are the students' own translations.

The words boiling, arrangement, lose, strong, weak, and making seem to be used in almost an identical manner in both Arabic and English. All the students related to the words strong, weak and make without the aid of a dictionary, though it should be noted that most students required a dictionary (Google Translate) to get the Arabic word for boiling and arrangement, and thereafter they gave their own everyday example of the word. In the corpus study it was shown that boiling is used to refer to heating things, or its informal sense as 'extremely hot'. Every student gave Arabic sentences relating to boiling water for the purpose of making tea: "tell me if the water is boiling" (Qassim), "the water is boiling" (Khalid). The informal use of boiling as extremely hot, however, was not given as an everyday example in Arabic.

Arrangement was used, like in English, to refer to organising things: "I do…arrange my room yesterday" (Muhannad), or to make plans, "I arranged for the meeting yesterday" (Salman). In addition, the examples of 'making' showed a close resemblance to English as it was used in the sense of producing things, "my father make bread" (Muhannad), and even relating to qualities of a person (e.g. she had the makings of a good teacher), "you're not making something good" (Nasr). The use of examples with opposite meanings for strong and weak, and gain and lose, indicates another similarity between English and Arabic in terms of antonyms. Strong was often used to describe someone or something's strength, and weak was used with the opposite meaning: "eat healthy food and become strong…eat bad food and become weak" (Feras). Similarly, opposite meanings of gain and lose were given. For instance, Badr's Arabic examples were, "I gained one mark" and "I lost one mark."

It is expected that different languages would use words in a multiple of ways and that word-for-word translations would not necessarily fit well in certain contexts. Ziyad and Qassim raised this point. In Ziyad's case he said that the word “yaktaseb” and “yahsul” could be used in the “same way in Arabic” but not in English because “yaktaseb is gain and yahsul is have.” Qassim too made the same point about the word “masaytar” when translating ‘strong’. Though he did not elaborate on his point, Google Translate gives the equivalent word of ‘dominant’ for this word. Some other relatively subtle differences in everyday usage were also noted. A few students used ‘gain’ in association with ‘win’, as in “Ziyad always win when he plays” (Muhannad) and “I won a trophy” (Musa). In everyday English, according to Oxford Dictionaries, there is an archaic, and therefore not an everyday use of ‘gain’ as ‘win’, in the context of winning one's interest or view (e.g. ’to gratify the queen, and gain the court’).

In everyday English, people use collisions with reference to events which are fatal (e.g. ‘a mid-air collision between two aircraft’, Oxford Dictionaries). The students did not represent collision in this respect in their examples, as they often mentioned an accident between two cars. Feras said, “in traffic jam car accident,” which shows that the car accident may not have been a major or fatal accident considering it took place in a traffic jam. A few students struggled to provide examples in Arabic for the word impurities, and this was even with them knowing the equivalent Arabic word (shawaib). After seeing the Arabic equivalent, they commented “like not clean” (Feras), “something not good” (Hammad), thus showing a similar possible connotation to English. Yusuf could not construct a sentence, and so looked at other related synonyms from the list of Arabic words on Google Translate and used the word “talawuth” and translated it himself as “dirty water.” This shows that it is not sufficient to expect

EFL students to simply understand translated words, as they refer to other synonyms in the given list and take them as equivalent translations. Khalid too struggled to make an Arabic sentence with “shawaib” and said that it is “common in scientific…but not everyday.” From the students who did manage to construct an Arabic sentence, they related it to things which were not needed, but in a general way: “I found impurity in my car machine” (Muhannad), and “there is some impurities” (Hammad). This may suggest that expecting students to simply translate a word into one’s own language may not be sufficient due to an individual’s own limitation in his/her first language.

Although most of the non-technical words shared a reasonably common everyday meaning when translated into Arabic, the translation of ‘base’ was quite unique as the everyday usage is considerably different. The word ‘base’ was used in Arabic by students in two everyday senses, and they did so in most cases without the need to translate the word. The first sense is similar to how it is used in English. The examples referred to the bottom, or lowest part of things like “the base of television is not safe” (Nasr), or it was used as the foundation or core of something, “the reading is base for learning” (Hammad). Contrary to English, the second sense in Arabic differed much with how ‘base’ is used in English. Several students used the Arabic equivalent “qaaidah” as a rule: “learn the right grammar” (Feras), “if you want to make a cook you have to switch on fire…like a rule” (Qassim).

6.2.3 Variable Usage within Arabic

Though the students are native speakers of Arabic, it appeared that their Arabic proficiency varied and there seemed to be inconsistencies with respect to how they express themselves in their native language.

The words that some students considered to be everyday Arabic words were not always agreed upon, in the sense that the way that they use their language in an everyday context differs from one student to another. All the students said that “tarteeb” was the meaning for arrangements in Arabic, and when they were asked about other common everyday words in Arabic with a similar meaning, there was no shared agreement other than “tandheem” which was mentioned by four students. The range of words included “tandheef” (Badr), “taqseem” (Hammad), “tahjeez” (Nasr), “tanseeq” (Khalid and Salman), and “tawze’a” (Feras and Hammad). Similarly, the word ‘making’ had a common translation (yasna), which was given by all the students without the need to refer to a dictionary. In addition to this word, six other different Arabic words were given for making, with a maximum of two students referring to the word.

The students demonstrated through their ability to provide examples in Arabic, and the range of words recalled in their own language, that their Arabic proficiency varied much. Nasr gave the widest variety of synonymous everyday Arabic words, and often said that “it’s how we use it…in my family…no other student will use it.” He said that his “accent” was different to the other students. He claimed to be using “old” Arabic words like “yafour”, to talk about boiling water for tea, and even slang words such as “tasaqa’ ” to refer to collisions. On the other hand, some students showed noticeable limitations in their first language. Badr was at times unable to produce examples in his own language, and often referred to a dictionary. He was the only student who did not recognise the Arabic word “shawaib” (impurities). Salman incorrectly thought that “maghli” (boiling) is the verb form, showing some limitations in understanding parts of speech in his own language. This form of the word, according to Google Translate, is an adjective.

There were a few contradictions with regards to how the students believed that synonymous words can be used in everyday Arabic. Some students said that the words “tabakhur” and “ghalayaan” (translated for boiling) have exactly the “same meaning in Arabic” (Feras) when providing an everyday example. Hammad also claimed the same, but added that “tabakhur” is used more than “ghalayaan.” Whilst Muhannad said that “tabakhur is more scientific” and “ghalayaan is everyday.” With the translated words for arrangement, “tarteeb” and “tandheem,” some students said that they can be used in “same” way (Yusuf) and that there is “no difference” (Qassim). Muhannad, on the contrary, understood “tandheem” as a word “for important things.” Even when Ziyad gave his example of “the car is arranged,” he felt that “tandheem” would not be appropriate, and that it is better to use the word with a “lab,” perhaps indicating something more formal.

6.3 NON-TECHNICAL WORDS INFLUENCING STUDENTS’ IDEAS

As each non-technical word was accompanied with a specific instance, and in order to avoid repetition of these scenarios, the cases are presented under the heading of each non-technical word so that the reader can appreciate the contextual nature of the word. The non-technical words are ordered in terms of their familiarity amongst the students as found in the previous section (6.2) with the most familiar words listed first. The potential non-technical word ‘collisions’ is not mentioned as it was found that its everyday meaning had no bearing in the context of chemistry, and so is reported on in section 6.4.

6.3.1 Gain & Lose

Though the term lose was more familiar to students than gain (see section 6.2.1), they were able to work out the meaning of gain as they recognised lose as an antonym and the Arabic and English usage bared much similarity (see section 6.2.2).

In response to a reaction between sodium and chlorine which results in an ionic bond, several students thought that chlorine was better than sodium as it gained an electron. Yusuf, Ziyad and Hammad said that chlorine is “better” after the reaction, but were not able to affirm this for sodium, meaning it is neither good or bad for sodium. In the following excerpt, Muhannad shows that he understands that the process of gaining and losing electrons is related to becoming stable, but he also holds other alternative conceptions such as sodium being in a worst state at the end (i.e. in the product), “but not really bad”, and that chlorine has benefitted most from the reaction:

> The sodium lose…losing electron…It’s bad because…but not really bad…because sodium has one electron in last shell…he want get rid of it…he want to be stable more stable by losing one electron…he (sodium) own one electron he want lose it and give it to chlorine to be more stable. He (sodium) would be better…but he only one electron.

He added that chlorine is “the winner” because it has “eight in last shell” and that it “gained an electron.” Badr did not make any reference to stability, but used his everyday understanding of words and experiences to make sense of gaining and losing electrons. He said that it is “bad” for sodium as it is like “losing money,” yet, he believes that the end-product is “good for both” because “working together” is better than working alone.

Contrary to these students, Nasr said that it is good for sodium and bad for chlorine as he thinks that electrons are a bad thing to possess:

> The electron is negative…nothing negative is good…bad luck for chlorine…Sodium when he give something negative he gain something good…so sodium will be positive…but chlorine he took he gain something negative…so negative.

This may also indicate an alternative conception at the symbolic level, as he thinks positive ions, denoted by +, are better than negative ions, denoted by -.

6.3.2 Making & Breaking

All the students readily provided examples of making and breaking in both English and Arabic, as they did with strong and weak, and the contextual usage of these words in Arabic is very similar to English (see section 6.2.2). They seemed to be very familiar with the everyday meaning of these words. Students were asked to make sense of the concept of breaking bonds requiring energy and making bonds releasing energy in exothermic reactions.

Most students were unable to provide an explanation. They accepted the breaking of chemical bonds as it related to their everyday life experience, however, they could not make sense of energy being released when chemical bonds are made as it was “opposite to our life” (Feras), and often saying that it was “strange.” Hammad tried to make sense of it by saying that making and breaking are “the opposite” in the sense that they are different processes, but still admitted it did not make sense. They sufficed with seeing it written in their textbook and did not ask for any further clarification. Yusuf said that he heard the teacher mention it in class but did not really think about it in depth until it was pointed out to him.

Two students responded with what seemed to be the beginnings of a canonical account, but when probed further, they were unable to explain their claims and so appeared to be using rational suggestions which sufficed them at that time, rather than a scientific one. In Musa’s case it took him a long time to make a suggestion as he had to keep asking questions to understand the situation:

> When did you lose when did you gain…because when you break you put in…no…wait a minute…does it mean you get or lose…because you don’t need it anymore…I don’t know actually…

Musa appeared to be reasonably proficient in English, so his stumbling was not because of a deficiency in understanding the question in English, but most likely due to trying to make sense of the science in relation to what he experiences in his daily life. Nasr attempted to come closer to a scientific explanation:

> …because it's got enough it's two things together this one have energy and that one have energy together they will have more energy so they must to release some.

However, when he was asked further to explain himself, he said, "I don't understand…energy I don't know…chemistry is strange…that's why I didn't understand it," and then he admitted not really believing in it:

Nasr:	If I have it in the exam I will believe it…I saw it in the book absolutely believe it.
Interviewer:	But really you wouldn't believe it?
Nasr:	Yeah.

This shows that by pressing students further at times by getting them to explain chemistry in terms of making sense of the non-technical word in context reveals that they may actually lack confidence and have doubts about their own scientific explanations.

6.3.3 Strong & Weak

The everyday examples provided by students pertaining to strong and weak were no different when given in Arabic or English (see section 6.2.2), and no student needed a dictionary for these terms. The students read a passage in the textbook which clearly explains that hydrochloric acid (HCl) is a strong acid, and that ethanoic acid is a weak acid. Furthermore, the passage clearly states that a strong acid is strong because the ions completely dissociate in water, and that ions in weak acids partially dissociate. When they were shown the example of two beakers with different measurements of water with these two acids, most of them did not attempt to explain the science at the submicroscopic level and sufficed with pointing out that in the book it says hydrochloric acid is strong and that ethanoic acid is weak. Even after reading this text, and having the text available as a reference point, several students still held alternative conceptions.

Yusuf recognised that HCl had H^+ ions, but did not seem to grasp the definition of strong and weak acids. He thought that as there are positive ions (H^+) in HCl, it is strong, and the opposite for ethanoic acid, as the negative ion (OH^-) makes it weak. He appears to have construed connotations of the symbols, weak being negative and strong being positive. With the beaker scenario, Feras was able to refer to concentration as he used the Arabic word "tarkeez," but still ended in a state of confusion by saying that water could actually make the acid weak. Qassim also held this idea and explained, "water is not base not acid…make it weak…like temperature you put hot water and cold water…it become neutral." He thought that water neutralises acids making them weak acids.

6.3.4 Boiling

When the students gave examples related to boiling in both English and Arabic, they commonly referred to water boiling, and used either the word "ghalayaan" (boiling) and a few mentioned "sahannat" (heat) (see section 6.2). When they were asked to comment on oxygen having a boiling point of -183^0 C, several students revealed alternative conceptions as they related boiling with liquids and not gases, or that it has to be hot in the everyday sense.

Ziyad and Nasr did not believe oxygen has a boiling point at all. Ziyad said, "oxygen…no, because the oxygen cannot be…it can't be boiled…it's gas." Nasr said he "won't believe that…because oxygen is gas…and the boiling situation is something you see in the eye." Ziyad and Nasr did not realise that oxygen could be a liquid as they were familiar with it as a gas. Muhannad and

Hammad's association of boiling with heat led them to think that a boiling point cannot exist at cold temperatures, and "it has to be hot" (Muhannad). Feras thought the same and added that oxygen only has a "freezing point," whilst Hammad held both ideas and added that -183^0 C cannot be the boiling point of oxygen as boiling only occurs in situations related to heat or liquids, and not gases.

The students who did not accept that oxygen has a boiling point of -183^0 C were shown this in their textbook, and though most accepted this at that point, a few others were still not convinced. Ziyad developed additional conceptions to make sense of the scenario as he said, "gases have another reactions from the liquids and solids," meaning that in the given context he still perhaps thinks that oxygen cannot be a liquid, or that the way oxygen boils is different to other elements. Qassim found it "amazing," but he admitted not really believing in it:

Interviewer:	So it's strange then?
Qassim:	Yes, amazing wallah.
Interviewer:	But do you believe it?
Qassim:	From me no.
Interviewer:	Even if it's in the book you don't believe it?
Qassim:	Yeah…I'll be honest yani…I don't know this.

Nasr did not believe what he saw in his book because he felt that he has to see the reaction with his "eye" to believe it "because not everything I read I believe." Such a stance may make many concepts unbelievable as much of chemistry is explained at the submicroscopic level.

6.3.5 Arrangement

Arrangement was familiar to some students only in the context of chemistry, and only a few understood it in everyday English terms. However, most students had to refer to a dictionary, and the Arabic usage was found to be similar to English in the sense of organising and ordering (see section 6.2.2).

When the students were asked to draw diagrams of various elements depicting the electrons in shells, half of them thought that the arrangement of electrons refers to the position/location of the electron on the shell, as opposed to the number of electrons orbiting each shell in an atom.

Ziyad, Yusuf, Nasr and Badr were from among the students who held this alternative conception. For instance, Badr was asked to draw the arrangement of electrons for helium (see Figure 6.1), he said that the one on the left is not arranged because "it's not equal." Muhannad correctly said that you "can't locate electrons" as they are "moving," but then referred to arrangements as though there are different degrees of arrangements:

> means in order…exactly mean like this but you write it like this more better…in order…because you can't locate electron in specific one time…this is more arrangement …the distance between here is close…this is more arranged…yeah

Salman had multiple idiosyncratic ideas as he thought that the arrangement of electrons refers to both the position, and the number of electrons in the sense that you need more than two electrons to arrange them: "two is not enough to be organised sometimes both…the number of the thing we want to arrange is not enough."

Figure 6.1
Badr's Representation of Electron Arrangements in Helium

6.3.6 Base

The common word given in Arabic for base was 'qaaidah' which could mean the lowest part of something that is used as a support , however, unlike English, it could also mean 'a rule' or 'a law' in Arabic (see section 6.2.2). Most students, even after checking the dictionary meaning, struggled to give an example of how it is used in everyday Arabic (see section 6.2.1). A few students recognised the term from chemistry class, but Yusuf said he had seen the word before in physics.

When Yusuf was asked why sodium hydroxide is a base in a neutralisation reaction, he explained it in terms of a ‘rule’, and incorrectly linked this with chemical symbols:

> Because sodium meaning…base of sodium is Na…and OH is meaning hydroxide…It’s a base of hydrogen and chloride acid … chlorine … Because formula when you mix it between hydrogen and chloride…it become hydrogen chloride…like short-cut…chemical formula yes…when you use sodium chloride difficult…so use NaCl.

Feras also did not know the meaning of the word base and resorted to a dictionary and similarly applied the Arabic meaning of ‘rule’ in this context. Though he muddled the words compound and element, he made it very clear that he meant base to mean that two elements or more make a compound. Even an Arabic synonym of rule was used by the interviewer (*Qanoon*) to clarify this:

Interviewer:	So if I had just one element it wouldn’t be a base?
Feras:	No not base.
Interviewer:	Why?
Feras:	Because base contains from 2 compound or other.
Interviewer:	But see this you said base like a rule…so is it the same meaning here?
Feras:	Yes, same meaning.
Interviewer:	Like a rule *Qanoon*.
Feras:	Yes.
Interviewer:	So what’s the rule here?
Feras:	Two compounds or more.

6.3.7 Impurities

With the exception of Musa (see section 6.2.1), all the other students resorted to a dictionary as the word ‘impurities’ was unfamiliar to them. Using Google Translate, they found the word ‘shawaib’ as the Arabic equivalent. The common everyday example they put forth was that related to remnants from an engine (see section 6.2.1). In the interview, students read a section of the book explaining the chemical process in the purification of iron in a blast furnace. Several students thought that sand was impure because it was "dirty." Those who appeared weaker in English, Hammad and Badr, were unable to elaborate on why they thought it was dirty, and Badr did not even recognise the equivalent Arabic word.

Ziyad thought that the sand "will make the iron dirty" in the blast furnace "because it make reaction with fire." Similarly, Salman said, "this sand will have another mixed with it…I think there's something not usual with it…it's got heat…it was with iron." Qassim related his own personal views of sand, and not based on the blast furnace chemical reaction. He thinks that sand is dirty to various degrees, as sand in the desert is "clean," and sand in "storms" is "not nice" so it is "dirty." In Saudi Arabia, sitting in the desert and experiencing sand storms are common events, so it appears that his attitude towards sand in general has derived from these experiences. Feras, also, thought that sand is dirty, but not very dirty:

Interviewer:	So is it dirty like my table is dirty?
Feras:	Yes because you have the sand. You should clean your table.
Interviewer:	Is it the same as walking on rubbish, *zibala* (rubbish)?
Feras:	No no…
Interviewer:	Why is it different?
Feras:	This is very dirty and smell very ugly…and sand little bit dirty.

Musa, appearing to be one of the better users of English, was able to provide a definition of impurity without the use of a dictionary and referred to the word "ghayr naqi," which he said means "not dirty." He knew the word pure and understood impure to be the opposite. He thought sand was dirty up to the point when he wanted to check the dictionary meaning (*shawaib*). At this point he changed his stance and correctly recognised that sand is not dirty, but an unwanted by-product of the reaction. He recognised that by using his own definition he had actually misinterpreted the meaning of impurities in this context. Though he said that he does not usually use a dictionary, it helped him in this case.

6.4 NON-TECHNICAL WORDS NOT INFLUENCING CONCEPTIONS

There were numerous cases where the students showed that they were unaffected by the everyday meaning of the English non-technical word. There appeared no application of the everyday meaning in the chemistry context. Some students were able to produce some form of a canonical account when explaining the concept. Students also used specific equivalent Arabic chemical terms, though not all of them could explain concepts at the submicroscopic level. Furthermore, students gave non-canonical accounts to justify the differences between the everyday and scientific meanings.

6.4.1 Scientific Explanations

The students demonstrated at times that the everyday usage of the non-technical word had no bearing on their understanding of concepts. They were able to give a reasonable scientific explanation even at the submicroscopic level and showed that chemistry is unopinionated. Some students were not deterred by persistent questioning and confidently held on to their views.

Several students demonstrated that they could explain concepts at the submicroscopic level. Feras, Musa and Qassim used the word “stable” when explaining the gain and loss of electrons in the reaction between sodium and chlorine. They recognised that there is no “bad” or “good” when electrons are gained or lost as the compound, sodium chloride, achieves stability through ionic bonding. When students were asked what was meant by strong and weak acids in relation to hydrochloric acid and ethanoic acid, Nasr specifically made reference to ions as he said that we need to “look at how ion split,” whilst Salman was a little more general by referring to the “structure” of the acids. Other students were not able to express themselves as clearly since they are EFL students, however, they were explaining science at the submicroscopic level, as shown in the following excerpt with Hammad:

Hammad:	Because he (strong acid) can split it…It (weak acid) only little…quantity is more…It’s weak acid but if you more quantity maybe he stronger than this…
Interviewer:	If you increase it will become stronger than that? So does that mean now that it will be a strong acid?
Hammad:	No.
Interviewer:	It’s still a weak acid?
Hammad:	Yeah.

Hammad did not refer to ions, but he used the word “split” as he attempted to explain that strong acids “can split it,” seemingly indicating that he was referring to the dissociation of molecules. Though it may appear in the beginning of the excerpt that he was confused between the concentration of acid solutions and the strength of the acid as the end of the excerpt makes it clear that he was talking about the splitting of ions. In a similar manner, Ziyad said, “it (HCl) the amount of hydrogen it’s big,” again referring to the concentration of H^+ ions. Khalid attempted to explain the phenomena submicroscopically but his justification is based on macroscopic terms: “because it has to do it to make the reaction.” Other students, though demonstrating some form of understanding, were limited to symbolic explanations. When asked about why sodium hydroxide is a base, they sufficed with, “because pH level is higher than 7” (Salman), and, “if more 7 it’s base” (Hammad).

Some students showed firmness and confidence when giving their responses by not doubting that there is no connection between the everyday usage of the non-technical word and its usage in chemistry. As Musa was pressed with further questions to probe his understanding of the meaning of arrangement of electrons he emphatically said, “No!...the number of electrons in one shell.” Feras made it clear that the arrangement of electrons was not related to its position in the shell, “anywhere no problem…here here here no problem…no how many there are.” Yusuf also kept repeating his point with respect to sand not being dirty, “It’s not dirty…but we need to see iron very clean and if you want iron very clean you need remove sand…but sand is not dirty.” Muhannad similarly understood sand was not dirty, and moreover, that it could be used again:

> You want just iron so the other things just shawaib impurities…sand no you can use it again…because they don’t want it right now…they just want the iron thing…it’s not dirty but it’s not important…

Musa appreciated that chemistry is not opinionated in that its stance is neutral. He did not regard collisions as either desirable or undesirable in chemistry:

> If you want it to be good…if you don’t want it to happen so it’s not good…it depends…nothing is good or bad in chemistry actually…it’s on your own intention…that’s science.

Hammad, appearing to be much weaker than Musa in English, was not able to express himself as clearly as Musa, though his responses showed that he shared the same stance, “Maybe good maybe bad.” He said that in chemistry reactions are not always good as some “may be dangerous in the lab.”

6.4.2 Non-scientific Explanations

Several students referred to aspects of their religion and culture to justify their explanation. When Khalid was asked why argon has a stable electron arrangement he replied, “Allah create it like that I don’t know Allah create it like that.” Qassim said that collisions in chemistry can be good and bad because the Qur’an teaches moderation in everything:

> When Islam equal wasatiyyah (equal) if put more them more more make dangerous…all thing some time good some time bad…you know Qur'an alasl (honey) if you eat alasl (honey) a lot make bad laakin (but) equally one in the morning one in the night is very good…shifa (cure) in Qur'an you know…

Salman related the connotation of collision in chemistry to a combination of Chinese philosophy and Islam, whilst still holding that overall in chemistry collisions are good thing:

> …there's a bad point in every good thing…but the most of it the chemical reaction good even for human body…that's the meaning of life you remember the symbol circle it's divided like two shapes and the one is white black and the clack shape have like a circle meaning in every good thing there is bad thing…even in Islam…sometimes the bad things have good things in it like for example alcohol…they use it for eczema I think…it's bad in general for liver…kidney

Qassim said that sand as an impurity of hematite means that it is dirty. He did not say this because of the word impurity, but he seemed to relate the dirtiness of sand with his experiences of it. He said that "all sand is dirty" and he has had both good and bad experiences with sand as Saudi Arabia is known for its vast deserts, but his good experiences are not because of the sand or desert itself, but what he actually does there:

> All sand is dirty…sand we have good and bad…but we have desert in the weather jaw (weather)…storm we are sad not like sand…we love in desert I go every week the desert like Thumamah we go to desert…why we have camel and we have other good things…relax make a fire talk…

Yusuf's understanding of sand is different to Qassim's as he said, "it's not dirty…we know sand is not dirty."

Salman used his own logic to explain and justify why there is no relationship between the everyday use of the non-technical word and its meaning in chemistry. It was logical to him in that it sufficed as an explanation, yet the explanation was non-canonical. He did not think that 'lose' is necessarily a bad thing in life in general and he gave the example of people "losing the cops" when they are being chased. He compared this with sodium losing an electron in ionic bonding to illustrate that it was not “a bad thing” for sodium. Both Salman and Qassim seemed to have developed some opinions of chemistry with regards to their expectations of the discipline. They felt that what happens in chemistry and life in general do not always coincide. Qassim said, “in our life not same chemistry…not all the time but some time.” When Salman was asked to comment about the boiling point of oxygen being -183^{0}C he said:

> Because in chemistry in general when you mix two things something awesome will happen…chemistry you can’t actually know stuff like that because you have to try it…when you open a small element something the opposite of the thing you have now will create or produce…

Most students either lacked or did not attempt to explain the concept at hand. They seemed to accept anything written in isolation in the textbook as a fact without trying to attempt to form an explanation of the concept. Several students did not believe the boiling point of oxygen is -183^{0}C until they saw it in their chemistry textbook, yet, they did not even ask for any further clarification, or attempt to make sense of what they read in the book. A similar occurrence occurred with most students when trying to understand the proposition of ‘bond making’ releasing energy. Some students quoted their teacher as a reference point when unable to explain the concept as Hammad said, “I teach that…should be like this,” and Qassim similarly, “we study base more than 7…Dr. told us.” This is not to suggest that it is wrong for them to accept what they read, or learn from their teachers, but the issue here is that the students did not demonstrate any attempt of explaining the science and were satisfied with isolated facts from their textbook or teacher.

6.4.3 Use of Precise Chemical Terminology in Arabic

A few students were able to give the precise chemical terms in Arabic without referring to a dictionary and differentiate these Arabic terms with what they use in everyday Arabic. They studied “all these” topics in “school…but in Arabic”

(Feras and Nasr), and for them it is like a “review” (Salman) of what they have already learnt. Musa went further to say that what they learnt in “high school is much more detailed.” This suggests that they have already encountered the equivalent Arabic non-technical words presented in this study during their schooling years. Furthermore, their teachers are not Arabic speakers and are teaching in the medium of English, thus it can be assumed that the possibility of them learning the Arabic equivalent term in their current class is minimal. This may also imply that the equivalent Arabic term may not be non-technical in nature in Arabic, though there may be other non-technical Arabic equivalents with that characteristic.

Knowing the precise Arabic terms assisted a few students as they did not incorrectly conflate the everyday meanings of the non-technical words with the chemical meanings. Musa distinguished between “qaaidee” and “qaaidah” as the equivalent of ‘base’, where the former relates specifically to the context of chemistry, and the latter to its everyday use. Earlier examples were given where the students took the everyday meaning of ‘base’ in Arabic in terms of rule, however, in Musa’s case, as he was aware that there is no correlation between the everyday meaning and the scientific meaning, he did not make this incorrect conflation. Additionally, with base, Khalid mentioned a related term, “qalawee,” which refers to alkalinity. In spite of knowing the precise chemical Arabic word, it was not always sufficient in terms of giving one the ability to explain the science, or even removing any form of connection with the everyday meaning. Nasr was still unable to point out what a base is despite knowing the precise word in Arabic. Ziyad claimed that the word “tadarab” is the specific term for the collision of particles in chemistry, and that “tasadum” is preferable for the everyday use of accidents, yet it was not enough for him to recognise neutrality in chemistry. Muhannad likewise pointed out that “ghalayaan” is the everyday word for boiling and that “tabakhur is more scientific,” and he still associated heat to the non-technical word boiling.

6.5 CHAPTER SUMMARY

This chapters reports the findings for research questions RQB, RQC and RQD. The findings from this part of the case study showed that the Saudi EFL college students varied in proficiency in both English and chemistry. This had implications on their understanding of non-technical words in their everyday sense, and in some cases, this translated into their conceptions of concepts in chemistry where they exhibited both idiosyncratic and commonalities in their conceptions of concepts in chemistry. Though, not all the students embedded the everyday meaning of non-technical words in the chemistry context.

CHAPTER SEVEN
DISCUSSION

7.1 INTRODUCTION

A review of the literature led to the formulation of the following overarching research question: how do Saudi EFL college students understand selected non-technical words from their core chemistry textbook? The findings from this research problem are first understood in relation to the theoretical model of this study which is premised on constructivism as a theory of learning. Following this, the four sub-research questions are discussed. The first of these sub-research questions (RQA) is discussed in relation to the findings from the corpus analysis (Phase One), and the remaining three sub-questions (RQB-D) are discussed with reference to the findings from the interview phase of this study.

7.2 THEORETICAL FRAMEWORK & STUDY FINDINGS

The present study adopted a theoretical framework based on constructivism as a theory of learning. Section 3.3.4 demonstrated how some key ideas of Vygotsky and Bakhtin on words are consistent with the seven hard core axioms (HCA) of constructivism that the present study is premised on (Taber, 2013). The findings of this study are also consistent with this notion of constructivism.

The Saudi EFL college students showed that they construct their own personal knowledge as they subjectively experience ideas as abstract principles (HCA 1). The chemistry curriculum that they study is based on an IGCSE chemistry textbook which contains a plethora of scientific concepts, and they subjectively experience the concepts presented in this textbook. In the interviews they engaged with chemistry concepts, at times, by relating to what they know of natural phenomena from existing ideas (HCA 2). For instance, some students thought that a substance could only boil at high temperatures as their everyday experiences of boiling involved situations where substances are subjected to high temperatures, well above standard room temperature. In this respect, such existing ideas have consequences for how they learn science (HCA 3), and science teachers, whether inside or outside Saudi Arabia, would need to take account of such existing ideas in order to effectively teach students the curriculum (HCA 4). Knowledge is represented in the brain as conceptual structures (HCA 5), and thus learners revisit ideas in a way that allows reflecting on “the semantic relationships that were originally understood” (Taber, 2009, p.142). Some of the students in this study, for instance, related their everyday understanding of ‘gain’ and ‘lose’ in the context of the reaction between sodium and chlorine to form an ionic bond and applied this understanding to make sense of the reaction. This did not lead to a canonical account of the nature of the reaction, partly due to the applied connotations, and resulted in the Saudi learners exhibiting both commonalities and idiosyncratic accounts (HCA 6). Whilst several students said that chlorine is better off as it gains an electron, and gaining is perceived by them as something good in everyday terms, one student felt that it is bad for chlorine, as it gains something negative (electron).

Taber’s (2013) mental model of Vygotsky’s spontaneous and academic concepts (see section 3.3.4) illuminates our understanding, to a certain extent, of some aspects of the Saudi EFL students’ conceptual structures (HCA 7). Other than English, these students never had any lessons delivered in English prior to joining the college as they were taught in the medium of Arabic in their high schooling years in Saudi public schools. Studying in the college was their first encounter of learning chemistry, as well as other subjects, in the medium of

English. Moreover, they are in a country where English is used as a foreign language, hence EFL students, with their mother tongue being the official language of the country, Arabic. We would expect that there is to some degree a shared environment between those who set the curriculum (target knowledge), those who teach the curriculum and represent this target knowledge in order to be interpreted as academic concepts by learners, and the everyday environment in which learners' experiences lead to implicit knowledge and in turn spontaneous concepts. In Western countries, the curriculum is designed for native speakers of English. However, these Saudi EFL college students are studying Western material in a different environment. To add to this complication, those who are representing the target knowledge are from various countries, though, representing the target knowledge in English. It is acknowledged that science textbooks in Saudi secondary public schools have been translated into Arabic from what was originally American science textbooks, despite this, these books have been modified accordingly to relate to Saudi society (Khaddoor, Al-Amoush & Eilks, 2017). Therefore, we can assume that the process of interconceptualisation, and the melded concepts constructed for these EFL students are significantly different to ELLs in English speaking countries, or even non-English speaking countries where English is used as the medium of instruction in schools. This would add to the complexity of a hybrid state (interconceptualisation) in which spontaneous concepts are acquiring something which is abstract in nature and academic concepts acquiring concrete referents.

Bakhtin's (1981) notion of heteroglossia stresses the importance of the contextual nature of a word. The Saudi EFL college students, being in a non-English speaking country, demonstrated that their use of certain non-technical words is limited to a particular context, a chemistry classroom, even though the nature of such words is that they can be used in an everyday sense. Emerson (2000) elaborated on Bakhtin's concept of dialogism and points out that "the more often a word is used in speech acts, the more contexts it accumulates and the more its meanings proliferate" (p.36). For example, some students only recognised certain non-technical words in their chemistry class such as gain. In this sense, their usage of this word in English is limited. This may be good from the angle of using appropriate words in context in the case of chemistry, presuming they understood the concept soundly; yet, they are restricted in expanding the meaning potential of this word as they have limited opportunities to use it considering they are in a predominantly Arabic speaking environment. Moreover, some Saudi EFL students give greater importance to preserving their mother tongue, Arabic, therefore, further limiting opportunities to use such words (Alrabai, 2016).

The Zone of Proximal Development (ZPD) is "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1934/1978, p.86). Applying this definition to the findings of the current study results in a peculiar educational setting. The Saudi EFL participants studied the same level of chemistry in secondary school directly before joining the vocational college. This has been established with reference to the course syllabus and the findings from the interview. Some students even claimed that the level of chemistry that they learnt at secondary school is of a higher level and that of the vocational college is much easier. The main difference is that in secondary school, they studied chemistry in Arabic, whereas in the college they are studying this subject in the medium of English. This raises the question of what is actually being learnt for learning to take place. Assuming that the students learnt the same chemistry concepts before, this would imply from an educational perspective that they are mainly learning the language of chemistry in English if they are indeed learning something new. Though, they could also be reinforcing previously learnt material. We would expect in any institution that the level of education being offered is higher than the qualification which precedes it. In this case, as the students are studying for a diploma which has a prerequisite of having secondary school qualifications, then in educational terms, the level of education in the diploma program should be more advanced. Despite this, it is not clear what the students are learning that is actually new other than the language of chemistry in the medium of English.

7.3 RESEARCH QUESTION A: What non-technical words are there in the Saudi EFL college students' core chemistry textbook?

The process of identifying potential non-technical words in the Saudi students' chemistry textbook required applying a working definition for a non-technical word within a corpus-based study (Phase One). In the literature, different terminology is used to describe these words, including semi-technical words (Wellington & Osborne, 2001), non-technical words (Childs, Markvic & Ryan, 2015), and dual-meaning vocabulary (DMV) (Song & Carheden, 2014). The general understanding of non-technical words (the term used in this thesis) is a word which has both an everyday and a scientific meaning, and when the everyday meaning is embedded in a scientific context (instead of its scientific meaning) it becomes a cause of confusion as learners may develop alternative ideas.

The classification of a non-technical word in this study required the researcher to interpret how an everyday word is used in an online dictionary (Oxford Dictionaries) and evaluate this against, again, the researcher's interpretation of how the same word is used 'scientifically' in the Saudi students' chemistry textbook (target knowledge). I believe that research on non-technical words should be explicit in terms of the sources of interpretation. Most research papers, with the exception of a few (e.g. Menon & Mukundan, 2010), do not provide details about how and where the two distinct meanings of non-technical words are derived and interpreted from (e.g. Song & Carheden, 2014; Vladusic, Bucat & Ozic, 2016).

Non-technical words have two defining characteristics. Firstly, it has an everyday meaning, and secondly, it has a meaning in science. This raises further questions in the line of how we should classify a word as having an everyday meaning, and equally how can we say that a word has a scientific meaning. In section 3.3, Vygotsky and Bakhtin's ideas in relation to words were reviewed and discussed, and were taken with caution so that these views are consistent with the hard core axioms of constructivism adopted in this study. Words are no more than one form of an imperfect representation of our ideas, as we can represent our ideas through gestures, role-play, and pictures (Taber, 2013). Bakhtin (1981) said that words accumulate meaning from multiple contexts, having a meaning potential which differs between people, and is related to how others construe that meaning. So in a Bakhtanian sense, to make a claim that a word is a non-technical word would mean: that it is used in both an everyday and scientific context; that these meanings would vary between individuals; and that how others use these words in specific contexts would have a bearing on how we use these words to represent our thoughts in some comprehensible form. The implications of this is that the nature of non-technical words relates to how a community use it in everyday terms (i.e. what is socially accepted), and to claim that it has a scientific meaning would mean that it is related to public scientific knowledge, which in itself could be a problematic term as this would mean that such knowledge is "an idealist referent," despite this, "ultimately, individuals – whether scientists, reviewers, textbook writers, curriculum developers, teachers, students or members of the general public – interpret public representations of personal understandings and form their own personal understandings (Taber, 2013, p.200).

In this study, a number of potential non-technical words in chemistry were identified, some of which have not been reported elsewhere to the researcher's knowledge, such as the words physical and agent. A broader working definition assisted in the identification of numerous potential non-technical words which would not normally be found in the literature of non-technical words. Part of identifying potential non-technical words relates to what is and what is not an everyday word, and this is a matter of subjectivity. What I hold to be an everyday term, may be an uncommon word to others. Bakhtin and Vygotsky appreciated that there are differences between people in terms of how they use words, in part, due to the contextual nature of words, and the more we use words in speech acts the more its meaning will proliferate (Emerson, 2000). Some people use words from the domain of business or politics in their daily lives, and in this way, it is everyday language for them. Therefore, I suggest that the everyday aspect of a word in relation to chemistry should refer to its usage in a non-chemical (not chemistry) context, regardless if the word is common, or uncommon, or particular to a discipline out of chemistry. If this understanding of everyday usage is embedded in a chemical context, and can be interpreted in other than its chemical usage, then we should define this word as a non-technical word.

The identification of potential non-technical words required interpreting beyond the meaning of the word in its context, and using resources, the students' core chemistry textbook, which are particular to the educational setting. The metasynthesis (section 3.5) demonstrated one way of exploring and searching for potential non-technical words within a fairly limited and defined sample of research through interpreting existing data and going beyond a standard review of the literature on non-technical words in chemistry. I believe it was useful as it showed how we need to look beyond the non-technical word itself in terms of how the usage of verbs differ in both the everyday and chemistry context (Taber & Watts, 1996), and how we associate particular adjectives to nouns in an everyday sense which are at odds with the canonical usage of such nouns. The appreciation of this insight assisted in identifying potential non-technical words which had particular verbal usages in an everyday sense that were different to the scientific meaning such as the words reverse and displace. Despite this, I believe corpus-based methods offer more as account is taken of specific resources used to represent the 'target knowledge' (or curriculum) related to the concerned setting. As students' target knowledge varies according to context, it may not be enough to suffice with non-technical words which have already been reported, but it may be more useful to identify potential non-technical words from resources specific to the educational setting. The corpus analysis utilised in this study provided useful tools which allowed for the search for colligational and collocational patterns as well as patterns for semantic prosody within the context of the language used in the designated curriculum (Hunston, 2001 & 2007), which was the Saudi EFL college students' core chemistry textbook. The production of keywords limits the words that need to be analysed with respect to the text (Scott, 2015). Moreover, the keywords would be limited to potential non-technical words as technical words would be omitted since a general English corpus is used as a reference corpus. Furthermore, the use of the concordance allowed the analysis of words which work in tandem with the non-technical words and provided further contextual clues to elicit its non-technical nature.

I acknowledge that Cassels and Johnstone (1980) in their conclusion suggested teachers should focus on four areas to improve pupils' understanding of words: "various connotations of a word…explain words in context…confusion [related to] similar sounding words…[and] words opposite in meaning…precision and discrimination [with respect to] different grammatical forms of the new word" (p.46). However, there also seems to be an implied oversimplification in the literature of a non-technical word being problematic as though it exists independently. A word in itself is not meaningful, but meaning comes about due to its relation to other words (Firth, 1957). This resulted in the identification of many potential non-technical words in the Saudi students' chemistry textbook, some of which can be found in the literature like 'strong' (Jasien, 2010), and 'organic' (Song & Carheden, 2014), whilst there were some newly found potentials such as 'fossils' and 'impurities'. Even with non-technical words that have already been reported, there are nuances in terms of how they are used in everyday terms and the aid of a dictionary such as Oxford Dictionaries can assist in this matter as it provides examples taken from a multibillion-word English corpus. A dictionary can provide an alternative perspective of words, for instance, Pekdag and Azizoglu (2013) analysed several textbooks in terms of how the term 'mole' is presented in these textbooks in misleading ways, yet, they did not discuss the point that “learners come to science learning with existing ideas about many natural phenomena” (Hard Core Axiom, Premise 2, Taber, 2013, p.7). To elaborate on this point, the term ‘mole’ was taken from an everyday perspective as defined in the dictionary, and this meaning was embedded in the chemistry context. Additionally, with the approach used in Phase One of this study, multiple usages of the everyday meaning could also be applied to chemistry contexts in search for potential non-technical words.

7.4 RESEARCH QUESTION B: How familiar are the Saudi EFL college students with the meaning and usage of the selected non-technical words?

The participants in this study included Saudi EFL college students with varied proficiencies in English. This was evident from the manner in which they engaged in the interviews. Whilst the selected non-technical words for this study ranged from what could be considered as common, including: strong, weak, lose, make and break; and uncommon, namely: collisions and impurities. The students’ familiarity of the other non-technical words was not consistent.

The students in this study follow a program where they have a combination of intensive English classes, taught by native speakers of English, and basic science courses. These students are expected to understand words in chemistry that would not be found in their EFL textbooks which are streamlined according to the CEFR levels. It seems as though there is a conflict of interest between the aims of the English and basic science courses. The former trying to guide students and progress them through the CEFR levels, and the latter expecting English courses to include chemical words which do not fit into the CEFR levels. Moreover, even if the word is taught in their English course, it would not resolve the issue of non-technical words as the scientific meaning would not be covered in these general English courses. Similarly, one of the findings from a study on Saudi students studying science in the medium of English in a university preparatory program was that the science teachers, and some of the students, felt that there was no correlation between what they learn in their intensive English program, and what they learn in science (Shamim, Abdelhalim & Hamid, 2015). Perhaps this could be partly due to invariance between the level of vocabulary taught in the basic science programs, and that being taught from their mainstream EFL textbooks based on CEFR levels.

Elaborating on this, the students were interviewed towards the end of the second semester of the Foundation Year whereby at the end of this year, they are expected to be A2 proficient users of English. English Profile provides a list of words appropriate for the A2 level (Cambridge English, 2012a, 2012b), and so the current Saudi EFL students are expected to know them. This list is produced from the Cambridge Learner Corpus which consists of more than 44 million words used by ELLs around the world. The English Vocabulary Profile categorises the words in the list according to the CEFR levels from the beginner (A1) to the independent level (B2). The words which students were generally familiar with are included in the A2 list (strong, make, break and lose), so this is not surprising. Strangely, weak was in the B1 list, nonetheless, all students were familiar with this word. The words which were not familiar amongst most of the students were listed in the B1 list (note: base listed as a phrasal verb – ‘base on’, not a noun), but collisions and impurities which were found to be the most unfamiliar words were not even on the B1 list. So in this sense, it is not surprising that most of the students did not recognise these words as their English program does not include this level (B1) of learning. A number of students recognised some of the uncommon words like arrangement and base but said that they forgot. “Memories are not actively ‘erased’, but memory traces that have not been called upon for a long time may have a higher threshold for activation” (Taber, 2013, p.97). Considering that these students were being interviewed towards the end of their chemistry course, we could not claim with near certainty that they likely forgot as they are in the midst of their chemistry course. However, we could say that they have had less exposure to these terms throughout their lives as they are EFL students.

The nature of non-technical words having distinct meanings in English and science is also problematic in terms of meeting the demands of science teachers in these programs. Students as EFL learners are faced with words which for a native, or near-native, English speaker is taken for granted as being familiar. However, for a lot of these EFL students, the familiarity of these so-called familiar words is strongly dependent on the context. Several students upon asking the meaning of the non-technical word gave examples in the context of chemistry as this was what they were familiar with. In particular, this was found to be the case with the words boiling, arrangement and base, all of which have been recognised as B1 words (Cambridge English, 2012b), yet the English program delivers an A1 and A2 course in the Foundation Year. So English teachers could equally demand that science teachers teach students the everyday meaning of these B1 listed words. Such exposure of higher level words early on in a students’ journey of learning English is not necessarily a negative thing. Two of the adult participants in Cink and Song’s (2016) study came from Ethiopia where they had learnt high level academic words in their schooling years. This meant that they were more familiar with the scientific meaning of non-technical words, rather than the everyday meaning, and as a result they did not struggle with such words in their academic studies.

A few of the students appeared to have a better level of English in comparison to what is expected in the Foundation Year as A2 CEFR learners, although they studied in Arabic medium schools prior to this program. There is a great demand for English in Saudi Arabia from both the government and the educated class, and it is rapidly increasing (Al-Kahtany, Faruk & Al-Zumor, 2016). So even though these students have studied in Saudi public schools, communicating in Arabic both in these schools and in their homes, English is still accessible in other ways as they have access to the internet and come across various multinational Western companies that use English terms. Therefore, the familiarity aspect of English words in Saudi Arabia is changing in a positive direction in terms of further exposure to English. This was also witnessed in this study with one student recognising the word base from his Netflix account. He was able to provide a meaning of this term due to his exposure to English out of the classroom.

7.5 RESEARCH QUESTION C: To what extent does the everyday meaning of the selected non-technical words influence the Saudi EFL college students' understanding of concepts in chemistry?

The findings showed that some of the Saudi EFL college students' conceptions were influenced by the selected non-technical words. On the contrary, there were also cases where the students were untroubled by the everyday meaning of the non-technical words.

The hard core axioms adopted in this thesis states that learners actively construct their own personal knowledge, and it “is represented in the brain as a conceptual structure” and “learners’ conceptual structures exhibit both commonalities and idiosyncratic features” (Taber, 2013, p.7). There were numerous cases of the students demonstrating both idiosyncratic conceptions, and commonalities, with some nuances in this regard. As an example, with the non-technical words lose and gain, several students applied everyday connotations of gain as winning, and lose as something bad when explaining the chemical bonding in sodium chloride. This led to an alternative conception whereby several students said that it is bad for sodium as it lost an electron, but it is good for chlorine as it gained an electron. There were some minor variations of this conception such as one student saying that at first it was bad for sodium, but at the end of the reaction sodium is better off. Many students exhibited idiosyncratic conceptions as well. Using the same conceptual example for the sake of brevity, one student associated his everyday connotation of negative with an electron. He appreciated the symbolic aspect of electrons being denoted with a negative charge (-), and said that since sodium lost the electron it was in a better state as if you lose anything negative it is good for you, further adding that it was “bad luck” for chlorine as it accepted an electron. This example also illustrates other aspects of the hard core assumptions such as students coming to science with existing ideas (Premise 2), and such ideas having consequences for the learning of science (Premise 3). Moreover, it shows that leaners can hold multiple conceptions at once about the same concept (Taber, 2009). There were many other cases of the students showing that they hold manifold conceptions whilst demonstrating a reasonable canonical account of the phenomena (Taber, 2000).

The alternative conceptions given by the Saudi EFL students showed both similarities and differences with respect to what has been reported in the literature. Similar to what Boo (1998) reported, the Saudi students found difficulties with the concept of making bonds releasing energy as in an everyday sense, when we make something, we are using our energy to make things. Boo (1998) also found students saying that 'breaking' bonds releases energy, as energy is released when something is destroyed, yet the Saudi students had no issues with the concept of breaking bonds requiring energy as they understood it as a person putting energy into the system. The Saudi students commonly associated boiling with water, as reported by Jasien (2013). Several students were therefore unconvinced that oxygen has a boiling point as it is a gas at room temperature. Similarities were also found with the applied connotations of non-technical words strong and weak (Jasien, 2011).

The students in this study also exhibited alternative conceptions which appear not to be reported in the literature. The word collisions has been reported in Yalcinkaya & Boz (2015), but their study did not suggest any relationship between this word and its everyday meaning, and moreover, their study was conducted in Turkey, which we could presume involved translating data into English from Turkish. Nonetheless, the present study found that while most Saudi EFL students recognised the negative connotation in everyday language, as this was also shared in the equivalent translated word in Arabic, they did not apply the same negative connotation in the context of chemistry. Rather, some said that it is the opposite of what is experienced in daily life and thought that there was a positive connotation associated with collisions in chemistry. Impurities was another non-technical word not found in the literature, yet, it appeared problematic for the Saudi students.

There were distinct instances (involving base and gain) that implied that Saudi students are embedding false everyday meanings in the chemistry context in the process of their translation, as opposed to real English everyday dictionary meanings. Song and Carheden (2014) noted a student referring to a base as being at the bottom as in everyday English it is referred to as the lower part of something, and therefore concluding acids are the opposite and on top. While in this study, several of the Saudi EFL students understood base to mean a rule, as that is one of the translated meanings of base in Arabic. This led them to define a base as some form of a rule related to compounds. Also, as mentioned earlier, gain was associated with win as the students commonly used the Arabic equivalent with this connotation, for example, 'he gained a trophy', and this is not how it would be used in English. This led to some students thinking of chlorine as a winner since it gains an electron when reacting with sodium. These findings are contrary to Mali and Howe's (1979) replication of Nussbaum and Novak's (1976) study a few decades ago as they found that their participants, Nepalese students, were forming similar conceptions to the participants of the replicated study who were American students.

It seems that studies on non-technical words, whether in the discipline of chemistry, or other science disciplines, have not been explicit about reporting on why students may not be influenced by the everyday meaning of non-technical words. For example, Child and O'Farrell (2003) compared native and non-native speakers of English understanding of non-technical words and recognised that the concern for non-natives is greater, but there was no elaboration on why some non-technical words were found to be unproblematic. From one perspective, it could be argued that suggestions for teaching practices (see for example Childs, Markic & Ryan, 2015; Wellington & Osborne, 2001) to make students aware of non-technical words' everyday and scientific meanings provide guidance for learners, and as such could reflect what skilled learners do to avoid such difficulties. However, exploring and reporting instances where non-technical words are found to be unproblematic, as was found in this study, can not only inform us on students' canonical accounts, but also how they provide non-canonical accounts in the process.

In an ideal situation, students who demonstrate a strong understanding of the target concept are not expected to embed everyday meanings of non-technical words as they can appreciate the scientific meaning and therefore provide a scientifically acceptable explanation. This was found in the present study as some students provided canonical accounts of the concept and negated any possible influence from the everyday meanings of the non-technical words. In spite of this, there were several cases whereby the everyday meaning of the non-technical word had no bearing on the students' conceptions, yet they still provided non-canonical justifications as they attempted to make sense of the scenario. In this study, some Saudi students resorted to principles from their religion to rule out everyday connotations, and applied these principles to make sense of the phenomenon in chemistry. One student said that in Islam there is good and bad in everything, and therefore in chemistry, collisions are neither a good or bad thing, shifting towards a neutral stance. Though his view of collisions being neutral in chemistry is on the surface canonical, the explanatory model used to justify this is not.

Some students often cited the textbook, their teacher, or a general rule derived from these two reference points, to justify why the non-technical words in the scientific context do not represent their everyday meanings. This could be indicative of a culture of rote learning in Saudi Arabia (Alrabai, 2016; Suliman & Tadros, 2011). Students who first thought that oxygen does not have a boiling point of $-183^{0}C$ did not even ask for an explanation after it was shown to them written in their chemistry textbook, as though it sufficed them. Nonetheless, rote learning does have a role and as a step towards understanding (Taber, 2013), but is secondary to meaningful learning (Ausubel, 2000), and in relation to non-technical words in this study, it appeared as though it prevented the students in applying the everyday meaning in its scientific context. As an example, when asked about why sodium hydroxide, NaOH, is a base within a particular reaction, several students kept repeating that it is a base because the pH value is above 7. They were applying a rule they learnt about bases, stressing that that there is no connection with its everyday meaning, but they could not explicitly relate this to why sodium hydroxide in particular is a base. They could have, for example, related to the context better by referring to it as a metal hydroxide, or that it reacts with an acid to form salt and water. This perhaps is indicative of the consequences of rote learning used in their cultural and educational practices and the inability to relate to novel contexts (Ausubel, 2000).

7.6 RESEARCH QUESTION D: What is the role of the Saudi EFL college students' first language in understanding the selected non-technical words in English?

Most of the non-technical words shared resemblance in terms of their everyday usage in both languages. Although there were some subtle differences such as commonly using the Arabic equivalent of gain with examples related to winning. Most notably, the only word which differed much between both languages was the everyday use of base, as in Arabic, it can be used to refer to a rule, and as mentioned earlier in this section, this meaning was incorrectly embedded in the scientific context leading to non-canonical accounts.

In the literature on words in science, studies which include ELLs give some importance to the students' proficiency in English (see for example Cink & Song, 2016), but it appears that their first language is given little importance; and this is perhaps because of the importance of the target language for learning in which case is the medium of English. Some of the students who appeared to have a high a proficiency in English held similar alternative conceptions as those who seemed less proficient. One particular student, though demonstrating to be very weak in English, provided canonical accounts of chemistry whilst those who were more fluent in English would provide otherwise. This particular case supports the findings of a study which found that Arab students who are confident in their scientific knowledge compensated for their deficiencies in English (Hayes & Mansour, 2017). Relevant to the students' first language, some students were able to recall precise Arabic terminology for the equivalent scientific meaning in English, such as 'qaa'dee' for base, and this aided students in using the non-technical word in the appropriate context. However, one student who identified the equivalent scientific Arabic term for base was unable to apply this meaning in context as he did not show any form of understanding the concept. This could be due to many reasons including 'forgetting' due to not using it often (Taber, 2013), or it could be another example of rote learning practices (Suliman & Tadros, 2011).

EMI studies have given the role of a student's native language attention in the form of code switching (Macaro, 2018), and even within the CEFR guidelines (Council of Europe, 2001) acknowledgement is given to students' first language as a resource, with some advocating for pluralistic use of languages (Daryai-Hansen et al., 2015). Yet, there seems to be a slight oversight in that EFL students are seen as equally proficient in their native language. In this study, it was found that the Saudi students varied in terms of their Arabic proficiency and certainly with regards to how they use words. As an example, some students, understandably, needed to use a dictionary to find the Arabic equivalent of impurities, and as all the students used Google Translate, the word ‘shawaib’ was the given word. Yet, students struggled to make sense of this word in their own language, and even one student said that he had never come across this word in Arabic. A few other students avoided using this word, and used another related synonym provided by Google Translate. This meant that when they were applying meanings from the dictionary translation, the word which they were familiar with was further away in meaning from the equivalent translated word. However, it was noted that the proficient users of English referred to the dictionary less, and relied on their own linguistic resources. Conflicting usage of Arabic words was also found amongst students, for instance, some were claiming that the concerned word should only be used in formal situations, and others thought that they could be used in both formal and informal situations. Therefore, as the Saudi EFL college students had such variations in their own native language, as well as in English, this had consequences on their understanding of non-technical words in English.

Bakhtin’s (1981) notion of heteroglossia stresses the importance of context as the meaning of an utterance is situated in a particular society and culture. Language and culture are essentially interlinked (Alharbi, 2019). Despite the importance and acknowledgment of culture, studies focussed on words in science, and moreover non-technical words in science involving ELLs, have not commented much on the role of culture in understanding non-technical words. In this study, one student had general negative experiences of sand, and thought that it is dirty in the purification of hematite. The environmental experience of students in heteroglossia is similar to what has been reported by Rosebery et al. (2010). Additionally, this instance could be appreciated through an adapted mental model based on Vygotsky's notions of spontaneous and academic concepts (Taber, 2013). Interconceptualisation here could be exemplified as between the student's experience of sand which forms part of the spontaneous concept, and that of the curriculum representing sand as an impurity in the purification of hematite (academic concept).

Several students referred to principles from their religion to make sense of the presented scenario, but Muslims' religious beliefs do not necessarily harmonise with that of science (Mansour, 2011), while Islamic beliefs have a high status for Saudi EFL students (Alrabai, 2016). The principles from the religion that were used such as taking things in moderation seemed to work as an explanatory model in terms of not applying the everyday meaning of the non-technical word in the scientific context, but it is not in line with the target knowledge as a basis to make such justifications. One student sufficed his explanation as God created it like this, whilst others, not on religious grounds, explicitly said that they do not believe in the concept. This has been reported elsewhere whereby students construct two separate conceptions, one in which they understand the ideas presented, and at the same time, a belief which does not coincide with the presented idea (Chinn & Samarapungavan, 2001). Though there is no harm in scientists having beliefs which are at odds with science, the goal should be on getting students to appreciate the 'explanatory power' of such science (Taber, 2009).

7.7 CHAPTER SUMMARY

This chapter discusses the findings of the research questions in relation to relevant literature in the field. Numerous issues were discussed. Firstly, the relevance of the adopted theoretical framework, constructivism as a theory of learning, was related to the findings of this study. The study findings were consistent with the hard core axioms of constructivism, and moreover, the application of other key concepts, namely, interconceptualisation, ZPD and heteroglossia provided greater insights into the study's findings. The corpus-based study assisted in the identification of potential non-technical words in chemistry by way of a broader application of the definition of non-technical words and looking beyond the non-technical word itself. This led to the identification of words which to the researcher's knowledge have not been reported before, and further providing alternative perspectives to non-technical words that are reported in the literature. The findings from the interview phase showed that Saudi students exhibit similar reported conceptions of chemistry concepts, whilst also demonstrating conceptions that have been influenced by matters which pertain to their surroundings, and to some extent, are particular to their cultural context.

CHAPTER EIGHT
CONCLUSION

8.1 INTRODUCTION

This chapter begins with a summary of the research findings, followed by addressing the implications of the findings on teaching practices in the given context, and utilising corpus-based methods. The limitations of this study are pointed out, followed by highlighting how the present study has contributed to knowledge in this area of research. The chapter ends with possible future directions for research and practice, and some brief concluding remarks reflecting on the impact of the research on the researcher.

8.2 SUMMARY OF RESEARCH FINDINGS

This study sought to gain insight into Saudi EFL college students' understanding of selected non-technical words as found in their chemistry textbook. The first phase of the case study involved analysing the students' chemistry textbook for the purpose of identifying potential non-technical words using corpus-based methods. Eleven of these words were taken forward and formed part of the interview phase involving eleven Saudi male students studying in the first year of a diploma program in a vocational college.

The corpus analysis of the participants' core chemistry textbook resulted in the identification of 46 potential non-technical words. As the chemistry corpus is referenced against a general English corpus, thereby omitting any technical words which would not appear in general English, it allowed for the analysis to focus solely on identifying potential non-technical words. The everyday meaning of the identified potential non-technical words contrasted to various degrees to the chemistry meaning. Some everyday usages were found to have a difference in meaning at a deeper abstract level (e.g. reverse), and other words with more apparent differences (e.g. strong). The difference in meaning became more apparent when analysing its meaning in relation to other words surrounding it (collocations), and there were also instances where the syntax structure (colligation) could potentially lead to misinterpreting the scientific context. There were also many instances of the everyday connotation differing with the scientific meaning and therefore could potentially be incorrectly applied. Overall, the range of words included those which could be considered common in daily language use (e.g. simple), and others that would be considered uncommon (e.g. activation).

The students in this study appeared to have varied proficiencies in English and this was noticed in their one hour interview with some demonstrating that their level of English is beyond the level of the program's English course (CEFR A2), even though they had come from Arabic public schools. This indicates that despite being EFL students, they are still exposed to English to a considerable extent. The students' familiarity of the selected non-technical words suggested that those words that were deemed to be classified above CEFR A2 tended not to be familiar, and thus required them to resort to a dictionary. Some words were only familiar to students in the context of chemistry, as EFL students they had not been exposed to such words in everyday English. Whilst the technical words everyday usage shared some common meaning in both languages, there were some notable differences (e.g. base). Even with this, the students appeared to vary in terms of their proficiency in Arabic.

The potential non-technical words identified in the corpus analysis appeared to have caused some confusion amongst the Saudi students. There were many instances where they provided non-canonical accounts of chemistry. These explanations had some commonalities amongst the eleven students, but some individuals also exhibited idiosyncratic conceptions. They seemed to take, for example, connotations and translated meanings from what they understood as everyday usages and applied these in the context of chemistry. However, not all the students' conceptions were influenced by the non-technical words. Some students gave reasonable canonical accounts of chemistry and did not falter when probed. Others were able to recall the precise term in Arabic, but this did not necessarily mean that they could give a reasonable explanation. The students' culture, especially principles from their religion, were used to justify the instance, yet, these were not based on scientific grounds and therefore could not be considered as canonical accounts.

8.3 IMPLICATIONS FOR TEACHING & LEARNING

The findings of this study have to some extent addressed some concerns related to the teaching and learning of chemistry in Saudi EFL Foundation Year (or Preparatory Year) programs. First, implications associated with similar educational settings are discussed, followed by relevant issues dealing with the teaching and learning of chemistry in the wider context. Further details pertaining to the implications of this study in relation to future research and practice are expanded on in section 8.7.

The Saudi EFL students in this research studied in the Foundation Year, which is similar to other preparatory year programs in Saudi Arabia. It appears that one of the biggest dilemmas that such a program is facing is the relationship between the intensive English course with the basic science courses (Shamim et al., 2015). On the one hand, subject specialists teaching science in the medium of instruction feel that the English course is not offering enough to aid the Saudi students in terms of dealing with the demands of the course. At the other end, English teachers have to follow mainstream EFL textbooks by teaching these students according to the CEFR levels which is planned according to the proficiency of EFL students. One of the concerns discovered in this study was that students were unfamiliar with the non-technical words that could be classified as appropriate for CEFR B2 learners (Cambridge English, 2012b). The vocabulary taught in similar kinds of English classes in preparatory year programs is limited to what publishers classify as being part of a particular CEFR level. In the current Foundation Year, students study CEFR A1 material for one semester for 20 hours a week, followed by a second semester covering CEFR A2 material for 15 hours a week. Students are using a chemistry textbook published for highly proficient users of English which includes vocabulary which goes beyond the CEFR levels covered in the English course. Moreover, the students are being taught chemistry five hours per week, over 15 weeks, though the content is equivalent to what they have studied in their high schooling years in the medium of Arabic.

Suggestions have been made in terms of teaching activities in the chemistry classroom to meet students' linguistic demands (see for example: Wellington & Osborne, 2001; Childs, Markic & Ryan, 2015), however, it may not be practical in this context due to the limited time available for teaching chemistry. Therefore, perhaps what is needed is for there to be some coordination between English and science teachers to use vocabulary-based activities during English classes. However, it would not be ideal to expect English teachers to teach the scientific meaning of non-technical words as they are not subject specialists. This could be materialised by using corpus based approaches to identify highly frequent words in the chemistry book, followed by classifying each word according to the CEFR level, and at least ensure that students have grasped the meaning of the A1 and A2 classified words. Again, expecting English teachers to teach, for example, B2 classified vocabulary would be unreasonable considering the program of study for English. Although, chemistry teachers can be informed of these words so that they are aware that students would not be exposed to such words in the English curriculum. In essence, what is being suggested is for science teachers to take more of a proactive role as subject specialists and understand what is actually being taught in these English programs and make adjustments as necessary to their lessons.

Recent reports have been published regarding the teaching of vocabulary in chemistry classrooms, and these could be incorporated as teaching activities within the current context. Rees, Kind and Newton (2018b) developed a Chemical Language Assessment (CLA). This tool included assessing students' use of affixes, word families and non-technical word choices. The non-technical word assessment came in the form of multiple-choice questions, and the word choice activity gets students to choose alternative words related to the key word being tested which essentially involves selecting synonyms of the key words. Yuriev, Capuano and Short (2016) developed a crossword puzzle which they claim prevents rote-learning practices as clues are provided to students to solve the crossword rather than word-for-word definitions. Furthermore, they made this crossword puzzle available online for students to access in their free time which can help them reinforce the meaning of chemistry words for extended periods of time. Given the time constraints with limited instructional hours of chemistry, and the inability of

English teachers to teach scientific meanings of non-technical words, chemistry teachers could consider adopting such vocabulary-based activities as self-access learning tools.

The teaching and learning implications of the present findings extend to the wider context. Educational institutions around the world utilise online learning platforms, and even the vocational college in the present study has recently incorporated Blackboard (a learning platform to complement existing courses) and are encouraging their staff to incentivise the use of it by uploading assignments and awarding marks as part of the overall continuous assessment mark. The advantages of incorporating the online vocabulary-based tasks within such learning platforms are manifold. Chemistry teachers could use learning tools such as those described above, placed online, to identify the most problematic non-technical words. Furthermore, as the words can be situated in multiple novel contexts in these vocabulary activities, it may assist in dealing with contexts where rote learning practices are rooted deeply within the education system. The findings of this study also found that students relied heavily on their lecture notes, more than their chemistry textbook, and such lack of interest in reading is an international concern despite the reported benefits of reading comprehension in science (Patterson et al., 2018). Comprehension related exercises could be designed on an institution's online learning platform to encourage students to read more, though this may also need to be incentivised. However, the difficulty of adopting such approaches will depend on the chemistry teachers' workloads as it would take time to not only produce appropriate exercises, but also to monitor students' performances.

Chemistry teachers around the world are teaching in contexts where their students are learning chemistry in a language other than their native language, and in some circumstances where the language of instruction is a foreign language. One of the key findings from the interviews with the participants is that the students experienced difficulties in acquiring the dual meanings of non-technical words due to some influence from the process of translating the non-technical word into their native language. This process involved the students to first find an equivalent Arabic term for the non-technical word using either a word they thought was similar in meaning to it, or by referring to a word given by Google Translate. Then this Arabic word was translated back into English with a term which they were familiar with in English and this inaccurate translation of the word was applied to the chemistry context which resulted in a meaningful sentence in an everyday English sense, yet, non-canonical in terms of the chemistry context.

If teachers are aware of the possibilities of foreign language students applying incorrect translated meanings to the chemistry context then they may be in a better position to facilitate learning. Teachers could assist students by drawing their attention to the incorrect usage of such terms. This could be implemented by chemistry teachers designing vocabulary exercises that target the non-technical words in three main contexts. Firstly, a context which is situated within an everyday English context; secondly, a chemistry specific context; and the third context, an assumed synonym of the non-technical word which could potentially be derived from the translation process described above. This third kind of word, when applied to a chemistry context, produces a meaningful sentence in everyday English terms, but demonstrates a non-canonical account of chemistry. Similar to how diagnostic tests are used to test students' understanding of the difference between the dual meanings of known non-technical words such as 'strong', this third context in particular can also come in the form of a multiple choice question, and the context of the sentence can vary between the everyday English sense and the chemistry context.

Chemistry teachers' awareness of ESL/EFL students' native language should expand beyond the linguistic aspect. The students in this study demonstrated that their natural environment influenced their understanding of non-technical words due to their interaction with their native environment. For instance, some students' association with sand relates to a place where they spend their leisure time and thus giving them a feeling of happiness. This feeling transformed into developing connotations of words which may not appropriately apply to a chemistry context. Rosebery et al.'s (2010) also reported on ESL students relating their native environment (not their current environment) to a scientific concept. If teachers become more aware of ESL/EFL students' native environmental surroundings (in addition to the present surroundings) they can possibly identify potential problematic areas whereby a non-canonical understanding of a scientific concept is derived (or influenced) from students' memories of their native country's environment.

8.4 IMPLICATIONS FOR CORPUS ANALYSIS

In this thesis, two distinct methods were used in the adopted sequential mixed methods design, one an established and widely used method, interviews, and the other, a corpus-based analysis. The present research has addressed some concerns in corpus linguistics.

Corpus based analysis is an insightful method, but the procedure from corpora construction to analysis is extremely time consuming. To analyse every word in a Frequency Wordlist would have taken even longer and thus this supports the use of Keyword lists to narrow the focus of key words in context

(Scott, 2015). Also, the findings from the corpus-based analysis partially agree with the view that semantic prosody is not universal (Whitsitt, 2005). For example, the collocation of strong and weak with acids (strong acids/ weak acids) clearly shows that the connotation drawn from everyday language cannot be transferred into chemistry in a canonical way. In an idealistic sense, the connotation of strong being powerful is unrelated to strong acids being powerful, and the same is true for weak acids. Also, 'collisions' is something which is neutral in chemistry, but undesirable in everyday terms. Hunston (2007) points out that connotations are universal to a certain extent, depending on its explanatory or predictability nature. 'Fossils' could be taken as a word which is situated negatively as the burning of fossil fuels causes pollution. Such words could develop into false connotations which are not necessarily appropriate, yet, for the learner, it can be taken as explanatory in nature.

Corpus analysis is dependent on a researcher using intuition and drawing conclusions from concordances and this informs the findings (Bennett, 2010). This alone as a process for informing research results would not work well within constructivist research in science education. So for example, if several recordings of interviews were collected from a similar sample of students, and then constructed as a corpora for analysis to act as results of a study, it would not be in the spirit of constructivism as a theory of learning. This would mean that students represented their ideas, from which a researcher interprets and transcribes this representation of her/his interpretation, which is then mixed with several other transcriptions, and interpreted by other researchers and represented as text for others to interpret. However, it can be useful in the sense of finding avenues for further research as was done in this study with the search for potential non-technical words within the Saudi EFL students' chemistry textbook, and having this conjecture tested on real students.

8.5 LIMITATIONS

Constraints due to time and resources, as well as shortcomings of chosen methods, would inevitably impact the quality of the research and the extent to which these findings could be generalised.

The main limitation in the corpus based study was that not all the words from the corpora were analysed. A keyword list is useful in that the calculations extract words which may be of interest from the corpus, though, it will always have a disadvantage against wordlists which contain every word type in the corpus. There may certainly be words of great interest which were missed due to this. Additionally, the corpora were based on a textbook specific to the current research setting. Therefore, care needs to be taken in making claims that the findings are applicable to all preparatory year programs. Despite this, we could expect that there is a great deal of fundamental content which overlaps across all institutions such as atomic structure and bonding.

The findings from the case study were taken from a considerably small sample size, and this is the nature of case study research and will likely continue to be considered by some as one of the shortcomings of this method (Yin, 2009). The extent to which the present findings could be generalised to other Saudi EFL college students in similar settings is limited as each context would for example have a different: English syllabus (though normally using mainstream EFL textbooks); chemistry syllabus and related resources such as different textbooks; EMI teachers who are bilingual; and students of higher or lower proficiencies in English. Despite this, taking into account the hard core axioms of constructivism adopted in this study, approaches such as case studies are needed to explore an individual learner's conceptions. Though surveying large samples of a population can be useful, we equally need detailed descriptive accounts of learners even if it is drawn from a small sample size, and this is one of the strengths of case study research (Flyvbjerg, 2006). Another limitation, is that the participants in this study were interviewed in one sitting, rather than multiple sittings:

> Longitudinal studies follow the same individuals over time. It is therefore possible to consider studying more nuanced changes in learners' ideas, as in-depth methodology may be applied to build sophisticated models of students' conceptual structures at different points in time. (Taber, 2009, p.342)

Access to the Saudi students was a great challenge in this study, which would have made it quite difficult to interview the students at regular intervals.

The role of the researcher would bear consequences on the interview data especially when there are differences in culture between the interviewee and interviewer (Kvale & Brinkmann, 2009). As I have limited proficiency in Arabic, I may not have followed up on students' cues effectively. Having said that, the students' teachers cannot communicate in Arabic, and are teaching in the medium of English. Thus, they would similarly share such challenges in interpreting students' utterances.

8.6 CONTRIBUTION TO KNOWLEDGE

A study on non-technical words in chemistry is consistent with the axioms of constructivism adopted in this research which understands constructivism as a theory of learning, and section 3.3.4 attempted to show how the theories of Vygotsky and Bakhtin, in particular, could be adopted within these axioms. The review of the literature concerning students' understanding of non-technical words in chemistry found that very little research has been conducted on non-traditional students, and more recent research is shifting in this direction. Research in this area pertaining to Saudi college students, according to the researcher's knowledge, is non-existent and therefore worthy of studying. These Saudi students study chemistry in their high school years in Saudi public schools in the medium of Arabic and then enter a Foundation Year (Preparatory Year) where they now have to study chemistry in the medium of English, and as in the case of this study, sometimes with a chemistry specialist who does not speak the students' native language. In addition, these students are in a country where English is used as a foreign language, thus having less exposure to English as compared to an ELL in an English speaking country. Thus, the research set out to find out how Saudi EFL college students understand selected non-technical words in chemistry.

The case study incorporated a sequential mixed methods design to address the research question using a corpus-based approach which builds into an interview phase. This required analysing the students' core chemistry textbook for potential non-technical words from which over forty words were found. Eleven of these non-technical words were selected by the vocational college's management team, and these words formed the basis of semi-structured interviews conducted on consenting Saudi EFL college students, eleven in total, as part of the case study. Some of the findings both diverge and converge from the conclusions drawn from past research. Despite this, the present thesis demonstrated numerous new findings which has not been reported before according to the researcher's knowledge and offers a theoretical contribution to research in this area. This includes the following with respect to the context of the study, Saudi Arabia:

- Recent studies on non-technical words in chemistry specifically are shifting in the direction of non-traditional students (Cink & Song, 2016; Rees, Kind & Newton, 2018a). These studies have reported on the challenges these students face as their educational background differs much with traditional students who would have followed a normal pathway to study chemistry. These differences could include having to learn chemistry in English at a later stage, for example, as an adult learner. The present study has contributed to our knowledge by detailing another group of non-traditional students' (Saudi EFL college students) challenges of dealing with non-technical words in chemistry.
- Saudi students may translate words into English by applying the everyday Arabic usage which leads to non-canonical accounts of chemistry. So, they are not associating 'acceptable' English everyday meanings with non-technical words, which is what is commonly reported, but also false applications of everyday meanings derived from Arabic.
- Saudi students exhibited non-canonical accounts of concepts involving non-technical words similar to earlier reported studies, but also some with a nuanced perspective drawing on aspects from their environmental context.
- Recalling specific equivalent Arabic scientific terminology does not necessitate that the everyday English or Arabic meaning would not be embedded in a scientific context, nor that it assists in them being able to explain scientific concepts in a canonical manner.
- Saudi students' proficiency in English has implications on how they understand non-technical words as those who are more proficient rely less on translated dictionary meanings.

- The globalisation of English in Saudi Arabia has led to Saudi students acquiring everyday meanings from their non-educational contexts which could influence their understanding of non-technical words in chemistry.

Additionally, this study's contribution to knowledge has international relevance:

- The present study demonstrated that the students' varied proficiency in their first language has consequences on their understanding of non-technical words. The achievement gaps between native and non-native English speakers learning science in the medium of English is not a new issue (Lee, 2001), and it continues to be a reported problem in recent years (Garza et al., 2018). The findings in this thesis suggest that science educators should focus on ELLs' proficiency with respect to their first language as this could have a role in the achievement gap rather than just concentrating on their linguistic abilities in the language of instruction (English). This is especially the case for older students, as in this study, who have encountered English at a later stage in their lives.
- Islamic beliefs do not always work in tandem with science (Mansour, 2011). The study's findings showed that this extends to the understanding of non-technical words in chemistry. The students in this study used principles from their religion, Islam, and applied associated connotations to understand the meaning of non-technical words in chemistry contexts.
- Numerous studies have pointed to the importance of learning the language of science and offered some ideas in terms of teaching activities (Childs, Markic & Ryan, 2015). Yet, it has been reported that science teachers neglect its importance (Oyoo, 2012), as the aims and purpose of science courses in this regard may not be explicit (Shamim et

al., 2016). The study identified one possible source of the problem related to the disunity between English and chemistry courses, and offers a potential solution so that there is a shared responsibility in this regard.

- Studies on non-technical words normally report on words which have been problematic due to the application of the everyday meaning in a science context. However, this study showed that whilst students may not incorrectly apply the everyday meaning of non-technical words in the context of chemistry, they may still justify such inappropriacy based on non-canonical accounts of chemistry.
- While studies justify how they selected non-technical words for their study (see for example Song & Carheden, 2014), they do not provide a sophisticated and detailed set of procedures to determine the identification of potential non-technical words which are worthy of investigating. This study offers a framework and details a set of procedures for carrying out a corpus analysis in search of potential non-technical words in chemistry specifically, though this can extend to the other science disciplines. The findings of this process led to the discovery of non-technical words which have not been studied before, and in addition, a nuanced novel perspective of some reported non-technical words in chemistry is given.

8.7 RECOMMENDATIONS FOR FUTURE RESEARCH

The findings from the present study has developed scope for further research in a number of areas related to students' understanding of non-technical words in chemistry for both the present and the wider context.

The corpus analysis of the chemistry textbook identified 46 potential non-technical words. The selection of these words came from a keyword list which in itself is derived from a comparison of the complete list of words from the chemistry textbook (frequency list) and a general English reference corpus. Moreover, only 11 words out of the total 46 words were used as part of this study. Although the corpus analysis included numerous potential non-technical words, only a limited sample was selected for further investigation. Therefore, I suggest that future studies could explore the maximum number of potential non-technical words in terms of the extent to which they are problematic for learners as this would provide a more comprehensive understanding of the range of non-technical words from a given textbook. This would ensure that the range of non-technical words includes diverse chemistry topics, and words which are non-technical in nature but varied in their familiarity in terms of their everyday usage. For instance, impurities was identified as a non-technical word, however, its familiarity cannot be considered to be at the same level of some other non-technical words such as strong or weak.

The present study explored one chemistry textbook published in England, yet future studies could extend this to include publishers from a wide selection of publishers from different examining boards around the world, in addition to material which students access via online websites, or any in-house produced material. Such rich data would enable teachers to take into account the reported difficulties of the non-technical words, and especially create awareness of the range of non-technical words which are most likely to be problematic for learners. Moreover, those involved with curriculum design, and even mainstream publishers, could take into account these findings and include some form of activity, or additional notes, to make others aware of such challenges.

One of the key findings in this study is that a few non-technical words were found to hold, through translation, everyday meanings in Arabic which were significantly different to the everyday meaning of English words, like base and gain. So, when the students applied the Arabic meaning to the chemistry context, the concept was misunderstood. Further exploration in this area would involve first of all identifying potential problematic non-technical words from the target knowledge (or curriculum). Then these words would need to be translated into the first language (for e.g. Arabic, Chinese etc.), and this translated meaning would need to be applied to the chemistry context to see if a meaningful sentence could be made which is at odds with the chemistry concept. Some words, when translated, may have several possible translations, and so each of these possibilities would need to be checked. Once this process has been completed a similar semi-structured interview format could be conducted with real learners to test this conjecture.

One extended area of research that could provide further insights into students' understanding of non-technical words in chemistry is to explore non-technical words in the medium of the first language itself. Vladusic and Ozic (2016) conducted a study based on Croatian students, and in the same way, one could be conducted on any ESL or EFL student. This could open-up possibilities for comparing studies in terms of how ESL/EFL students use non-technical words in the medium of English, and that of their first language. Ideally, the researchers should be reasonably fluent in the first language, as well as in English, to assess the plausibility of the word being identified as a non-technical word. Findings of this sort would be of great benefit to teachers who have students that rely on translating words into their first language due to their limited linguistic ability in English, and teachers can therefore act accordingly to facilitate learning.

Some of the participants in this study demonstrated that they were acquiring English words outside of the classroom, and some appeared to have grasped English at a level higher than what was being taught in the Foundation Year. It would be of much interest to understand the social context in which students interpret meanings of the everyday meaning of English non-technical words in their surroundings. Though this would be a complex study as social environments are not only of different kinds, but also dynamic in nature. For instance, presently, many popular social media platforms are being used such as Facebook, but it does not mean that in the near future this would be the case. The researcher would need to know firstly how students are engaging with English outside of the classroom, and then examine these environments in order to identify potential non-technical words. Such knowledge would not only assist teachers to become aware of these potential problematic non-technical words, but more so, build a better rapport with the students. By knowing the students' social environment, and being up-to-date with this, teachers can better relate to students in class as they would know about their students' personal interests.

It was found in this study that the Saudi students did not use Arabic in the same way, and it appeared that their proficiency in their first language was as variable as their proficiency in English. Whilst some students were able to produce several synonyms, others struggled to understand the meaning of the words in their first language. More research is needed into ELLs use of their first language. It would be interesting to know if there is any correlation between these varied proficiencies in both languages (first language and English) and their understanding of concepts in the medium of English. This could involve designing language proficiency tests for their first language, in addition to chemistry tests (or other science disciplines) in both the first language and in English. EFL textbook publishers already have a number of English proficiency tests available. With this data, a number of statistical tests could be conducted to make comparisons between all these tests. Moreover, interviewing these students throughout their program, as they progress in their proficiency in English, may provide insights into how ELLs' conceptions change as they become more proficient in English. Furthermore, it would be noteworthy to see if their understanding of non-technical words in chemistry changes over time as perhaps they become less reliant on translating between their first language and English, as it was found in the present study that those students who appeared to be more fluent in English relied less on dictionaries. Data of this kind can help institutions make informed decisions about their programs. For example, if it is found that there is no significant improvement in achievement in chemistry when English teaching contact hours exceed, for instance, 10 hours, then there may be no need to provide any excess contact teaching hours (i.e. above 10 hours per week). The additional hours which would have been allocated towards English could be spent on something more beneficial.

There is an ongoing dilemma in similar academic settings where English and chemistry (including other science disciplines) courses are not working in tandem for the benefit of the students. Responsibility of the linguistic needs of students learning science is not taken account of mutually. English as a medium of instruction is a widespread policy in all parts of the world (Macaro, 2018), and exploring effective ways of incorporating chemistry content within English courses would be of much use with the condition of not demeaning the importance of teaching English according to the CEFR levels. The present study suggested that due to the limited number of instructional hours of chemistry in these programs, teachers could utilise online learning platforms to give students ample time to practice using words in chemistry. However, research into the feasibility of accommodating such approaches needs to be explored when taking into account the likelihood of such programs being used effectively by ELLs in addition to the workload constraints on teachers. The findings in this thesis have shown that there is much scope for future research on language, and more specifically, vocabulary-based issues in similar contexts. Through this, better practices can be established to aid those who are involved in the teaching of these subjects and form part of their continued professional development. Suggestions could be put forth to authorities in charge of such programs so that necessary changes can be made, or even introducing policies to make such coordination compulsory as it benefits these kinds of programs as a whole since there would be a common goal for all courses under that one program, and a shared vision rather than disunity.

8.8 CONCLUDING REMARKS

The rationale for this research was rooted in a genuine concern with the importance of language in the teaching of chemistry. Though I believe that I have benefitted much in this research process, the most valuable aspect in terms of what I have learnt as a researcher has been the importance of accepting criticisms of one’s own work in a positive manner to develop further as a researcher. I have learnt that a researcher’s personal knowledge must be subject to scrutiny to hold any value in the public domain, and researchers must be willing to take on these comments and apply them constructively.

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APPENDIX 1

Procedure for Metasynthesis

Step 1: Inclusion Criteria

There were a total of six inclusion criteria which were developed primarily due to the needs of addressing the pre-defined research questions.

1) the study is a peer-reviewed journal

2) the study is related to misconceptions in an IGCSE chemistry topic

3) the study is a primary study with qualitative data

4) the sample includes English speaking students

5) the study exemplifies a non-canonical account with everyday words

Saini and Shlonsky recommend contacting the original authors to obtain information beyond what is contained in the research paper (Saini and Shlonsky, 2012). Others have argued that the “rigour of individual studies is less important than the attempt to be as inclusive as possible” (Walsh & Downe, 2005, p.208). Moreover, Evans and Fitzgerald (2002) did not use any form of appraisal in their qualitative synthesis. As verifying the quality of a study is beyond my scope, using peer-reviewed research papers aids in the credibility of the research as it is effectively a mark of quality. At the same time, it is acknowledged that this may affect the inclusiveness characteristic of the metasynthesis as potential studies may have been disregarded. For criterion two, the articles had to be related to the topic of misconceptions in chemistry and on an IGCSE chemistry topic due to the nature of the research question, and because the participants in the present study chemistry at this level. This means that topics that go beyond this level of study, such as Advanced-level or undergraduate chemistry, are not suitable for the aims of this metasynthesis. Primary data, criterion three, is an important criterion for conducting a metasynthesis as this method is deeply rooted in qualitative research; it is vital that qualitative data is analysed. The fourth criterion was applied to ensure that the sample involved English speaking students, and secondary school students was added to assist in narrowing down the search to include topics which do not go beyond the IGCSE level. The fifth criterion ensured that the study made reference to non-canonical accounts of chemistry with everyday words as this was the interest of the research question.

Step 2: Database Search Terms

The search terms used allowed for the application of criterion one, and criterion two partially. EBSCO host has an option to include only peer-reviewed papers, and the search terms included the term misconception and its related terms, and the term chemistry. Verifying that the chemistry concepts are related to IGCSE at this stage would have required reading the whole text and was therefore not carried out at this stage. Several databases were used for the initial screening stage through EBSCO host, namely ERIC, British Education Index, and Education Research Complete. Saini and Shlonsky (2012) suggest that the words used in the research question is inadequate with respect to retrieving all possible studies, and in order to make the retrieval process more successful further search terms need to be developed. Allen (2010) found that research into misconceptions in science have used the following terms: “misconceptions, children's science, naive conceptions, private concepts, alternative conceptions, alternative frameworks, intuitive theories, preconceptions, and limited or inappropriate propositional hierarchies” (p.7). As the aim was to retrieve as many potential studies as possible at this stage, the term ‘and chemistry’ was used along with the misconception terms. Therefore, the following search terms were used: (misconceptions or children's science or naive conceptions or private concepts or alternative conceptions or alternative frameworks or intuitive theories or preconceptions or limited propositional hierarchies or inappropriate propositional hierarchies) and chemistry.

Step 3: Abstract Screening

The initial screening process enables the researcher to quickly identify possible studies based on their abstract and title (Saini & Shlonsky, 2012). The abstracts were screened with respect to inclusion criteria two, three and four. Some abstracts clearly stated that the participants of the study were undergraduate students. So, in this regard, the papers were excluded. At times, the title clearly stated that the journal was a review; therefore, such papers were excluded as they did not contain primary data. Saini and Shlonsky (2012) suggest that by relying on the use of the term ‘qualitative’ in the key word search field, it may result in missing potential relevant articles. Therefore abstracts were searched for terms that represented qualitative data such as interviews and observations. The IGCSE chemistry topic for criterion two was not applied strictly at this stage, though if the topic was clearly at an undergraduate chemistry level then such papers were excluded. In cases where I could not verify if the paper met all the criteria due to limited information in the abstract, I retained them for further screening.

Step 4: Full Text Screening

The full text of the retained research studies from the abstract screening were first scanned further with respect to criteria three and four. Then the application of criterion five was conducted through extensive in-depth reading. For inclusion criterion two, the studies which had grade 11 and 12 students (16 – 18 year olds) were used in cases where the content under discussion was appropriate for IGCSE chemistry students. Some studies had a mix of the target age group with undergraduates, and exceptions were made in these rare cases as it was difficult to differentiate between the participants and more importantly the content was relevant to IGCSE chemistry. With regard to criterion three, some studies used a qualitative method for verification of their quantitative results. For example, some studies used interviews as part of their overall qualitative study, but they summarised the interviews into note form as a common sentence which expresses the thought of all the students. Such studies were not used, as through this, the data loses its individualism. Also excluded were studies where the reporting was based on teachers' experiences rather than data directly reported from students. Translated studies, of which there are many, were not included, and the focus was on English speaking students. The application of criterion five required reading carefully through the papers and diligently using my judgement to decide whether or not the everyday word can be interpreted as forming part of a non-canonical account of chemistry in relation to the information in the IGCSE chemistry textbook. A full list of references of the final selected research papers can be found in chronological order in Table Appx 1.

Step 5: Synthesis of Findings

Sain and Shlonsky (2012) argue that the goal of a metasynthesis is to gain new understanding of a phenomenon rather than simply reporting exactly what the original authors state. Qualitative metasynthesis studies can be synthesised in several ways, and the approach used is dependent on what the researcher wants to produce:

> The term qualitative metasynthesis does not itself signal any one method or technique, or any one way of executing methods or techniques. The approaches you use will depend on the purpose of your project, the product you want to produce…the end product of qualitative metasynthesis is always an integration of research findings, as opposed to a comparison or critique of them. (Sandelowski & Barroso, 2007, p.199)

In this study, the constant targeted comparison approach was used. This requires reducing the findings to a set of abstract statements or taxonomies, and then this is compared across all the selected studies (Sandelowski & Barroso, 2007). Each research paper was analysed in chronological order, starting from the oldest, and coded with a description of the non-canonical account of chemistry with everyday words. Then the next research paper was analysed in the same way, and then compared with the previous description. As each study was analysed, interpreted, and coded, it was again compared against all the studies which were analysed prior to it.

Details of the Studies Included in the Metasynthesis

A total of 942 studies were retrieved after the initial database search dating to 2016. This was reduced to 154 papers following abstract screening. The full text screening led to a final sample of 13 studies, and the details of these studies are chronologically listed in Table Appx 1.

Table Appx 1
Details of Studies in the Metasynthesis

Study	Chemistry Topic	Qualitative Data Collection Method	Sample
Ross & Munby (1991)	acids and bases	interviews (n=2)	Canada, n=34, (grade 12)
Hesse & Anderson (1992)	chemical change	interviews (n=11); open-ended questions	n=100 (high school juniors and seniors)
Ebenezer & Gaskell (1995)	solution chemistry	interviews	British Columbia, n=13 (grades 11-12)
Harrison & Treagust (1996)	atoms and molecules	interviews	Australia, n=48 (aged 13-15)
Boo (1998)	chemical bonds and energetics	interviews	n=48 (aged 17-19)
Johnson (1998)	particle theory	interviews	United Kingdom, n=33 (aged 11-14)
Toplis (1998)	acids and alkalis	observations; interviews	United Kingdom, n=17 (year 8)
Selley (2000)	solution chemistry	open-ended questions	United Kingdom, n=217 (aged 12-14)
Brosnan & Reynolds (2001)	change in materials	open-ended questions	United Kingdom, n=82 (aged 11-17)
Adadan (2009)	particulate nature of matter	interviews (n=15); open-ended questions	United States, n=42 (grades 9-12)
Garcia Franco & Taber (2009)	particle theory	interviews	United Kingdom, n=48 (years 7-11)
Taber & Garcia Franco (2010)	particulate structure of matter	interviews	United Kingdom, n=48 (aged 11-16)
Hilton & Nichols (2011)	chemical bonding	classroom recordings; open-ended questions	Australia, n=49 (year 11)
Mayer (2011)	gases, mass and composition	classroom recordings	United States of America, n=63 (grade 10)

APPENDIX 2

Keyword Lists for Corpora

***All p-values (p<0.0000001) for calculations**

Corpus I – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	6	LEADED	3
ACIDIC	3	LIME	7
AIR	21	LIMESTONE	10
ANIMAL	8	METAL	12
ANIMALS	8	METALS	5
ARE	64	METHANE	8
ARGON	3	MILLION	5
ATMOSPHERE	12	MILLIONS	5
BE	177	MONOXIDE	4
BURN	8	NITROGEN	15
BURNING	8	ORE	6
CAN	29	ORES	6
CARBON	40	OVERLEAF	3
CAUSE	9	OXYGEN	17
CELL	9	PETROL	9
CHEMICAL	5	PETROLEUM	4
CHEMICALS	5	PHOTOSYNTHESIS	4
COAL	6	PLANT	10
COMBUSTION	3	PLANTS	10
CRUST	11	POLLUTANT	3
CYCLE	9	POLLUTANTS	3
DIOXIDE	35	POLLUTION	5
DISTILLATION	3	POWER	14
EARTH	22	PROBLEM	22
ELECTRICITY	6	PROBLEMS	11
ENERGY	19	PRODUCE	13
EXTRACTION	4	PRODUCED	7
FIGURE	23	PRODUCES	6
FOSSIL	11	QUANTITIES	4
FRACTIONAL	3	QUANTITY	4
FUEL	30	RAIN	6
FUELS	12	RECYCLE	4
GAS	33	RECYCLING	4
GASES	25	RENEWABLE	10
GLOBAL	5	RESOURCE	16
HEAT	6	RESOURCES	16
HYDROGEN	19	RESPIRATION	3
IMPORTANT	11	ROCK	7
IS	113		

Corpus II – Keyword List

Keyword	Frequency	Keyword	Frequency
ARE	143	KNOWN	15
ATOM	116	LIQUID	89
ATOMIC	22	LIQUIDS	21
ATOMS	64	MAGNESIUM	5
BE	149	MAGNETIC	5
BOIL	40	MASS	49
BOILING	34	MASSES	9
BOILS	6	MATTER	15
BOND	4	MEASURE	7
BONDED	4	MEASURED	7
BROMINE	3	MELT	34
BUNSEN	3	MELTED	4
CAN	102	MELTING	27
CARBON	27	MELTS	3
CHANGE	16	METAL	5
CHANGES	16	METALS	5
CHEMICAL	18	MIXTURE	39
CHEMICALLY	8	MIXTURES	7
CHLORINE	9	MOLECULE	18
CHROMATOGRAPHY	11	MOLECULES	18
COLLISION	3	MOTION	7
COLLISIONS	3	NEUTRON	22
COLOURINGS	3	NEUTRONS	22
COLUMN	6	NITROGEN	7
COMPOUND	19	NUCLEI	9
COMPOUNDS	12	NUCLEON	4
COMPRESSIBLE	3	NUCLEUS	26
CONDENSATION	4	NUMBER	43
CONDENSE	4	NUMBERS	11
CONDENSES	4	ORE	4
CONTAINER	5	ORGANIC	6
COOL	10	OVERLEAF	8
COOLED	4	OXYGEN	17
COOLING	6	PAPER	15
CRYSTAL	5	PARTICLE	50
CRYSTALLISATION	4	PARTICLES	50
CRYSTALS	5	PARTICULAR	16
CURVE	8	PERIODIC	5
DALTON	9	PHYSICAL	19
DIFFERENT	44	POINT	53
DIFFUSION	14	POINTS	11
DIOXIDE	7	POWDER	8
DISSOLVE	32	POWDERED	3
DISSOLVED	10	PRESSURE	26
DISSOLVES	10	PROCESS	19
DISSOLVING	4	PROPERTIES	17
DISTIL	3	PROPERTY	17
DISTILLATION	8	PROTON	35
DISTILS	3	PROTONS	25
DYE	3	PURE	30
DYES	3	PURIFY	3

EASILY	11	PURIFYING	3
ELECTRICALLY	3	PURITY	6
ELECTRON	43	RADIATION	11
ELECTRONS	36	RADIOACTIVE	10
ELEMENT	64	RADIOACTIVITY	6
ELEMENTS	40	RADIOISOTOPES	7
ENERGY	17	REACT	3
ETHANOL	8	REACTION	16
EVAPORATE	9	REACTS	3
EVAPORATES	5	RELATIVE	9
EVAPORATING	4	RUTHERFORD	3
EVAPORATION	10	SAME	24
EXPLAIN	9	SAMPLE	9
FIGURE	42	SEAWATER	4
FILTRATION	4	SEPARATE	26
FRACTIONAL	5	SEPARATING	15
FREEZE	8	SEPARATION	15
FREEZES	3	SEPARATIONS	6
FREEZING	5	SHELL	8
GAS	52	SHELLS	8
GASES	15	SHOW	15
HEAT	16	SHOWS	15
HEATED	7	SIMPLE	5
HEATING	9	SIMPLER	5
HELIUM	4	SOLID	70
HYDROGEN	13	SOLIDS	13
IMPORTANT	19	SOLUBILITY	9
IMPURE	3	SOLUBLE	7
IMPURITIES	3	SOLUTE	11
IMPURITY	6	SOLUTION	35
INSOLUBLE	7	SOLUTIONS	7
IRON	9	SOLVENT	26
ISOTOPE	30	SOLVENTS	8
ISOTOPES	20	SPACE	10
KINETIC	5	SPECTROMETER	3
KNOW	15	STATE	18

Corpus III – Keyword List

Keyword	Frequency	Keyword	Frequency
ALKALI	11	HELD	22
ALLOY	17	HELIUM	8
ALLOYS	10	HOLD	22
ALUMINIUM	6	HYDROGEN	22
ARE	169	IODIDE	3
ARGON	7	IODINE	5
ARRANGE	6	ION	89
ARRANGED	6	IONIC	37
ARRANGEMENT	18	IONS	59
ATOM	89	IRON	7

ATOMS	61	LATTICE	21
ATTRACTION	6	LATTICES	7
BE	181	LAYER	11
BETWEEN	31	LAYERS	11
BOIL	4	MAGNESIUM	5
BOILING	4	MELT	12
BOND	88	MELTING	12
BONDED	6	METAL	123
BONDING	55	METALLIC	26
BONDS	15	METALLOIDS	3
BRITTLE	4	METALS	82
BROMIDE	6	MOBILE	5
BROMINE	3	MOLECULAR	15
CARBON	12	MOLECULE	41
CHARGE	12	MOLECULES	31
CHEMICAL	17	NAME	10
CHLORIDE	19	NAMES	10
CHLORINE	15	NEAR	7
COMBINE	9	NEAREST	7
COMPOUND	66	NEGATIVE	17
COMPOUNDS	54	NICKEL	4
CONDUCT	8	NOBLE	27
CONDUCTIVITY	3	NON	41
CONTAIN	8	NUMBER	24
CONTAINING	8	ON	16
COPPER	7	OUTER	27
COVALENT	33	OVERLEAF	6
COVALENTLY	3	OXIDE	4
CRYSTAL	15	OXYGEN	12
CRYSTALS	9	PERIODIC	24
DIAGRAM	6	PHYSICAL	11
DIAGRAMS	6	POINT	10
DIAMOND	9	POINTS	10
DIATOMIC	4	POLYATOMIC	8
DIFFERENT	24	POSITIVE	17
DIMENSIONAL	3	POTASSIUM	9
DIOXIDE	5	PROPERTIES	53
DISTINCTIVE	7	PROPERTY	53
EACH	39	PROTON	3
ELECTRICITY	9	PROTONS	3
ELECTRON	99	RADIOACTIVE	4
ELECTRONS	73	REACT	8
ELECTROSTATIC	6	REACTIVE	15
ELEMENT	113	REACTIVITY	8
ELEMENTS	90	SHARE	9
EXAMPLE	39	SHARING	9
EXAMPLES	11	SHELL	16
EXIST	7	SHELLS	5
FIGURE	50	SILICON	9
FLUORINE	3	SIMPLE	15
FORCE	10	SODIUM	14
FORCES	10	SOLID	13
FORM	41	SOLIDS	6
FORMED	9	STABLE	17

FORMULA	22	STAINLESS	4
FORMULAE	11	STEEL	11
FRANCIUM	3	STRONG	12
GAIN	8	STRUCTURE	52
GAS	40	STRUCTURES	20
GASES	22	SUBSTANCE	8
GIANT	19	SUBSTANCES	8
GRAPHITE	13	SULFUR	4
GROUP	85	TABLE	54
GROUPS	18	THESE	46
HALOGENS	17		

Corpus IV – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	11	EXTRACTING	3
ACIDIFIED	3	FIGURE	37
AGENT	9	FLOW	10
ALUMINIUM	12	FORM	14
ANIONS	3	FORMED	14
ANODE	37	FORMULA	4
ANODES	3	FORMULAE	4
ARE	125	GAIN	8
ATOM	31	GAS	17
ATOMS	23	GRAPHITE	13
BALANCE	8	HALOGEN	3
BALANCED	8	HEAT	7
BATTERY	6	HYDROCHLORIC	5
BE	349	HYDROGEN	30
BECOME	10	HYDROXIDE	10
BECOMES	10	IMPORTANT	15
BOND	6	INDUSTRIALLY	4
BONDING	6	INSOLUBLE	6
BROMIDE	4	INSULATOR	3
BROMINE	4	INSULATORS	3
CABLE	7	IODIDE	14
CABLES	7	IODINE	10
CAN	60	ION	97
CARBON	11	IONIC	17
CATHODE	30	IONS	86
CATIONS	3	IS	224
CELL	16	LEAD	10
CHANGE	45	LIQUID	20
CHANGES	15	LIQUIDS	8
CHEMICAL	36	MAGNESIUM	7
CHLORIDE	15	MANGANATE	5
CHLORINE	19	MELT	22
CHROMIUM	3	MEMBRANE	4
CIRCUIT	10	METAL	73
COLOUR	9	METALLIC	4
COLOURLESS	4	METALS	24
COMBUSTION	10	MOLECULE	17
COMPOUND	24	MOLECULES	11

COMPOUNDS	13	MOLTEN	22
CONCENTRATION	6	MOVE	18
CONDUCT	26	NEGATIVE	12
CONDUCTIVITY	12	NEUTRALISATION	7
CONDUCTOR	5	NICKEL	5
CONDUCTS	6	NITRATE	5
COPPER	45	NITROGEN	4
CURRENT	10	OXIDATION	32
DECOMPOSITION	10	OXIDE	13
DEFINITION	12	OXIDISED	11
DICHROMATE	3	OXIDISING	8
DILUTE	5	OXYGEN	40
DISCHARGE	14	PHYSICAL	10
DISCHARGED	14	PLACE	19
DISPLACE	6	PLATE	7
DISPLACEMENT	8	PLATED	7
DISPLACES	3	POSITIVE	12
DISSOLVE	9	POTASSIUM	14
DISSOLVED	4	PRECIPITATE	3
DISSOLVES	5	PRECIPITATION	8
DURING	27	PROCESS	12
ELECTRICAL	9	PRODUCE	30
ELECTRICITY	26	PRODUCED	14
ELECTRODE	21	PRODUCES	7
ELECTRODES	14	PRODUCT	15
ELECTROLYSED	3	PRODUCTS	15
ELECTROLYSIS	46	PURE	9
ELECTROLYTE	14	REACT	10
ELECTROLYTES	6	REACTANT	3
ELECTROLYTIC	8	REACTANTS	3
ELECTRON	41	REACTION	149
ELECTRONS	41	REACTIONS	70
ELECTROPLATE	12	REACTIVE	14
ELECTROPLATING	12	REACTS	3
ELEMENT	8	REDOX	9
ELEMENTS	8	REDUCE	8
ENDOTHERMIC	6	REDUCING	8
ENERGY	25	REDUCTION	19
EQUATION	41	SALT	21
EQUATIONS	18	SALTS	9
EXAMPLE	29	SILVER	14
EXAMPLES	8	SODIUM	15
EXOTHERMIC	10	SOLID	17
EXTRACT	3	SOLIDS	4

Corpus V – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	214	INDICATOR	27
ACIDIC	22	INDICATORS	5
ACIDITY	9	INDIGESTION	6
ACIDS	67	INSOLUBLE	14
ADD	17	ION	95

ADDED	17	IONIC	9
ALKALI	74	IONISATION	3
ALKALINE	8	IONISED	5
ALKALIS	42	IONS	81
ALUMINIUM	11	IRON	7
AMMONIA	12	KETTLE	3
AMMONIUM	9	KETTLES	3
AMPHOTERIC	8	KEY	9
ANTACID	4	KNOW	15
ANTACIDS	6	KNOWN	15
AQUEOUS	3	LABORATORY	6
ARE	151	LIME	6
AT	6	LIMESTONE	5
BARIUM	6	LIMEWATER	3
BASE	32	LITMUS	28
BASES	16	MAGNESIUM	6
BE	155	METAL	59
BLUE	17	METALS	21
BURETTE	3	METHOD	15
CALCIUM	16	METHYL	3
CAN	57	MOLECULE	18
CARBON	11	MOLECULES	11
CARBONATE	23	NEUTRAL	8
CARBONATES	6	NEUTRALISATION	12
CARBONIC	4	NEUTRALISE	14
CHEMICAL	8	NEUTRALISED	4
CHLORIDE	14	NITRATE	4
COLOUR	22	NITRIC	6
COLOURED	6	OVERLEAF	5
COMPOUND	9	OXIDE	35
COMPOUNDS	9	OXIDES	29
CONCENTRATION	20	PAPER	11
CONCENTRATIONS	5	POTASSIUM	4
CONTAIN	22	POWDER	5
CONTAINS	8	PRECIPITATE	24
COPPER	6	PRECIPITATES	10
CRYSTAL	17	PRECIPITATION	7
CRYSTALLISATION	6	PREPARE	7
CRYSTALS	17	PREPARING	7
DEFINITION	10	PRODUCE	15
DEPEND	6	PROTON	7
DEPENDING	6	REACT	19
DIBASIC	3	REACTION	49
DILUTE	7	REACTIONS	19
DIOXIDE	9	REACTIVE	8
DISSOCIATE	7	REACTS	3
DISSOCIATED	7	RED	13
DISSOLVE	36	REPLACEABLE	3
DISSOLVED	11	SALT	90
DISSOLVES	4	SALTS	44
DISTIL	4	SCALE	9
DISTILLED	4	SHOW	12
EQUATION	13	SHOWS	12
ETHANOATE	3	SLAKE	3

ETHANOIC	10	SLAKED	3
EVAPORATE	3	SODIUM	33
EVAPORATED	3	SOIL	10
EXAMPLE	19	SOLID	12
EXCESS	16	SOLUBILITY	4
FERTILISERS	3	SOLUBLE	20
FIGURE	29	SOLUTION	124
FILTER	4	SOLUTIONS	52
FILTERED	4	STAGE	10
FLASK	6	STRONG	15
FORM	15	STUDY	14
GAS	19	SUBSTANCE	21
GASES	4	SUBSTANCES	11
GIVE	41	SULFATE	12
GIVES	11	SULFUR	4
HYDRATED	3	SULFURIC	9
HYDROCHLORIC	12	TABLE	20
HYDROGEN	39	TABLET	6
HYDROXIDE	55	TABLETS	6
HYDROXIDES	6	TEST	21
IMPORTANT	24	TESTS	8

Corpus VI – Keyword List

Keyword	Frequency	Keyword	Frequency
ALKALI	3	MASSES	17
ALWAYS	15	MEASURE	8
AMMONIUM	3	MEASURED	8
AMOUNTS	13	MOLAR	10
AND	65	MOLE	23
ATOM	14	MOLECULAR	13
ATOMIC	13	MOLECULE	5
ATOMS	30	MOLECULES	11
AVOGADRO	5	MOLES	19
CALCULATE	6	NUMBER	19
CALCULATED	5	ON	9
CALCULATING	5	OXIDE	19
CALCULATION	9	OXYGEN	14
CALCULATIONS	10	PARTICULAR	14
CAN	42	PERCENTAGE	10
CHEMICAL	25	PHOSPHORUS	7
CHLORIDE	5	PLOTTED	3
COMPOUND	17	PRESENT	13
COMPOUNDS	7	PRODUCT	12
CONCENTRATION	16	PURITY	7
CONTAIN	6	RATIO	9
CONTAINS	14	REACT	7
COPPER	7	REACTANT	4
CRUCIBLE	5	REACTANTS	9
CRYSTALLISATION	3	REACTING	7
CUBIC	11	REACTION	19
DECIMETRE	7	REACTIONS	10
ELEMENT	11	RELATIVE	33

ELEMENTS	13	SALT	5
EMPIRICAL	12	SALTS	3
EQUATION	19	SAME	15
ETHANOL	4	SILICON	5
EXAMPLE	15	SODIUM	6
EXPERIMENT	6	SOLID	5
EXPERIMENTS	5	SOLIDS	3
FIGURE	18	SOLUBILITY	4
FIXED	6	SOLUTE	4
FOOTBRIDGE	4	SOLUTION	23
FORMULA	52	SOLUTIONS	7
FORMULAE	9	SUBSTANCE	22
FOUND	16	SUBSTANCES	5
GAS	14	SULFATE	3
GASES	7	SULFUR	9
GIANT	6	TABLE	9
GRAMS	12	TEMPERATURE	6
HEATED	4	TIP	6
HOW	21	UNIT	10
HYDRATED	5	UNREACTED	3
HYDROGEN	9	USED	16
ION	4	USEFUL	10
IONS	4	VOLUME	21
IRON	9	WATER	13
IS	136	WE	45
ISOTOPES	4	WEIGH	4
LIME	4	WEIGHING	6
MAGNESIUM	23	YIELD	7
MASS	89		

Corpus VII – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	17	INCREASES	10
ACTIVATION	13	INDUSTRIALLY	3
AMMONIA	31	IONS	6
ANALOGY	4	IS	201
ARE	96	LIQUID	6
ATMOSPHERES	3	MAGNESIUM	4
ATOMS	10	MANGANESE	3
BIOLOGICAL	6	MASS	8
BIOMASS	3	MEANS	16
BONDS	30	METHANE	8
BREAK	10	MIXTURE	13
BREAKING	8	MOLECULES	20
BROMIDE	3	MORE	54
BURNING	6	NITROGEN	11
BUT	8	OCCUR	9
CAN	48	OPTIMUM	4
CARBON	14	OVERLEAF	7
CATALYST	20	OXIDE	7
CATALYSTS	22	OXYGEN	17
CATALYTIC	6	PARTICLES	18

CHANGE	14	PEROXIDE	3
CHANGING	9	PHOTOCHEMICAL	3
CHATELIER	3	PHOTOSYNTHESIS	7
CHEMICAL	24	POWDER	7
COLLIDE	6	POWDERED	7
COLLISION	10	POWDERS	6
COLLISIONS	11	PRESSURE	18
CONCENTRATED	7	PROCESS	18
CONCENTRATION	13	PRODUCE	12
CONCENTRATIONS	5	PRODUCED	10
CONDENSED	3	PRODUCTS	16
CONDITIONS	23	RATE	38
CONVERTER	6	REACT	8
CONVERTERS	3	REACTANT	8
CURVE	6	REACTANTS	25
DECOMPOSITION	4	REACTING	5
DEHYDRATION	3	REACTION	154
DILUTE	3	REACTIONS	66
DIOXIDE	9	REACTS	5
DISAPPEAR	5	REVERSE	7
DYNAMIC	6	REVERSED	5
EMULSION	3	REVERSIBLE	10
ENDOTHERMIC	11	SALTS	5
ENERGY	72	SAME	22
ENZYMES	11	SAMPLE	7
EQUATION	5	SILVER	10
EQUILIBRIA	4	SODIUM	4
EQUILIBRIUM	26	SOLID	17
EXAMPLE	15	SOLIDS	4
EXITS	3	SOLUTION	8
EXOTHERMIC	19	SOLUTIONS	8
EXPERIMENT	17	STUDY	13
EXPERIMENTS	7	SULFUR	10
FASTER	15	SURFACE	21
FIGURE	39	SURROUNDINGS	7
FINELY	6	SWIMMING	6
FLASK	4	TEMPERATURE	33
FORMED	9	TEMPERATURES	10
FUELS	5	THESE	31
GAS	17	TIP	9
GASES	8	TRIOXIDE	4
GRAPH	7	UNCHANGED	4
HABER	8	USED	29
HEAT	27	VANADIUM	3
HYDRATED	3	VOLUME	10
HYDROCARBON	3	WAS	10
HYDROCHLORIC	6	WERE	3
HYDROGEN	16	YOU	8

Corpus VIII – Keyword List

Keyword	Frequency	Keyword	Frequency
ACIDS	5	HYDROGEN	10

ADDED	9	HYDROXIDE	43
ALKALI	20	HYDROXIDES	3
ALKALINE	5	IONIC	4
ALUMINIUM	35	IONS	38
AMMONIA	6	IRON	33
ARE	72	LAYER	5
ATOMS	9	LITHIUM	6
BLUE	8	MAGNESIUM	15
CALCIUM	4	MAGNETIC	5
CAN	32	METAL	49
CARBON	8	METALS	93
CARBONATE	9	MODERATELY	4
CARBONATES	4	MORE	31
CATALYSTS	3	NICKEL	3
CELL	7	NITRATE	7
CELLS	7	ORES	6
CHARACTERISTIC	7	OXIDATION	4
CHROMIUM	3	OXIDE	21
COATED	3	OXYGEN	8
COLOUR	13	POSITIVE	7
COLOURED	6	POTASSIUM	16
COLOURLESS	4	PRECIPITATE	14
COLOURS	10	PRECIPITATES	3
COMPOUNDS	18	PRODUCE	12
COPPER	42	PRODUCED	9
CORROSION	5	PROPERTIES	13
DECOMPOSE	4	REACT	7
DILUTE	4	REACTING	3
DISPLACE	5	REACTION	28
DISPLACEMENT	8	REACTIONS	20
DISPLACES	3	REACTIVE	45
DISSOLVE	5	REACTIVITY	23
DISSOLVES	3	REACTS	6
DISTINCTIVE	6	REDOX	5
ELECTRICAL	5	SALT	9
ELECTROCHEMICAL	3	SALTS	14
ELECTRODE	6	SILVER	6
ELECTRODES	5	SODA	3
ELECTROLYSIS	3	SODIUM	43
ELECTRONS	11	SOLUTION	26
ELEMENTS	18	SOLUTIONS	8
EXAMPLE	15	SULFATE	6
EXCESS	8	SULFIDE	3
EXTRACTED	4	TABLE	10
FIGURE	14	THERMIT	3
FIREWORKS	3	THESE	25
FLAME	11	TRANSITION	18
FORM	16	USED	24
GAS	7	USEFUL	7
GELATINOUS	3	VALENCY	7
GIVE	17	WAS	7
GROUP	32	WATER	21
HEAT	6	WHITE	11

HEATED	4	ZINC	34
HEATING	5		

Corpus IX – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	31	METAL	23
ACIDIC	3	METALS	17
AIR	14	MINED	3
ALLOYS	5	MINING	5
ALUMINIUM	29	MIXED	8
AMMONIA	20	MIXTURE	8
AMMONIUM	14	MOLTEN	15
ANODE	4	NEUTRALISE	3
BAUXITE	5	NITRATE	7
BLAST	11	NITROGEN	16
BRINE	3	ORE	17
CALCIUM	15	OVERLEAF	8
CAN	35	OXIDE	22
CARBON	25	OXYGEN	8
CARBONATE	6	PAGE	10
CATALYST	3	PHOSPHORUS	5
CATHODE	6	PLANTS	12
CELL	11	PLASTIC	6
CHEMICAL	15	POTASSIUM	5
CHLORIDE	5	POWDERED	3
CHLORINE	6	PROCESS	22
CHROMIUM	7	PRODUCED	19
COKE	5	PRODUCTION	12
COMPOUNDS	9	PROTECTION	7
CONCENTRATED	7	PROTECTIVE	7
COOLED	3	RAW	6
CORROSION	4	REACTION	9
CRYOLITE	5	REACTIVE	5
DEHYDRATING	3	REACTS	4
DIOXIDE	13	RECYCLE	4
ELECTRODE	4	RECYCLED	9
ELECTROLYSIS	10	RECYCLING	13
ELECTROLYTIC	8	REDUCTION	6
ELECTROPLATING	3	REMOVES	3
ENERGY	15	REVERSIBLE	3
EXTRACTING	3	RUST	10
EXTRACTION	13	RUSTING	11
FERTILISER	6	SAND	5
FERTILISERS	15	SAVES	6
FIGURE	31	SILICATE	4
FORM	19	SLAG	7
FURNACE	26	SODIUM	13
GASES	10	SOLUBLE	3
GLASS	10	STAINLESS	3
HABER	5	STEEL	36
HYDRATED	3	STEELS	10
HYDROGEN	9	SUBSTANCES	8

HYDROXIDE	8	SULFATE	4
IMPORTANT	17	SULFIDE	3
IMPURITIES	6	SULFUR	23
INDUSTRY	10	SULFURIC	13
IONS	6	TEMPERATURE	6
IRON	65	THAT	21
IS	203	TIN	5
KILN	3	TIP	6
LANDFILL	4	TRIOXIDE	5
LAYER	19	USED	44
LIME	15	USES	20
LIMESTONE	19	WAS	5
LIQUID	5	WASTE	7
MAGNESIUM	3	WATER	28
MAKE	25	YOU	9
MANUFACTURE	11	ZINC	14
MATERIAL	9		

Corpus X – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	30	GROUP	12
ACIDS	16	HOMOLOGOUS	12
AIR	9	HYDROCARBON	11
ALCOHOL	6	HYDROCARBONS	20
ALCOHOLS	12	HYDROGEN	10
ALKANE	7	HYDROGENATION	4
ALKANES	23	IONS	4
ALKENE	6	IS	129
ALKENES	14	ISOMERISM	4
ANAESTHETIC	3	ISOMERS	5
ARE	81	KNOWN	13
ATOM	13	LIQUIDS	5
ATOMS	44	MANGANATE	3
BOILING	6	MARGARINE	3
BOND	14	MELTING	5
BONDING	3	METHANE	8
BONDS	13	METHANOL	3
BRANCHED	3	MOLECULAR	11
BROMINE	12	MOLECULE	13
BUTANE	4	MOLECULES	24
CAN	40	MONOXIDE	8
CARBON	61	NAMES	8
CARBOXYLIC	4	NAMING	5
CATALYST	5	OIL	8
CHAIN	29	OILS	6
CHEMICAL	8	ORGANIC	24
CHEMISTRY	7	OVERLEAF	3
CHLORINE	4	OXIDATION	3
COLOURLESS	4	OXYGEN	7
COMBUSTION	6	POINTS	8
COMPOUND	16	POTASSIUM	3
COMPOUNDS	34	PRODUCE	10

CONTAIN	10	PROPERTIES	7
CONTAINS	6	REACT	5
COVALENT	3	REACTION	21
DEFINITION	6	REACTIONS	10
DIFFERENT	15	REACTS	3
DIOXIDE	7	SATURATED	8
DOUBLE	19	SERIES	23
ETHANE	4	SHOWS	12
ETHANOATE	3	SIMPLEST	7
ETHANOIC	7	SOLUTION	11
ETHANOL	31	SOLVENT	5
ETHENE	9	STRUCTURAL	9
FATS	6	SUCH	20
FERMENTATION	9	SUGAR	7
FIGURE	24	SULFURIC	3
FLAME	4	SUPPLY	7
FORMULA	28	TABLE	10
FORMULAE	14	TO	64
FUEL	10	UNSATURATED	11
FUELS	4	VEGETABLE	4
FUNCTIONAL	8	VINEGAR	4
GAS	11	WAS	4
GASOHOL	3	WATER	13
GASOLINE	3	YEAST	3

Corpus XI – Keyword List

Keyword	Frequency	Keyword	Frequency
ACID	12	HYDROLYSIS	4
ACIDS	15	INCINERATION	3
ADDITION	12	KNOWN	9
ALKENE	5	LINK	6
ALKENES	5	LINKAGE	4
ALTERNATIVE	6	LOCATING	3
AMINO	15	MADE	21
ARE	87	MATERIAL	7
ATOMS	5	MIXTURE	5
BIODEGRADABLE	3	MOLECULE	5
BOND	5	MOLECULES	27
BROKEN	6	MONOMER	14
CAN	39	MONOMERS	16
CARBOHYDRATES	9	NAME	9
CARBON	7	NATURAL	8
CARBOXYLIC	3	NYLON	13
CATALYTIC	4	OIL	15
CHAIN	16	PEPTIDE	3
CHAINS	5	PETROLEUM	14
CHLOROETHENE	3	PLASTIC	13
CHROMATOGRAPHY	3	PLASTICS	11
CONDENSATION	12	POLY	17
CONTAIN	6	POLYESTERS	3
CRACKING	8	POLYMER	6
CRUDE	5	POLYMERISATION	10

DIAGRAMS	3	POLYMERS	25
DIESEL	7	POLYSACCHARIDES	3
DIFFERENT	22	PRODUCE	10
DISTILLATION	7	PRODUCED	7
DOUBLE	6	PROPENE	7
ENGINES	6	PROPERTIES	6
ETHENE	11	PROTEINS	14
FATS	7	PVC	3
FIBRES	7	REACTIONS	4
FIGURE	13	RECYCLING	4
FORMED	10	REFINERY	3
FOSSIL	6	SATURATED	3
FRACTIONAL	5	SEPARATED	5
FRACTIONS	15	SHALE	4
FUEL	5	STARCH	7
FUELS	9	STRUCTURE	9
GAS	12	SYNTHETIC	7
GEOLOGICAL	4	TEMPERATURE	6
GLUCOSE	9	TERYLENE	4
HOMOPOLYMERS	3	TOWER	5
HYDROCARBON	8	UNSATURATED	3
HYDROCARBONS	6	WAS	7
HYDROGEN	4	WASTE	9

Corpus XII – Keyword List

Keyword	Frequency	Keyword	Frequency
ACCURACY	6	IDENTIFY	5
ACCURATE	8	INORGANIC	4
ACID	5	INSOLUBLE	3
ACIDS	4	INVESTIGATION	5
AGENTS	5	IONS	7
ALKALI	3	LINE	9
AMMONIA	6	MEASUREMENTS	4
ANALYSIS	9	MEASURING	12
ANHYDROUS	5	METAL	5
ANIONS	5	OBSERVATIONS	7
APPARATUS	11	OVERLEAF	4
ARE	50	PLOT	4
AXIS	5	PLOTTING	3
BOILING	4	PRECIPITATE	6
BROMINE	5	PRECIPITATION	4
CAN	28	PRESENCE	6
CATIONS	3	PURE	5
CHLORIDE	9	REACT	5
CHROMATOGRAPHY	4	REACTION	11
COBALT	6	REACTIONS	5
COLOURLESS	8	RESULTS	12
COMPOUND	8	SHOULD	17
COMPOUNDS	7	SILVER	5
DELIVERY	7	SODIUM	5
DISSOLVE	3	SOLUTION	13
DISSOLVES	3	TEMPERATURE	5

DRYING	5	TEST	24
ERROR	7	TESTED	6
ESTER	3	TESTING	7
EXPERIMENT	11	TESTS	18
FIGURE	22	THERMOMETERS	3
FLAME	4	TUBE	8
GAS	17	UNSATURATED	4
GASES	17	USED	16
GRAPH	4	USING	12
GRAPHS	3	VARIABLE	7
HYDROXIDE	5	VARIABLES	9
HYDROXIDES	5	WAS	4
HYPOTHESIS	11	WATER	28

APPENDIX 3

Inter-rater Agreement for Corpus Analysis

Non-technical Word	Second-Rater	Non-technical Word	Second-Rater
1. Air	Agree	22. Discharged	Agree
2. Gases	Agree	23. Reduction	Agree
3. Cell	Disagree	24. Base	Agree
4. Energy	Agree	25. Salt	Agree
5. Power	Agree	26. Strong	Agree
6. Fossils	Agree	27. Weak	Agree
7. Renewable	Agree	28. Relative	Agree
8. Boiling	Agree	29. Mole	Agree
9. Liquid	Agree	30. Activation	Agree
10. Organic	Agree	31. Collision	Agree
11. Particle	Agree	32. Carbon	Disagree
12. Physical	Agree	33. Hydrogen	Disagree
13. Space	Agree	34. Oxygen	Disagree
14. Substance	Agree	35. Glucose	Disagree
15. Arrangement	Agree	36. Equilibrium	Agree
16. Gain	Agree	37. Heat	Disagree
17. Lose	Agree	38. Making	Agree
18. React	Agree	39. Breaking	Agree
19. Simple	Agree	40. Reverse	Agree
20. Giant	Agree	41. Copper	Agree
21. Agent	Agree	43. Displace	Agree

44. Air (4.10)	**Agree**	**53. Carbon monoxide**	**Disagree**
45. Impurities	**Agree**	**54. Cracking**	**Agree**
46. Steel	**Disagree**	**55. Link(age)**	**Agree**
47. Alcohol	**Agree**	**56. Nylon**	**Disagree**
48. Margarine	**Disagree**	**57. Plastic**	**Disagree**
49. Natural Gas	**Disagree**	**58. PVC**	**Disagree**
50. Branched	**Agree**	**59. Colourless**	**Textbook Authors**
51. Chain	**Agree**	**60. Bubbles**	**Textbook Authors**
52. Carbon dioxide	**Disagree**		

Description of 'Disagreed' Non-technical Words

Cell

Disagreement: everyday meaning unlikely to be used in this way

Sense 1 in Oxford Dictionaries (2017) defines the noun cell as "a small room in which a prisoner is locked up" (e.g. "The authorities locked all the inmates in their cells."). In biology a cell refers to "the smallest structural and functional unit of an organism, which is typically microscopic…" (Oxford Dictionaries, 2017). The connotation of small is strongly attached to its meaning, though it is defined in a variety of ways in different contexts. In this chemistry chapter, out of the nine entries, it collocated with fuel at the L1 position seven times, and the remaining two were an article (the) and a demonstrative pronoun (this) which in both cases referred to fuel (see Table Appx 3.1).

Table Appx 3.1
Selected Concordance Lines for 'Cell'

No.	Concordance
1	h venture uses the hydrogen in a fuel cell. Electricity from this cell then powe
2	in a fuel cell. Electricity from this cell then powers an electric motor (Figure
3	sly, with no need for recharging. The cell supplies energy as long as the reacta

Although students may know other forms of cells such as a jail, or a cell in biology, it may be difficult for them to visualise what a fuel cell is due to its unfamiliarity, even with the aid of diagram of a cell in the textbook. It is a case of a familiar word being reconceptualised into something unfamiliar due to its description being governed by its context.

Carbon, Hydrogen, Oxygen and Glucose

Disagreement: everyday meaning does not appear very different to chemistry context

A student may be familiar with some elements due to their everyday use and this includes carbon, hydrogen and oxygen. They are also aware of everyday compounds such as glucose due to the food and drinks they consume on a daily basis. It may be challenging for some students to reclassify certain compounds according to what they are made of especially when they are familiar with both the compound and its elements in an everyday context. Students may be familiar with glucose, but understanding at a level where they view it as a compound made up of carbon, oxygen and hydrogen may not be achieved. An alternative unfamiliar compound such as hydrogen peroxide may be easier do view on a submicroscopic level even though its elements, hydrogen and oxygen, are familiar in an everyday context as the contextual sentences of this compound would be embedded in a submicroscopic context.

Heat

Disagreement: everyday meaning does not appear very different to chemistry context

Energy has different forms such as heat and sound. In an everyday sense, heat is referred to as something which has the “quality of being hot” (e.g. “The fierce heat of the sun.”) (Oxford Dictionaries, 2017). The concordances in Table Appx 3.2 make this point clear. Concordances 1 and 2 are relating to heat in the everyday sense, whereas, concordances 3 and 4 are closer to the meaning of heat as a form of energy. Students may experience difficulties with differentiating heat in its macroscopic context and that of its submicroscopic meaning. Understanding heat as a form of energy is necessary for other related topics at this educational level. IGCSE students need to appreciate the ‘heat of reaction’ and especially as it is measured in joules, which is the standard unit of energy.

Table Appx 3.2
Selected Concordance Lines for ‘Heat’

No.	Concordance
1	were left burning out of control. The heat given out was sufficient to turn the
2	producing overpowering waves of heat (Figure 7.2). Bringing such fires under
3	ting mixture. If a reaction gives out heat to the surroundings, the mixture has
4	making and gives out energy: The heat of reaction, ΔH, is the energy change

Steel

Disagreement: not convinced as it does not seem plausible

Steel is an alloy in which iron is mixed with various transition metals, and thus is not an element in any form. However, the context in which it usually appears could give steel a false status of being an element. This can be exemplified by the examples in Table Appx 3.3 which are taken from Oxford Dictionaries (2017).

Table Appx 3.3
Example sentences of ‘Steel’

No.	Example Sentences
1	A magnet is the device that attracts certain types of metals, like iron or steel.
2	Iron and steel are highest, copper and aluminium are lowest, brass and the like are in the middle.
3	He went on to remind me that China consumes more steel, copper and iron ore than any other country in the world.

Steel is placed in sentences where other metals that are elements are also made reference to such as copper, iron, and aluminium. The textbook, though clarifying that steel is an alloy (see concordance line 4, Table Appx 3.4), also portrays steel in a similar manner as the everyday context (see concordance lines 1- 3, Appx 3.4). If a student was to comprehend what an alloy is, this would aid them in being well aware that steel is not an element, though it shares some similar properties to other known metal elements.

Table Appx 3.4
Selected Concordance Lines for ‘Steel’

No.	Concordance
1	each year replacing damaged iron and steel structures, or protecting structures
2	most commonly recycled are aluminium, steel, glass, plastics and paper. Aluminium
3	Electroplating a layer of chromium on steel is used to protect some objects from
4	process - the uses of different types of steel alloys - the problem of the rusting

Margarine and Natural Gas

Disagreement: everyday meaning does not appear very different to chemistry context

Students are expected to reconceptualise their understanding of something familiar in the macroscopic context, and modify the word’s meaning due to its relation to the submicroscopic realm. For example, natural gas is referred to as methane when used in a submicroscopic context, and margarine is essentially an alkene (hydrocarbon with double bonds between carbon atoms). These cases exemplify situations where knowing an everyday word’s submicroscopic noun equivalent can broaden the meaning of familiar words to suit a chemical context rather than drawing incorrect analogies from what they understand from their everyday experience.

Carbon dioxide/monoxide

Disagreement: everyday meaning does not appear very different to chemistry context

Extending on the aspect of broadening the meaning of a familiar word with its submicroscopic noun equivalent (see Margarine and Natural Gas), it is also possible to make false conflations. Both carbon dioxide and carbon monoxide are familiar gases in terms of everyday language as the former is known to be in air, and the latter as a poisonous gas. The keyword carbon collocates 11 times with monoxide, and 12 times with dioxide (see Table Appx 3.5).

Table Appx 3.5
Selected Concordance Lines for 'Carbon'

No.	Concordance
1	ese have not even reacted to produce carbon monoxide. It is these fine carbon pa
2	mber of people die accidentally from carbon monoxide poisoning because of poorly
3	scale (calcium carbonate), producing carbon dioxide and dissolving the scale: Co
4	hydrocarbons when burnt. They give carbon dioxide and water vapour as long as

These two compounds are almost identical morphologically and phonetically, as it is only the prefix 'di' and 'mono' that differentiate them in this way. Moreover, at the symbolic level it is only the subscript number that is different, their empirical formulas (simplest formula) are CO_2 (carbon dioxide) and CO (carbon monoxide). This issue arises when a student knows that the intended product is either carbon dioxide or carbon monoxide, but due to their unfamiliarity of how they are represented symbolically, they may write the incorrect chemical formula. As an example, when methane burns in limited air, carbon monoxide is produced and not carbon dioxide; therefore, by writing CO_2, the incorrect symbol is used.

Nylon, Plastics and PVC

Disagreement: everyday meaning does not appear very different to chemistry context

Examples have been given of everyday nouns having a submicroscopic noun equivalent, and the importance of making a connection between the two was raised for the purpose of avoiding application of any false analogies from the everyday experience of that particular word. In this textbook chapter, several other words are of this nature (see Table Appx 3.6). The microscopic name assists in the understanding of the science, such as polyamide (commonly known as nylon, concordance 1), as this would inform you that there is an amide group in this polymer, and from this information, students can comprehend better the associated chemical reactions.

Table Appx 3.6
Selected Concordance Lines for 'Nylon', 'Plastics' & 'PVC'

No.	Concordance
1	ormed during polymerisation, nylon is known as a polyamide. A version of nylon p
2	y. Synthetic polymers, often called plastics, are to be found everywhere in mode
3	Poly(chloroethene) (known by the trade name of polyvinyl chloride or PVC) and poly

APPENDIX 4

Semi-Structured Interview Schedule

PART 1

Have you seen this word before?

A. (If Yes) How would you use it? (then D)

B. (If No) If you don't know a word what would you do? (then D)

C. (If Chemistry) Do you use it in everyday English like that? (then D)

D. How would you use it in Arabic? How would you say that in English?

(elicit other common similar words, see probing below)

PART 2

Non-Technical Word	Notes
Boiling	PowerPoint, then p.24, Table 2.2
Arrangement	Read p. 59 + Diagrams + Draw on paper
Gain/Lose	p. 71, Fig. 3.23
Base	p.132 reaction
Strong/Weak	Read p.269, then PowerPoint
Collisions	Read p.190, rust example
Impurities	Read p.227
Making/Breaking	p.176 Fig. 7.4

Probe Students Further:

- Why/ Why not?
- What do you mean?
- Can you tell me more…?
- Why do you think that?

APPENDIX 5

Material for Interview Schedule

PowerPoint Slides

PP Slide 1

Boiling

PP Slide 2

Oxygen

Boiling Point -183^0 c

PP Slide 3

Arrangement

PP Slide 4

Gain
Lose

PP Slide 5

Base

PP Slide 6

Strong
Weak

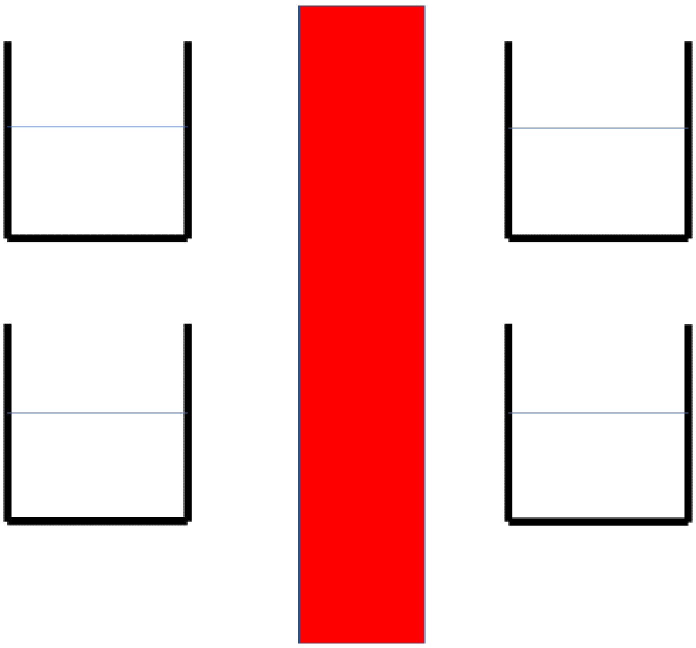
PP Slide 7

Hydrochloric Acid
(20 ml)

Water
(100 ml)

Ethanoic Acid
(60 ml)

Water
(100 ml)



Hydrochloric Acid
(10 ml)

Water
(500 ml)

Ethanoic Acid
(120 ml)

Water
(50 ml)

PP Slide 8

Collisions

PP Slide 9

Impurities

PP Slide 10

Making
Breaking

Textbook Material

Taken from:

Harwood, R., & Lodge, I. (2014). *Cambridge IGCSE chemistry coursebook* (4th ed.). Cambridge: Cambridge University Press.

APPENDIX 6

Sample Transcript for Ziyad with Predefined Codes

Note:

non-technical word familiar (F), non-technical word not familiar (NF), chemistry concept influenced by non-technical word (I), chemistry concept not influenced by non-technical word (NI), Part 1 of Interview (P1), Part 2 of interview (P2)

		Predefined Codes
I	Ok, you see this word here boiling	
Z	Boiling	
I	Have you seen this word before?	**P1 F**
Z	Yes in the chemical ... the boiling of water is one hundred	
I	What does it mean boiling? In English what does it mean?	
Z	It's a chemical reaction to make the water evaporation	
I	Do you use it in English, like every day, do you use the word boiling?	
Z	No	
I	Not really... Ok if I said give me that word in a sentence, could you use it in a sentence?	
Z	the coffee is boiling	
I	Ok what's that word in Arabic?	
Z	Tabakhar	
I	Could you write that word here if you don't mind?	
Z	In Arabic?	
I	In Arabic. Do you have other words similar to this word in everyday Arabic?	
Z	Yes, ghalayaan	
I	Ok, how would you use this in Arabic?	
Z	Al maa yatabakar	
I	Could you put that in writing? Would you use this word in the same way?	
Z	Yes	
I	Or different?	
Z	Actually it's different	
I	It's different?	
Z	Yes, because the ghalayaan is before the tabakhar	
I	So how would you translate this in English. The tarjamah (translation) in English what is it?	
Z	I think it's the same. No…the water is evaporate	
I	Uh ha	
Z	This word	
I	Uh ha and this one? If you use this word	
Z	The water is boiling	
I	Uh ha. So is it different? Or is it the…	

Z	Sometimes	
I	Yeah	
Z	But in the English it is the same word	
I	You used water as an example, so if I said…. What does it mean the water is boiling, what does it mean?	
Z	The water is boiling	**P2 I**
I	But what does that mean?	
Z	It's…because of the heat it's…boiled	
I	What temperature does that happen?	
Z	One hundred and six	
I	Or hundred degrees Celsius right?	
Z	Yes	
I	Water is boiling. It's very hot. Alright, look here… if I said to you oxygen yeah boils at minus one hundred and eighty three degrees what would you think about this? What would you think?	
Z	Oxygen…	
I	Yeah, so water boils at one hundred degrees, but if I told you oxygen boils at minus one hundred eighty-three. It's very cold right…minus?	
Z	Yes	
I	You think it's possible?	
Z	No, because the oxygen cannot be.. it can't be boiled	
I	Why not?	
Z	It's gas	
I	You can't boil it ah?	
Z	Yes	
I	Ok, but what if it's in the book? Like here page 24… Do you have this book? Did you buy it?	
Z	I count on the slides	
I	Ahhhh I see. It's good though the book you know	
Z	I can see that	
I	Yeah, lets see page 24. You see oxygen like in water yeah	
Z	Yes	
I	Boiling point one hundred but oxygen the boiling point is minus one hundred eighty three. What do you think now?	
Z	It's right, I was wrong	
I	Yeah but what does that mean though?	
Z	It mean, ok let me see… I think	
I	But it's very cold right? Minus hundred and eighty-three, it's quite cold	
Z	I think the gases have another reactions from the liquids and solids	
I	Uh ha, so it's different	
Z	It's different	
I	Yeah ok now remember any time you can use your dictionary, if you… do you use an application?	
Z	Yeah I have one	

I	Yeah, ok, no if you need to use it, if you need to. Now look at this word here arrangements. Remember if you're tired you can go at anytime	
Z	No no no, no problem	
I	Yeah. Arrangements, have you seen this word before?	**P1 NF**
Z	Yes, I heard about it	
I	What does it mean?	
Z	Maybe the physical state?	
I	Yeah, ok let's say someone says this word and you don't know what it means, would you use your dictionary?	
Z	Yes	
I	Do you want to use it or do you want to use google translate? Which one?	
Z	Anything, it's same	
I	Yeah. Ok, so… arrangement, put that into Arabic	
Z	Oh!...to order the…yes yes I got it	
I	This is tarteeb right. So, but you never use this in English, the word arrangement?	
Z	I heard about it just. I didn't use it	
I	But you've never used it yeah	
Z	I didn't use it	
I	So tarteeb what other everyday words are there like tarteeb in Arabic. Can you write it here by the way. So write tarteeb here. What other words are there like this in Arabic. The same meaning	
Z	Tandheem	
I	Ok, you put it here. That's the other common one ha, are there any other ones?	
Z	No, I don't think	
I	Can you give me an example sentence of this?	
Z	Tarteeb, uh I have to arrangement the chairs in the class	
I	Uh ha. Have you ever used it like that before? Or your using it now?	
Z	No	
I	First time yeah. So how would you use that this word in Arabic. How would you normally use it. Everyday situation tarteeb, how would you use it?	
Z	I use it everyday, in the car in the room in the…	
I	Give me an Arabic sentence	
Z	Ratabt is the past of tarteeb	
I	Uh ha ok no problem	
Z	Ratabt as sayyara	
I	You just write that down here. So what does that mean exactly in English?	
Z	It means that car is arrangement	
I	Yeah, the car	
Z	Is arrangement	
I	Ah ha, like when you clean it?	
Z	Yes	

I	Like cleaning or..	
Z	Yes	
I	Can you use that word in the same way? What's that tandheem	
Z	It's not the better way	
I	Is that tandheem? What is that?	
Z	Tandheem is organisation	
I	Or tanadhaf, tanadhaf what is that word? How do you say this?	
Z	Tandheem, tandheem	
I	Uh ha. So can you use it in the same way?	
Z	No. We can use it but it's not the better	
I	Yeah. How would you use that in Arabic?	
Z	Uh…	
I	Everyday Arabic how would you use it? Any example	
Z	It's like	
I	Or you don't really use that word?	
Z	Tarteeb it's usually	
I	Do you have a slang word amiyyah word?	
Z	Because we use tarteeb for it	
I	ahhh so you don't really use that word. Ok, no problem. But when would you use that word then?	
Z	In the lab	
I	In the lab yeah. So in Arabic you will use it in the lab?	
Z	Yes	
I	Yeah	
Z	Tam tandheem al mukhtabar	
I	What's mukhtabar?	
Z	The lab is organised	
I	Ahhh, ok. Could you write that here? So what did you say, you said… Ta tum	
Z	Tam is done	
I	Ta tum. Ok read that for me	
Z	Tum at tarteeb al mukhtabar	
I	Meaning?	
Z	The lab is organised	
I	Uh ha. Now, back here.. ok let's go to page 59. You should use this book though you will learn a lot	**P2 I**
Z	It's very good	
I	Ok, we'll go one page back. Alright, could you read this for me. Do you have the application where you put it over like that?	
Z	Yes, but	
I	Is that what you use?	
Z	No I don't think I need it	
I	Ok	
Z	Keratin	
I	Certain…	
Z	(reads passage)	
I	Do you know what the word stable means?	

Z	Yes	
I	What's stable?	
Z	Organised in the good way	
I	Uh ha. Ok… This…	
Z	This arrangement uh…	
I	This makes	
Z	Makes it uh…	
I	More it says this makes them more difficult to break up	
Z	Uh, this makes them	
I	More difficult to break up	
Z	Yes, the most stable arrangement are those of the noble gases (reading)	
I	You know noble gases?	
Z	Yes	
I	What's a noble gas?	
Z	Uh… Oxygen	
I	What is a noble… like this you see, helium, neon, argon on that side right?	
Z	Oh ok	
I	You remember?	
Z	Yes	
I	So what does it mean stable arrangement?	
Z	Stable arrangement. Electrons arrangement in a good way, like this you see?	
I	But what do you mean good way?	
Z	The way it had to be uh… to be	
I	Yeah. No problem. Explain, no problem, like how? You said good way	
Z	I didn't I didn't	
I	Like ok here is an example of argon, right? It's a noble gas, yeah how is this arrangement, how is it stable?	
Z	Ok, now right now this is arrangement right? If the electrons all of them goes right or left, that's not arrangement	
I	Uh ha. Can you draw me an example of something that is not arranged. Ok let's draw helium. It's only two electrons right?	
Z	Yes	
I	Ok, so let's draw helium here. So do He. Big H small E and do… then the shell go around and do a circle ok that's two electrons ok	
Z	Yes	
I	So when it's arranged how are the electrons?	
Z	Like that	
I	And when it's not arranged… You can draw another one here no problem	
Z	Like this	
I	Uh ha, that's what you mean it's all to one side	
Z	Yes	

I	Like that…Ok. Now, you still feeling alright, yeah? Ok, gain and lose, gain and lose. What's gain? You heard this word before?	**P1 F**
Z	Yes, gain it's like in this reac… this… the potassium and the alkali atoms	
I	No like in everyday English, have you used it in class or outside?	
Z	I didn't use it usually but…	
I	What about lose?	
Z	Lose, maybe I can say I lose two marks	
I	Or football, do you watch football?	
Z	No, I don't like football	
I	Oh! You don't like football! Ok, like you lose two marks, Yeah, alright. Err, what's the word, but you know what gain means right?	
Z	Yes…gain mark	
I	What's the word for gain in Arabic?	
Z	Ahh yaktasib	
I	Uh ha. Could you write that word here. Ok, are there any other words in Arabic that have the same meaning?	
Z	Yes	
I	Are there many or what are the common ones?	
Z	Yahsul, yazeed, la, not this one. That's all I think	
I	Ok, no problem. It's ok. Can you give me an example sentence for that yaktasib yeah. Common example, something you use all the time. Ok what does that say?	
Z	Kasabtu ashara mikaat fil ikhtibaar it means I gained ten scores in the quiz	
I	Ok good. What about this word can you use it in the same way?	
Z	Yes	
I	Yahsul you use it the exact same way? So I can change that word for yahsul and it has the same meaning?	
Z	No	
I	Oh how does the meaning change?	
Z	Ah because it's the same meaning in Arabic, but in English yaktasib is gain, yahsul is have, he have it	
I	But if you use it in Arabic to someone who speaks Arabic, would it have the same meaning?	
Z	Yes	
I	Let's go to page seventy-one. Do you like chemistry by the way?	
Z	Yeah	
I	You like it ha? Ok, alright page seventy-one. Right, look at this, so you know what that is?	**P2 NI**
Z	Yes	
I	Sodium	
Z	Sodium chloride	
I	Yeah good. Sodium chloride. Do you know type of bonding this is?	
Z	Oh, the sodium lose one electron	

I	Good, chlorine?	
Z	And the chloride gain one electron	
I	Good and you have sodium chloride	
Z	Sodium chloride	
I	Do you know what kind of bonding this is?	
Z	Ionic?	
I	Yeah because the charges right, one, the metals lost an electron, the non-metal has gained an electron and you have plus on the sodium, minus on the chlorine	
Z	Yes	
I	Ionic bonding with charges. Yeah	
Z	Yeah	
I	Now look sodium has lost an electron and it's like that now, so what does that mean? Is it a good thing? Is it a bad thing? Or it doesn't matter?	
Z	No it's a reaction it will…	
I	But if sodium has lost an electron is it good? Is it bad? Or it doesn't matter?	
Z	I don't know how to explain it but uh, I think it doesn't matter because the sodium will be uh the sodium and the chloride will make a new substance	
I	Uh ha. But it's lost an electron	
Z	The chloride gained an electron!	
I	Ok, chlorine has gained an electron, so is that good for chlorine?	
Z	Yes, I think that	
I	Why?	
Z	Because it's not uhh, I don't know how I can say that the electrons is not erm	
I	Like you gave an example you gained ten marks it's a good thing so if chlorine gained an electron is it a good thing? Or it doesn't matter?	
Z	I think it doesn't matter	
I	So it's not the same like that like you gained ten marks?	
Z	Yes because this is a new substance	
I	Yeah and for sodium it doesn't matter uh?	
Z	Yes	
I	Uhh but when you lose something it's not good isn't it, like you lose your phone	
Z	That's right	
I	Or you lose your money. But why is it ok here? Or is it not ok?	
Z	It's nothing here	
I	Nothing like that	
Z	Yeah nothing	
I	Ok. Now look at this word here, base	**P1 F**
Z	Yes	
I	Have you used this word before?	
Z	Yes	

I	Have you used it in class? Or outside? Not in chemistry like normal English	
Z	Not really	
I	No, ok. Erm… What do you think it means in everyday English. What is base?	
Z	Maybe we can say it's like the rules	
I	What do you mean?	
Z	Like rule.	
I	In English?	
Z	Uhh…or like this is a base for a computer	
I	Yeah, so what's the word in Arabic for base in Arabic?	
Z	Qaaida	
I	Could you write it here, and what other words are similar to this?	
Z	In Arabic there is no uh…	
I	Other word	
Z	Yes	
I	Ok this is the main word yes. How would you use this in a sentence in Arabic? Everyday sentence	
Z	We don't use it usually	
I	You don't use it much uh ha	
I	So how would you say that in simple sentence in Arabic?	
Z	haza qaa'ida	
I	What does that mean in English then?	
Z	This rule	
I	Now, erm let's look here now yeah, look at this, now, in a chemical reaction you have an acid, plus base gives you salt and water, you've done this right?	**P2 NI**
Z	Yes	
I	Do you know what type of reaction this is?	
Z	Covalent?	
I	Neutralisation, neutralisation	
Z	Yes yes yes	
I	You remember this now yeah?	
Z	Yes	
I	So this is hydrochloric acid, sodium hydroxides the base, so why is this the base?	
Z	Uhh, because the power of hydrogen is less	
I	Uh ha	
Z	No sorry it's more than seven	
I	Uh ha ok	
Z	From eight to eleven or twelve	
I	But why is it a base?	
Z	Why it's base….. No I don't uh…	
I	Like if I do a reaction and put hydrochloric acid, sodium hydroxide the base, what does that mean? Does it mean something?	
Z	It's base because uh the power of hydrogen if it's less than seven it's acid if it's more than seven it's base	

I	Do you think it means maybe it goes to the bottom like the computer base?	
Z	Yes	
I	You think that? You think it's the same?	
Z	Not in the Chemistry	
I	Uh ha, ok. So do you think the meaning of base here is different?	
Z	Yes	
I	It's different…so what's base in chemistry?	
Z	I said Ph more 7…	
I	Ok, now… Let's look at this word here, strong and weak. Easy, you know these words right you use it all the time right?	**P1 F**
Z	Always	
I	So give me an example in English for strong	
Z	Uh the ox head in the WWE is strong	
I	Did you watch it?	
Z	Yes, I went there	
I	Oh really! Ok, where was it? Here in Riyadh right?	
Z	In Riyadh	
I	Ok and weak?	
Z	Yes	
I	Who is weak, undertaker?	
Z	The weak is maybe the small animals	
I	Yes small animals are weak. Ok, in Arabic what words would you use for strong?	
Z	Qawee	
I	Qawee, so write here qawee. Any other words similar to qawi? Everyday Arabic?	
Z	It's many words…but main word	
I	That's the main word yeah	
Z	Yes	
I	Yeah and for weak?	
Z	Uh daeef	
I	Daeef, so you write… Are there any other words you would use for weak?	
Z	There are many words but	
I	What's common?	
Z	Daeef is the best way, the best word for the weak	
I	Uh ha, there's no other common words for daeef, no? Give me a sentence with qawee in Arabic. Something you use all the time in Arabic… Ok what does that say	
Z	Atadarab leekai yusbiha qawee	
I	Ok what does that mean?	
Z	train to become strong	
I	Uh ha and weak, give me one for weak	
Z	Weak ahh..	
I	You can write next to here no problem	
Z	ahhh al qittut haywaanaat da'eefa	
I	What does that mean?	

Z	The cats is a weak animals	
I	Ahh like you said before yeah animals are weak. Now let me just go to this page here…page 269. None of the students have the book?	
Z	Some	
I	Really!	
Z	Yes	
I	Ok. 269, ok read this…ethanolic acid is a weak acid	
I	Ok, Whereas…	
Z	Whereas a strong acid such as hydrochloric acid is completely spilt	**P2 NI**
I	Split	
Z	Split	
I	You know what split means?	
Z	No	
I	Like separate	
Z	Oh oh	
I	Yeah split	
Z	Split into ions, ethanolic acid only…	
I	Partially	
Z	Partially	
I	What does partially mean? You know partially? Like a little a bit shwaya like partially, partially disassociates, disassociates like spilt yeah same meaning, into ions…	
Z	Into ions and water	
I	So look whereas a strong acid, so hydrochloric acid is a strong acid, ethanolic acid is a weak acid why is that?	
Z	The ethanolic acid…	
I	Why is that weak?	
Z	Because its near to seven	
I	Near to seven ah	
Z	Yes, above five near to seven maybe eight, I think its six, five no five	
I	And hydrochloric acid why is that strong?	
Z	Because the power of hydrogen is 1	
I	so what does that mean…the power of hydrogen	
Z	the amount of hydrogen in the acid..yes..the acid	
I	just the hydrogen	
Z	I think	
I	so like water is H_20 right…so does that mean it's a strong acid then?	
Z	no because the amount of hydrogen is less	
I	why?... what does it mean by ions?	
Z	Ions… yes because it's uh the hydrogen and the oxygen is uh…	
I	Separated?	
Z	No it's a (unclear)	
I	This is hydrochloric acid right HCl, so if I put that in water these two will separate right?	
Z	Yes.	

I	Hydrogen and chlorine will be ions, H+ Cl- so there will a lot of Hydrogen ions, but in this one your saying there are less hydrogens right? Ok, look at this… so if I have let's say a beaker, I put 20ml of hydrochloric acid yeah and 100ml of water and in this one I put 60ml of ethanolic acid so more in the same amount of water. Which one will be a strong acid which one will be a weak acid?	
Z	I say no difference	
I	Same amount water. No difference? When you say no difference what do you mean?	
Z	Uh… Because of the amount of HCl is a… it doesn't make a sense in the water and the ethanolic acid is a big but it's a weak	
I	It's still weak? But I put more in there that's got 20 and that's got 60	
Z	The water will make it uh… Because the water is neutral it doesn't make it different	
I	No difference	
Z	Yes	
I	Yeah, ok. So if you look at these two, so I'll ask you now which ones a strong acid then? Hydrochloric acid or ethanolic acid?	
Z	Hydrochloric acid	
I	This will still be the strong acid	
Z	Yes	
I	Because	
Z	It have uhhh the… shismu the amount of hydrogen it's big	
I	What do you mean? There's less acid here…less HCl…more water…here there is more ethanoic acid…less water… so…	
Z	Still same…because more hydrogen	
I	HCl is still a strong acid?	
Z	Still more hydrogen	
I	Uh ha, ok now how are you feeling by the way? You ok?	
Z	Yes I'm good	
I	You good. Ok, you enjoying it?	
Z	Yes	
I	Alright, look at this word collision, have you seen this word before?	
Z	Don't think I have	**P1 NF**
I	First time you're seeing it?	
Z	Yes	
I	Ok if there's a word, you don't know what it means, your in class now, what would you do?	
Z	I would use my phone	
I	Ok, do you need internet? Do you have internet?	
Z	Yes I have, how I can spell it?	
I	C-O-L-L-I-S-I-O-N-S. Did you find it?	
Z	Yes, oh tassadum… like the accident	

I	Uh ha, so yeah like accident yeah? So now that you know the word how would you use it in English?	
Z	I don't think it's… maybe in the cars	
I	Cars had a collision, yeah like accident, what's that word in Arabic?	
Z	Uh tassadum	
I	tassadum, just put it here. Ok, are there any others words like this in Arabic with the same meaning?	
Z	Tadarub	
I	Ok just these two right? Yeah so now, how would you use these two in a sentence?	
Z	itstadamat as sayaaraat	
I	What does that mean?	
Z	The cars is collisions	
I	Oh like collided we say yeah, like hit each other. Can you use that word in the same way the other one?	
Z	Not really	
I	You can't? Why is it different?	
Z	Uh… tadarub it's a collisions but you can use it in the chemistry	
I	Oh really? You can't use it in every day…	
Z	Yes	
I	Ok, so how would you use it in Arabic?	
Z	Tadarub al jazayaat…the ions is collision	
I	Uh ha, particles maybe	
Z	Particles	
I	Could you write that in Arabic over here in this… ok. Now, let's go to page 190, ok if you read from here collision theory…	**P2 I**
Z	(reads passage)	
I	You know exposed?	
Z	No	
I	Exposed means to see, like you can see yeah so…	
Z	(reading) This means there are more places where collisions can take place	
I	Do you understand that?	
Z	Yes	
I	What does it mean?	
Z	The collision is uh… is uh… the particles collision	
I	Uh ha, good, why? For a reaction. For a reaction yeah the particles have to collide	
Z	If you add another element it will make a new substance	
I	Good ok, now do you think that the colliding of particles do is a good thing all the time?	
Z	Yes	
I	Why?	
Z	It makes a new substance	
I	But like here when cars collide it's a bad thing so how come it's a good thing here?	
Z	In the chemistry almost of the… it's good	

I	Ok like you see this key if I leave it outside after one year or two years it'll become brown, is that a good thing?	
Z	No	
I	But the particles here are colliding with air particles, it's a bad thing right, so is it always good?	
Z	No, sometimes if they use it in the right way of course then it will be good	
I	so sometimes good sometimes it's bad, yeah so in chemistry do we want collisions to happen?	
Z	Yes	
I	So is it good? Or bad?	
Z	Chemistry we want collision	
I	What do you mean?	
Z	Collision good in chemistry	
I	OK. So now, how are you feeling by the way, you good?	
Z	Yes	
I	Let's look at this word here, impurities, have you seen this word before?	
Z	No	**P1 NF**
I	Never!	
Z	No	
I	Ok so you said when you don't know a word you would use your dictionary right? Which application are you using?	
Z	Google translation	
I	Is that what you use? You don't have another application?	
Z	No	
I	I see some students have some special one. They go over the book like that, what's that called?	
Z	It's Microsoft	
I	Oh is it Microsoft? Is that good or is this better?	
Z	I've use that for a long time so I like it	
I	Oh you're used to Google	
Z	How I can spell it?	
I	I – M, M for mother yeah I-M-P-U-R-I-T-I-E-S. Nothing?	
Z	Shawaib	
I	So what does that mean?	
Z	Particles doesn't reaction with the…	
I	Like is it a good thing or a bad thing what is it?	
Z	It doesn't matter, I think it's a bad thing	
I	So what does that mean, like what's another word for shawa'ib? You've got some examples?	
Z	Pollute maybe pollute	
I	Pollute so is it like a dirty thing? Like rubbish?	
Z	Yeah like that…like in chemistry if you put fire in the acids it will make a brown…	

I	Ok, like other things. So could you write that word here shawa'ib. Do you have any other words for this in Arabic?	
Z	This word no there is no…	
I	It's very specific. So how would you use it then in Arabic? You probably don't use it right, everyday language, when you're speaking at home or at the shops	
Z	You can find shawa'ib in the cars it's like the sign	
I	Ahhh the exhaust pipe yes	
Z	That's what you call shawa'ib	
I	How would you use this word?	
Z	the impurities of tyres	
I	I want you to read this	**P2 I**
Z	(reading passage)	
I	So sand here…Why is it an impurity?	
Z	This way it's dirty	
I	Why?	
Z	It will make the iron dirty	
I	Normally is sand dirty?	
Z	Yeah because it make reaction with fire	
I	So because it reacts with fire it's dirty?	
Z	yeah…	
I	Ok this is the last one. Making…you know making…give me an example.	**P1 F**
Z	Yes…I made a book.	
I	Ok…are there any other words similar to this in English?	
Z	Create	
I	Ok good…anything else?	
Z	No	
I	Ok what's making in Arabic?	
Z	sunea (writing an example)	
I	Any other words…in Arabic?	
Z	Yes	
I	What's that word? Are there many words?	
Z	Yes, but like inventive	
I	So how would you use sana in Arabic?	
Z	Sanatul kitab	
I	Oh…same in English	
Z	Yeah	
I	What about that one can you use it in the same sentence? Khalaq kitab	
Z	It's not better because khalaq make something from nothing	
I	So how would you use that word	
Z	Uhh (writing)	
I	What does that say?	
Z	Khalaqul Allah min kitab	
I	Ok you see this…you read this	
Z	(reading passage)	

I	So what does that mean?	
Z	If I make a chemical bond it gives out energy?	**P2 I**
I	Ok but you said to make a book…does it give out energy?	
Z	No really	
I	So what does it mean here? You understand right. Like you have a chemical bond	
Z	Yeah	
I	So look here. You see break this bond it says it takes in energy but when this bond is made	
Z	Yeah I get it…gives out energy	
I	Does that make sense?	
Z	I'm not sure about that because…strange	
I	Why is it strange?	
Z	Actually…how it's make energy?	
I	Ok in a chemical reaction bonds are broken and new ones are made…so you see that methane	
Z	Methane plus oxygen become carbon dioxide plus water	
I	Because the bonds are broken then new compounds are made…You understand now?	
Z	Oh Yeah I got it yes I got it now	
I	But how is it that when bonds are made it gives out energy?	
Z	Give out energy…this is the only thing I didn't got it	
I	Strange? What about breaking bonds?	
Z	Maybe because this is sensible…I can understand it…but gaves out energy…	
I	It doesn't make sense?	
Z	Yeah it's like a magic	
I	(ended by thanking him)	

APPENDIX 7

Sample Coding for Chapter 6

Theme	Category	Description	Excerpt
No Influence of Non-Technical Word	Scientific Explanation	Sub-microscopic	**Salman** **strong/weak** the quantity is not the most important…it's the **structure of the acids**…there's no way it's going to be strong…it's weak khalas
			Nasr **Strong/weak** I understand from the book the left one…HCl…that's what I understand from the book that ethanoic is weak…it will still weak…**we look at how ion split**…
			Hammad **Strong/weak** M: Because he (strong) can **split it**…It (weak) only little…quantity is more…It's weak acid but if you more quantity maybe he stronger than this… I: If you increase it will become stronger than that? So does that mean now that it will be a strong acid? M: No I: It's still a weak acid? M: Yeah
			Ziyad **Strong/weak** No difference…the ethanoic acid is a big but it's a weak…it (HCl) the amount of hydrogen it's big
			Feras **Gain/lose** Chlorine better now…strong…we become **stable**…because gain one electron it become stable.
			Musa **Gain/lose** Losing…no it's good…**stable**…it's mutual gaining…they both stable now…you need to make them stable that's the main

			thing…in chemistry you lose to be stable…it's a good thing to gain also…they both have to be stable
			Qassim **Gain/lose** Not bad for sodium…sodium will **stable**…sodium has one what can he do give chlorine…
		Macroscopic	**Khalid** **boiling** Nitogen it's liquid it's solid state is at minus one hundred and ninety seven…Because it's the same with the nitrogen, nitrogen has a low boiling point
			Khalid **Gain/lose** …because it has to do it to make the reaction
		Symbolic	**Salman** **Base** Because **pH level is higher than 7**…it has its own qualities…
			Hammad **base** If **more 7** it's base…that's another meaning… chemistry different
		Firmness	**Musa** **arrangements** …No! of the number of electrons…the number of electrons in one shell
			Feras **arrangements** In first shell 2…second shell 8…anywhere no problem but you should 2 in first shell…here here here no problem…no how many there are
			Yusuf **impurities** It's not dirty…but we need to see iron very clean and if you want iron very clean you need remove sand…but sand is not dirty…we know it's not dirty

			<u>Muhannad</u> **<u>impurities</u>** you want just iron so the other things just shawaib impurities…sand no you can use it again…because they don't want it right now…they just want the iron thing…it's not dirty but it's not important…
		Chemistry is neutral	**<u>Musa</u>** **<u>Collisions</u>** If you want it to be good…if you don't want it to happen so it's not good…it depends…nothing is good or bad in chemistry actually…it's on your own intention…that's science
			<u>Hammad</u> **<u>Collisions</u>** Maybe good maybe bad…maybe you need hot water can you take water increase the heat evaporation…in chemistry yeah..no not always good…maybe dangerous in the lab…maybe good maybe bad…

APPENDIX 8

Certificate of Ethical Approval

GRADUATE SCHOOL OF EDUCATION

St Luke's Campus
Heavitree Road
Exeter UK EX1 2LU

http://socialsciences.exeter.ac.uk/education/

CERTIFICATE OF ETHICAL APPROVAL

Title of Project: Saudi Foundation Year Students Understanding of Semi-Technical Words in English Secondary School Chemistry

Researcher(s) name: Asad Feroz Shafi

Supervisor(s): Dr. Lindsay Hetherington, Dr. Darren Moore

This project has been approved for the period

From: 14/08/2018
To: 17/05/2019

Ethics Committee approval reference: D/17/18/61

Signature: Date: 14 Aug 2018
(Professor Justin Dillon, Professor of Science and Environmental Education, Ethics Officer)

APPENDIX 9

Information and Consent Form for Dean of College

INFORMATION SHEET AND CONSENT FORM FOR RESEARCH

Title of Research Project

Saudi Foundation Year Students Understanding of Semi-Technical Words in English Secondary School Chemistry

Details of Project

1. What is this project?

This project aims to understand how foundation program students from Saudi Arabia who use Arabic as their first language understand words that have both a meaning in chemistry and an everyday meaning in English. These words have been selected from your chemistry coursebook in your foundation year program.

2. Who is conducting this research?

I am a PhD student at the University of Exeter and this research forms part of my PhD. My supervisor is Dr. Lindsay Hetherington (REMOVED). This research is self-funded.

3. What does being part of this study mean for me?

I will need your assistance in recruiting approximately 12 students for this research strictly on a volunteer basis. Two of these students will be used for the pilot study. In addition I would need the students to sign the consent forms in your presence in case any further issues need to be clarified. We strongly advise you to read both the English and Arabic version of the students' information/consent forms.

I would like to interview these students individually at your institution, face to face, and each interview is likely to last around an hour. I would like to record these interviews with a digital voice recorder. The students can stop the interview at any time and they do not need to answer any questions that they do not wish to answer. Sections of the transcript of the interview may be published, either in journal articles or elsewhere, following this research. The students' real names' will not be used.

4. Who can I contact for further information?

For further information about the research or your interview data, please contact:

Asad Feroz Shafi (see details below)

If you have concerns/questions about the research you would like to discuss with

someone else at the University, please contact:

Dr. Lindsay Hetherington (see details below)

5. What will happen to the interview data?

Please also read the section on '**Data Protection Notice'** below.

a. Interview recordings

The digital recording of the interview will be deleted as soon as there is an authoritative written transcript of the interview.

b. Interview transcripts and contact details

Interview data will be held and used on an anonymous basis, with no mention of name, but we will refer to the group of which the student is a member. Personal and contact details will be stored separately from the interview transcript and may be retained for up to 5 years. If the student requests it, it will be supplied with a copy of *the* interview transcript so that the student can comment on and edit it as the student sees fit. Third parties will not be allowed access to interview tapes and transcripts except as required by law or in the event that something disclosed during the interview causes concerns about possible harm to the student or to someone else.

Contact Details

For further information about the research /interview data (amend as appropriate), please contact:

Name: Asad Feroz Shafi

(REMOVED)

If you have concerns/questions about the research you would like to discuss with someone else at the University, please contact:

Name: Dr. Lindsay Hetherington

(REMOVED)

Confidentiality

Interview tapes and transcripts will be held in confidence. They will not be used other than for the purposes described above and third parties will not be allowed access to them (except as may be required by the law). However, if the student *requests it, it will be supplied with a copy of the interview transcript so that* the student *can comment on and edit it as* the student *sees fit.* The students' *data will be held in accordance with the General Data Protection Regulation.*

Data Protection Notice

Data Protection Notice - The information you provide will be used for research purposes and your personal data will be processed in accordance with current data protection legislation and the University's notification lodged at the Information Commissioner's Office. Your personal data will be treated in the strictest confidence and will not be disclosed to any unauthorised third parties. The results of the research will be published in anonymised form. Please see the Data Protection Information for Research at the University of Exeter document for further information.

Anonymity

Interview data will be held and used on an anonymous basis, with no mention of the students' *names, but we will refer to the group of which* the student *is a member.*

Consent

I have been fully informed about the aims and purposes of the project.

I understand that:

- there is no compulsion for me to participate in this research project and, if I do choose to participate, I may withdraw at any stage;
- I have the right to refuse permission for the publication of any information about me;
- any information which I give will be used solely for the purposes of this research project, which may include publications or academic conference or seminar presentations;
- If applicable, the information, which I give, may be shared between any of the other researcher(s) participating in this project in an anonymised form;
- all information I give will be treated as confidential;
- the researcher(s) will make every effort to preserve my anonymity.

....	....
(Signature of participant)	(Date)
………………………………………………	………………………………………………
(Printed name of participant)	(Email address of participant if they have requested to view a copy of the interview transcript.)
....	....
(Signature of researcher)	(Printed name of researcher)

One copy of this form will be kept by the participant; a second copy will be kept by the researcher(s).

Your contact details are kept separately from the interview data.

APPENDIX 10

Information and Consent Form for Saudi Students in Arabic

جامعة إكسيتر **نموذج صحيفة البيانات والموافقة على إجراء البحث**

اسم مشروع البحث

فهم طلاب السنة التأسيسية بالمملكة العربية السعودية للكلمات شبه الفنية في كيمياء المرحلة الثانوية باللغة الإنجليزية.

تفاصيل المشروع

1. ما هو هذا المشروع؟

هذا المشروع يهدف لمعرفة كيف يفهم طلاب البرنامج التأسيسي من المملكة العربية السعودية الذين يستخدمون اللغة العربية كلغتهم الأولى الكلمات التي لها معنيان أحدهما في الكيمياء والآخر في الحياة اليومية باللغة الإنجليزية. تم اختيار هذه الكلمات من كتاب مقرر الكيمياء الخاص بكم في برنامج السنة التأسيسية.

2. من الذي يجري هذا البحث؟

أنا طالب متقدم للحصول على درجة الدكتوراه في جامة إكستير وهذا البحث هو جزء من رسالة الدكتوراه الخاصة بي. المشرف على رسالتي هي د. ليندساي هيثرينجتون (REMOVED). هذا البحث يجري تمويله بشكل شخصي.

3. ما الذي يعنيه لي أن أكون جزء من هذه الدراسة؟

إنه سيتضمن إجراء مقابلة شخصية، وجهاً لوجه، والتي من المرجح أن تستمر لحوالي ساعة واحدة. سأقوم بتسجيل هذه المقابلة باستخدام جهاز تسجيل صوت رقمي وذلك بعد الحصول على موافقتكم. يمكنكم إيقاف إجراء المقابلة في أي وقت لا تريدون الإجابة على أية أسئلة لا ترغبون بالرد عليها.

قد تم نشر أجزاء من بيان المقابلة التي أجريت معكم، سواء في مقابلات بالجرائد أو أي مكان آخر بعد إجراء هذا البحث. لن يتم استخدام اسمكم الحقيقي.

4. من الذي يمكنني التواصل معه لأجل المزيد من المعلومات؟

لأجل المزيد من المعلومات حول البحث أو بيانات المقابلة الشخصية معكم، برجاء التواصل مع:

أسد فيروز الشافي (انظر التفاصيل أدناه).

في حالة كانت لديكم مخاوف/ تساؤلات حول البحث والتي تودودن مناقشتها مع شخص آخر في الجامعة، برجاء التواصل مع:

د. ليندساي هيثرينجتون (انظر التفاصيل أدناه)

5. ما الذي سيحدث لبيانات المقابلة الشخصية معي؟

برجاء قراء الجزء "**إشعار الحماية الشخصية**" أدناه.

أ. تسجيلات المقابلة الشخصية

سيتم حذف التسجيل الرقمي الخاص بالمقابلة الشخصية المجراه معكم فور صدور نسخة مكتوبة موثوقة من المقابلة الشخصية معكم.

ب. نسخ المقابلة الشخصية وبيانات التواصل

سيتم الاحتفاظ ببيانات المقابلة الشخصية واستخدامها بصفة المجهول، بدون ذكر لاسمكم، ولكننا سنشير للمجموعة التي أنت عضو فيها. سيتم تخزين بياناتكم الشخصية وبيانات التواصل الخاصة بكم بشكل مستقل عن بيان المقابلة الشخصية الخاصة بكم وقد يجري الاحتفاظ بها لمدة تصل إلى 5 سنوات. في حال طلبكم لها، سيتم تزويدكم بنسخة من بيان المقابلة الشخصية وبهذا يمكنكم التعليق عليها وتحريرها كما ترونه ملائماً (برجاء ذكر البريد الإلكتروني الخاص بكم أدناه). لن يسمح لأي طرف آخر بالوصول إلى أشرطة وبيانات المقابلة الشخصية عدا ما يلزم قانوناً أو في حالة أن يكون شئ ما مما جري الإفصاح عنه أثناء المقابلة الشخصية قد يسبب مخاوف حيال أذى محتمل لكم أو لأي شخص آخر.

بيانات التواصل

برجاء المزيد من المعلومات حول بيانات البحث/ المقابلة الشخصية (التعديل حسب ما يلزم)، برجاء التواصل مع:

الاسم: (أسد فيروز الشافي) Asad Feroz Shafi

(REMOVED)

في حالة كانت لديكم مخاوف/ تساؤلات حول البحث والتي تودودن مناقشتها مع شخص آخر في الجامعة، برجاء التواصل مع:

(د. ليندساي هيثرينجتون **Dr. Lindsay Hetherington**

(REMOVED)

السرية:

سيتم الإبقاء على سرية أشرطة تسجيل المقابلة ونسخها الورقية. لن يتم استخدامها لغرض خلاف الموضح أعلاه ولن يسمح لأي طرف ثالث بالوصول إليها (عدا ما يكون لازماً قانوناً). مع ذلك، في حال طلبكم لهذا، سيتم تزويدكم بنسخة من المقابلات الشخصية الخاصة بها وبهذا يمكنكم التعليق عليها وتحريرها كما ترونه ملائماً (برجاء ذكر البريد الإلكتروني الخاص بكم أدناه وبهذا أستطيع التواصل معكم فيما بعد). سيتم الاحتفاظ ببياناتكم وفقاً لقانون حماية البيانات.

إشعار حماية البيانات

إشعار حماية البيانات – إن المعلومات التي تقدمونها سيجري استخدامها لأغراض البحث وستتم معالجة بياناتكم الشخصية وفقاً لتشريعات حماية البيانات الحالية وإشعار الجامعة المودع في مكتب مفوض المعلومات. ستتم معالجة بياناتكم الشخصية بسرية تامة ولن يجري الإفصاح عنها إلى أي طرف ثالث غير مفوض. سيتم نشر نتائج البحث بصيغة المجهول. يرجى الاطلاع على معلومات حماية البيانات للبحث في وثيقة جامعة إكستر لمزيد من المعلومات.

إخفاء الاسم

سيتم الاحتفاظ ببيانات المقابلة الشخصية واستخدامها بصيغة المجهول، بدون ذكر لاسمكم، ولكن سنشير إلى المجموعة التي كنتم عضواً فيها.

الموافقة

لقد تم إعلامي بشكل تام بأهداف وأغراض المشروع.

وأتفهم أنه:

- أنني غير مجبر على المشاركة في مشروع البحث هذا، وإذا اخترت عدم المشاركة يمكنني الانسحاب في أي مرحلة؛
- لدي الحق في رفض منح التصريح بنشر معلومات عني؛

- أي معلومات أدلي بها سيتم استخدامها فقط لأغراض مشروع البحث هذا، والتي قد تتضمن منشورات أو مؤتمرات أكاديمية أو عروض ندوات؛
- في حالة كان معمولاً به، المعلومات التي أدلي بها يمكن مشاركتها بين أي من الباحثين الآخرين المشاركين في هذا المشروع بصيغة المجهول؛
- جميع المعلومات التي أدلي بها ستعامل بشكل سري؛
- سيبذل الباحثين قصارى جهدهم لإخفاء هويتي.

....

(توقيع المشارك)

....

(اسم المشارك مطبوع)

....

(توقيع الباحث)

....

(التاريخ)

....

(البريد الإلكتروني الخاص للمشارك إذا طلب استعراض نسخة من المقابلة)

....

(اسم الباحث مطبوع)

سيتم الاحتفاظ بنسخة من هذا النموذج من قبل المشارك؛ وسيتم الاحتفاظ بالنسخة الثانية من قبل الباحث.

بيانات التواصل الخاصة بكم سيتم الاحتفاظ بها بشكل مستقل عن بيانات المقابلة الشخصية الخاصة بكم.

APPENDIX 11

Transliteration of Arabic Words

Non-technical Word	Transliteration	Arabic Word	google translate
Gain	yaktaseb	يكتسب	acquire
	ya'tee	يعطي	give
	yahsul	يحصل	gets
	ya'khudh	يأخذ	taking
	faaz	فاز	win
Lose	yafqad	يفقد	loses
	yatruk	يترك	leave
	yakhsur	يخسر	loses
Making	yasna'	يصنع	manufacture
	khalaq	خلق	create
	a'adda	أعد	prepare
	yaj'al	يجعل	makes
	sawah	سوي	to make/to do
	amal	عمل	action/work
	intaj	إنتاج	to produce
Breaking	kasar	كسر	breaking
Strong	qawee	قوي	strong
	maheel	محيل	solute
	masaytar	مسيطر	dominant
Weak	da'eef	ضعيف	weak
	miskeen	مسكين	needy
	faqeer	فقير	poor
Boiling	ghalayaan	غليان	boiling
	tabakar	تبخر	evaporation
	tasakan	تسخن	to heat up
	yafour	يفور	evaporates
Arrangement	tarteeb	ترتيب	arrangement
	tandheem	تنظيم	organise
	tawwazee'	توزيع	distribution
	tanseeq	تنسيق	coordinate
	tajheez	تجهيز	preparation
	taqseem	تقسيم	division
	tandheef	تنظيف	cleaning
Base	qaaidah	قاعدة	base
	qanoon	قانون	law
	qaa'ideeyaa	قاعدية	basicity
	qalwee	قلوي	alkaline
	asassi	أسسي	basic

Collisions	tasaddum	تصدم	collisions
	tadaarib	تضارب	hitting
	takhaabut	تخابط	bumping
	tasaaqa'	تساقع	fall
Impurities	shawa'ib	شوائب	impurities
	telawwuth	تلوث	pollution
	najaasah	نجاسة	impurity
	baqayah	بقايا	leftover/residue
	awaa'ib	عوايب	unwanted/rubbish
	ghayr naqee	غير نقي	not pure