Effectiveness of writing-to-learn activities in enhancing learners' performance on the topic of Intermolecular forces

BY

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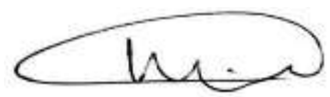
DECLARATION

I declare that “**Effectiveness of writing-to-learn activities in enhancing learners’ performance in the topic of Intermolecular forces**” is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.



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DEDICATION

This study is dedicated to my mother Victoria Hlabane for her perpetual love and support of my dreams since I started this journey

ABSTRACT

An important goal of South Africa's National Development Plan is for the country to achieve a target of at least 450000 learners by 2030 qualifying to study for the Bachelor's degree programmes in STEM disciplines in various institutions of higher learning. However, research studies and results from the National Senior Certificate show that South African learners are performing poorly in STEM subjects such as Physical Sciences where the number of learners who pass the subject with 40% and above has not reached 100000 since 2015. One of the identified challenges for poor performance is related to the language of instruction. Writing is one of the most important aspects of language that contributes to poor performance, and it is a fundamental skill associated with critical and creative thinking skills that are important for learning Physical Sciences. This study was an attempt to design a pedagogical intervention using 'writing-to-learn as a pedagogy to enhance learners' understanding of Physical Sciences concepts. A mixed-method approach was used to elicit responses from 317 Grade 11 learners from three schools in Mpumalanga Province of which 154 were taught through the normal traditional way and 163 through writing-to-learn pedagogies to develop their abilities to construct scientific written explanations. The quantitative data was collected from tests (pre- and post-tests) focusing on overall academic achievement, science inquiry skills, and how learners define and explain concepts in the topic of intermolecular forces. Physical Sciences teachers from the participating schools were interviewed and learners participated in focus group interviews. The overall findings from the tests which were analysed through ANCOVA showed a statistical significance ($df = 316$; $F = 65.54$; $p < 0.05$) in favour of the learners who were engaged in writing-to-learn strategies. The WTL strategies also enhanced learners' science Inquiry Skills ($df = 316$; $f = 40.600$ and $p < 0.05$) and understanding of basic IMF concepts ($df = 316$, $F = 79.798$ and $p < 0.05$). Data from the interviews and focus group interviews showed that the teachers and learners were positive about the incorporation of writing-to-learn activities in science classes. To offer recommendations for practice, a framework for incorporating writing-to-learn strategies in science education was developed.

Keywords: Intermolecular forces, writing, writing-to-learn, writing-intensive teaching, Physical Sciences, science education, language of science, chemistry education, language of learning and teaching, writing across the curriculum

NAGANWAGO

Maikemišetšo a bohlokwa a Leanotlhabollo la Bosetšhaba la Afrika Borwa ke gore naga e fihlelele nepo ya baithuti bao e sego ka fase ga 450000 ka ngwaga wa 2030 bao ba swanelegago go ithutela mananeo a Bachelor's degree ka dithutong tša STEM ka ditheong tša go fapafapana tša thuto ya godimo. Le ge go le bjalo, dinyakišišo tša dinyakišišo le dipoelo go tšwa go Setifikeiti sa Bosetšhaba sa Bagolo di laetša gore barutwana ba Afrika Borwa ga ba šome gabotse dithutong tša STEM. Physical Sciences ka mo go kgethegilego ke ye nngwe ya dithuto tša STEM tšeo barutwana ba di hwetšago e le tlhohlo. Palo ya baithuti bao ba phasago Physical Sciences ga se ya fihla go 100000 go tloga ka 2015. E nngwe ya ditlhohlo tšeo di lemogilwego tša go se šome gabotse e amana le polelo ya go ruta. Go ngwala ke ye nngwe ya dikarolo tše bohlokwa kudu tša polelo tšeo di tsenyago letsogo go tshepedišo ya go se šome gabotse gomme ke bokgoni bja motheo ka ge gantši bo tswalanywa le mabokgoni a go nagana gabotse le a boitlhamelo ao a lego bohlokwa go ithuta Physical Sciences. Thuto ye e be e le maitekelo a go hlama tsenogare ya thuto ka go šomiša 'go ngwala go ithuta bjalo ka thuto go godiša kwešišo ya baithuti ya dikgopolo Physical Sciences. Mokgwa wa mokgwa wa go hlakantšhwa o šomišitšwe go hwetša dikarabo go tšwa go barutwana ba 317 ba Mphato wa 11 go tšwa dikolong tše tharo tša Profenseng ya Mpumalanga tšeo ba 154 ba tšona di rutilwego ka mokgwa wa tlwaelo wa setšo wa go ruta gomme ba 163 ka dithuto tša go ngwala go ithuta go hlabolla bokgoni bja bona bja go aga dingwalwa tša mahlale ditlhaloso. Datha ya boleng e ile ya kgoboketšwa go tšwa ditekong (pele le ka morago ga tlhahlobo) yeo e lebeletšego kudu phihlelelo ya thuto ka kakaretšo, mabokgoni a nyakišišo ya mahlale le ka fao baithuti ba hlalošago le go hlaloša dikgopolo ka ga hlogotaba ya maatla a magareng ga dimolekule. Barutiši ba Physical Sciences go tšwa dikolong tšeo di tšerego karolo ba ile ba boledišanwa le baithuti gomme baithuti ba tšea karolo dipoledišanong tša sehlopha sa nepo. Dikutollo ka kakaretšo go tšwa ditekolong tšeo di sekasekilwego ka ANCOVA di bontšhitše bohlokwa bja dipalopalo (df= 316; F=65.54; $p<0.05$) bjo bo thekgago baithuti bao ba bego ba swaregile ka maano a go ngwala go ithuta. Maano a WTL a ile a godiša gape Mabokgoni a go Nyakišiša sa mahlale (df= 316; F=40.600 le p= 0.05 le kwešišo ya dikgopolo tša motheo tša IMF (df=316; F=79.798 le p=0.05) Datha go tšwa dipoledišanong le dipoledišanong tša sehlopha sa nepo e bontšhitše gore barutiši le baithuti ba be ba na le maikutlo a mabotse ka ga go tsenywa ga mediro ya go ngwala go ithuta ka phapošing ya mahlale. Go fa ditšhišinyo tša go itlwaetša, go ile gwa hlangwa tlhako ya go tsenya maano a go ngwala go ya go ithuta thutong ya mahlale.

Mantšu a bohlokwa: Matla a magareng ga dimolekule, go ngwala, go ngwala go ithuta, go ruta mo go tseneletšego go ngwala, Physical Sciences, thuto ya mahlale, polelo ya mahlale, thuto ya khemikhale, polelo ya go ithuta le go ruta, go ngwala go ralala le kharikhulamo

Xianakanyiwa

Xikongomelo xa nkoka xa Kungu ra Nhluvukiso wa Rixaka ra Afrika-Dzonga i ku va tiko ri fikelela xikongomelo xa vadyondzi lava nga riki ehansi ka 450000 hi 2030 lava faneleke ku dyondzela tiphurogireme ta tidigiri ta Bachelor’s eka tidyondzo ta STEM eka swivandla swo hambana swa tidyondzo ta le henhla. Hambiswiritano, tidyondzo ta ndzavisiso na mbuyelo ku suka eka Xitifikheti xa le Henhla xa Rixaka swi kombisa leswaku vadyondzi va Afrika-Dzonga a va tirhi kahle eka tidyondzo ta STEM. Ngopfungopfu Physical Sciences i yin’wana ya tidyondzo ta STEM leti vadyondzi va ti kumaka ti ri na ntlhontlho. Nhlayo ya vadyondzi lava pasaka Physical Sciences a yi si fika eka 100000 ku sukela hi 2015. Yin’wana ya mintlhontlho leyi kumiweke eka matirhelo yo biha yi fambelana na ririmi ra dyondzo. Ku tsala i xin’wana xa swiyenge swa nkoka swinene swa ririmi leswi hoxaka xandla eka matirhelo yo biha naswona i vuswikoti bya xisekelo tanihileswi byi talaka ku fambelanisiwa na vuswikoti byo ehleketa hi vukheta na byo tumbuluxa lebyi nga bya nkoka eka ku dyonda Physical Sciences. Dyondzo leyi a ku ri ku ringeta ku dizayina ku nghenelela ka dyondzo hi ku tirhisa ‘ku tsala-ku-dyondza tanihi dyondzo ku ndlandlamuxa ku twisisa ka vadyondzi eka miehleketo ya Sayense ya Ntivo-vutomi. Endlelo ra maendlelo yo hlangana ri tirhisiwile ku kuma tinhlamulo ku suka eka 317 wa vadyondzi va Giredi ya 11 ku suka eka swikolo swinharhu eXifundzheninkulu xa Mpumalanga laha 154 wa vona va dyondzisiweke hi ku tirhisa ndlela ya ntolovelo ya ndhavuko yo dyondzisa na 163 hi ku tirhisa tiphedagoji ta ku tsala ku dyondza ku hluvukisa vuswikoti bya vona byo aka leswi tsariweke hi sayense tinhlamuselo. Data ya nhlayo yi hlengeletiwile ku suka eka swikambelo (pre na post-test) leyi kongomisaka eka ku humelela hi ku angarhela ka dyondzo, vuswikoti byo vutisa sayense na ndlela leyi vadyondzi va hlamuselaka na ku hlamusela miehleketo eka nhlokomhaka ya matimba ya le xikarhi ka timolekhuli. Vadyondzisi va Sayense ya Miri ku suka eka swikolo leswi ngheneleke va burisanile naswona vadyondzi va nghenelerile eka mimbulavurisano ya ntlawa lowu kongomisiweke. Swikumiwa hinkwaswo ku suka eka swikambelo leswi kamberiweke hi ku tirhisa ANCOVA swi kombisile nkoka wa tinhlayo ($df=316$, $F=65.54$; $p<0.05$) ku seketela swichudeni leswi a swi nghenelerile eka tindlela to tsala ku dyondza. Maqhinga ya WTL ya tlhele ya ndlandlamuxa Vuswikoti bya Vulavisisi bya sayense ($df= 316$; $f=40.600$ na $p= 0.05$ na ku twisisa miehleketo ya masungulo ya IMF ($df=316$; $F=79.798$ na $p=0.05$) Data ku suka eka mimbulavurisano na mimbulavurisano ya ntlawa lowu kongomisiweke yi kombisile leswaku vadyondzisi na vadyondzi a va ri na ntshembo hi ku nghenisiwa ka migingiriko ya ku tsala ku dyondza etlilasini ya sayense. Ku nyika switsundzuxo swa ku titoloveta, ku endliwile rimba ro nghenisa tindlela to tsala ku dyondza eka dyondzo ya sayense.

Marito ya nkoka: Matimba ya le xikarhi ka timolekhuli, ku tsala, ku tsala-ku-dyondza, ku dyondzisa hi ku tsala ngopfu, Sayense ya Miri, dyondzo ya sayense, ririmi ra sayense, dyondzo ya tikhemikhali, ririmi ro dyondza na ku dyondzisa, ku tsala ku tsemakanya kharikhulamu

ABBREVIATIONS AND ACRONYMS

ANCOVA:	Analysis of Covariance
ANOVA:	Analysis of Variance
BICS:	Basic Interpersonal Communication Skills
CALP :	Cognitive Academic Language Proficiency
CAPS :	Curriculum and Assessment Policy Statement
CPR:	Calibrated Peer Review
COVID-19:	Coronavirus Disease of 2019
DBE:	Department of Basic Education
DOE:	Department of Education
FET:	Further Education and Training
IMF:	Intermolecular Forces
LoLT:	Language of Learning and Teaching
NSC:	National Senior Certificate
NDP:	National Development Plan
NPC:	National Planning Commission
PBL:	Problem-Based Leaning
PIRLS:	The Progress in International Reading Literacy Study
SACMEQ:	The Southern and Eastern Africa Consortium for Monitoring Educational Quality
SGB:	School Governing Body
SIS:	Science Inquiry Skills
SMT:	School Management Team
SPS:	Science Process Skills
STEM:	Science, Technology, Engineering and Mathematics
TIMSS:	Trends in International Mathematics and Science Study
WAC:	Writing Across the Curriculum
WTL:	Writing-to-learn

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CHAPTER 1: ORIENTATION TO THE STUDY

1.1 Introduction and Background

Physical Sciences in South Africa is regarded as a difficult school subject since the majority of learners do not perform well in it. It is one of the STEM subjects (Science, Technology, Engineering and Mathematics) that enable development of the knowledge and skills necessary to drive economic growth and development (McCarthy & Bernstein, 2011). What makes the subject even more important is that the majority of careers that contribute to economic growth, such as science, engineering, health, information communication technology (ICT), and architecture, require that learners obtain good marks in the subject (Naidoo & Paideya, 2015).

One of South Africa's educational goals in the National Development Plan is to increase the number of learners who pass Physical Sciences in Grade 12. The National Development Plan emphasises that science and technology are key to development and therefore the country proposes a target of 450 000 learners being eligible for bachelor's programmes in Mathematics and Science by the year 2030 (National Planning Commission [NPC], 2012). For this reason, the country has emphasised the centrality of mathematics and science as part of its human development strategy for South Africa.

Despite these aspirations, there has been little improvement regarding academic performance in science subjects, particularly Physical Sciences. Table 1.1 below presents the National pass rate for Grade 12 Physical Sciences in the National Senior Certificate (NSC) from 2015 to 2019.

Table 1.1

NSC Physical Sciences Performance: 2015-2019

Year	Number wrote	Number achieved at 30% and above	% achieved at 30% and above	Number achieved at 40% and above	% achieved at 40% and above
2015	193 189	113 121	58.6	69 699	31.1
2016	192 710	119 467	62.0	76 068	39.5
2017	179 561	116 862	65.1	75 736	42.2
2018	172 319	127 919	74.2	84 002	48.7
2019	164478	124237	75.5	85035	51.7

Although there has been a slight improvement in the number of learners who pass Physical Sciences from the 2015 to 2019 academic years with 30% and above, South African universities will only consider learners who have passed Physical Sciences with a minimum of 40% and above for admission into science-related undergraduate qualifications. In 2019 only 85035 (51.7%) of the learners passed Physical Sciences with 40% and above. The table also shows that there has been a decline in the number of learners who majored in Physical Sciences from 193189 in 2015 to 164478 in the 2019 academic year. This is a concern considering the NDP 2030 target of 450 000 learners who will be eligible for a bachelor's programme in mathematics and science by 2030 (NPC, 2012, p. 305).

Challenges resulting in poor performance in science-related subjects are a worldwide concern (Kirui & Kaluyu, 2018) as revealed by various research studies such as in the United States of America (USA) where many students struggle with developing an integrated understanding of science due to its abstract and unobservable nature (Ryoo, Toutkoushian & Bedell, 2018). In Africa, poor performance in science is often attributed to technical science language and problem-solving skills (Kirui & Kaluyu, 2018). It has been reported in numerous South African schools and universities that the language of learning and teaching (LoLT) is a contributory factor to poor performance (Probyn, 2016, Oyoo, 2017; Msimanga & Lelliott, 2014; Setati, 2011; Charamba, 2017). The Department of Basic Education (2014a) further contend that a plethora of studies and surveys from different organisations such as the Annual National Assessment (ANA), the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ), the Progress in International Reading

Literacy Study (PIRLS), the Trends in International Mathematics and Science Study (TIMSS), and the National Senior Certificate (NSC) provide abundant evidence in this regard. English, which is the language of learning and teaching (LoLT) in the majority of schools in South Africa, is cited in many studies as a barrier to learning. Language difficulties do not only impact English as a subject but encroach on content subjects, resulting in dismal results.

In 2014, the DBE published a document on teaching English across the curriculum to improve the status of the language of learning and teaching (LoLT) in South African schools. The DBE states in the document that:

> Language is a tool for conceptualising content and knowledge and expressing oneself accordingly in a rational, "academic" style, based on subject-specific conventions and registers. In every institution of learning, the language of learning and teaching, LoLT, should be developed, not only by the English teacher but by all teachers while disseminating knowledge (DBE, 2014b).

The argument raised above show that teachers of English should not be solely responsible for reducing the language gap, but that content subject teachers also have a responsibility in this regard as language is a tool for conceptualising content knowledge in their subject areas. To affirm that language is a tool for understanding concepts in subject areas, the DBE further states in diagnostic reports (examination reports) that content subject teachers need to ensure that terminology and definitions in each subject are clearly understood. There is thus a need for greater emphasis on language competence and comprehension and these skills must be developed in each classroom, in all subjects (DBE, 2018).

These language concerns indicate that there is a need for the development of LoLT in South Africa, and more concerted efforts need to be made to address the situation. However, anecdotal evidence suggests that few, if any, science teachers in South Africa have developed the heuristics for using language as a tool for ease of access in comprehension and conceptual understanding. It is against this background that I embarked on a study to investigate the use of language as a tool in teaching in science education, particularly writing, since learners are expected to demonstrate their competence in all subjects through writing.

Ernst, Hodge and Schultz (2015) define writing as “the cognitive, emotional, collaborative, and physical task of written communication”. Writing plays an important role in content subjects like Physical Sciences in supporting learning and comprehension as well as promoting critical thinking (Mason, et al., 2014). The literature on writing indicates that meaningful self-directed learning is encouraged when learners are asked to explain, reflect and elaborate through writing in science classes (Schultz & Gere, 2015). What makes writing regarded as learning is the process involved when learners write; they are expected to search for ideas, organise information, and check and revise information through which thinking takes place (Klein & Boscolo, 2016). Language teachers and researchers agree that writing has the potential to facilitate learner understanding, critical thinking and construction of knowledge (Klein, 2000). Writing activities that encourage learners to communicate their understanding of concepts should therefore be encouraged.

Writing in the science classroom is something that happens often even though it is ignored by many science teachers (Wellington & Osborne, 2001). The kind of writing done in science class includes learners copying notes from the board, writing up experiments, drawing and labelling diagrams, drawing graphs and charts, writing experimental reports, and summarising and explaining ideas. However, most of the writing tasks are of lower order thinking and do not encourage higher-order thinking and reflection (Wellington & Osborne, 2001; Rivard, 1994). In the context of this study, an attempt is made to understand whether writing can be used to enhance the understanding of science concepts by giving learners short informal and also extended writing tasks to elicit understanding.

A long-standing concern about writing and learning in science education was sparked by my experience as a Physical Science teacher in a rural school in South Africa. I realised that when learners are taught in class, they seem to be engaged and to participate in discussions as if they understood what is being said or taught. However, when given formative assessment tasks where they are required to respond through writing, to my astonishment the enthusiasm that is observed in class evaporates and the content is absent in what they write. For many science learners, it is a challenge to put their thoughts into writing even though they can speak and discuss science concepts. It became clear that proficiency in language especially in the language of instruction was crucial. I therefore decided to interrogate the issue of writing to establish a nuanced understanding of how learners engage in writing in science class and to seek possible ways in which writing can be incorporated to promote meaningful learning and to enhance academic performance.

Another aspect that sparked my curiosity as I embarked on this journey on writing in science education was to look at the influence of language on gender and science performance. Although a plethora of research has always advocated that females have outperform males in language proficiency, recent research suggests that a more complex view is necessary as this may depend on the type of language activities learners are engaged in (Wucherer & Reiterer, 2016). I was tempted to investigate the effects of writing in science education in relation to gender differences. The 2018 World Economic Forum's Global Gender Gap Report revealed that although more females participate in education, they are less likely to obtain degrees in STEM disciplines. In South Africa, more inclusive pedagogies in the teaching of science are necessary to encourage more females to engage in science.

One of the difficulties learners struggle with are questions requiring extended writing explanations. The Department of Basic Education (DBE) diagnostic reports on the Grade 12 National Senior Certificate (NSC) examinations revealed that many learners in Physical Sciences, including high performing learners, could not express themselves clearly in questions that required explanations (DBE, 2012; DBE, 2013; DBE, 2014b; DBE, 2015; DBE, 2016; DBE, 2017; DBE, 2018). These types of questions, which are mainly higher-order questions, were poorly answered by the majority of learners. Examples of such questions are 3.2 and 3.3 extracted from the 2019 NSC Physical Sciences exam paper shown in Figure 1.1 below:

Figure 1.1:

An exemplar of question items extracted from DBE (2019b)

QUESTION 3 (Start on a new page.)

The boiling points of five organic compounds (**P**, **Q**, **R**, **S** and **T**) are studied.

COMPOUND	IUPAC NAME
P	Pentanal
Q	2,2-dimethylbutane
R	3-methylpentane
S	Hexane
T	Pentan-1-ol

3.1 Define the term *boiling point*. (2)

The boiling points of compounds **Q**, **R** and **S** are compared.

3.2 Give a reason why this is a fair comparison. (1)

The boiling points of **Q**, **R** and **S** are given below (NOT necessarily in the correct order).

55 °C	49,7 °C	68 °C

3.3 Which ONE of the three boiling points is most likely the boiling point of compound **R**? Explain the answer. (4)

The majority of learners found it difficult to answer questions 3.2 and 3.3 as they require written scientific explanations. These types of questions appear in all Physical Sciences topics and account for about 15% of the question paper. The reports also indicate that many candidates still lack an understanding of the basic concepts, for example question 3.1. Although these questions are recall types of questions, they still require learners to have both comprehension and writing ability. The focus of this study was on how learners engage with questions requiring an understanding of basic concepts plus a written explanation.

Writing is associated with critical and creative thinking since learners are forced to think about what they are writing. Defazio et al., (2010) agree that effective writing is a skill grounded in the cognitive domain and involves learning, comprehension, application and the synthesis of new knowledge. Writing encompasses creative inspiration, problem-solving, reflection and revision, all of which results in an authentic writing product. In Singapore, one of the countries with top results in TIMSS, learning does not only focus on mastery of content knowledge but also on learners' ability to critically understand information and generate ideas from their understanding (Bhaw & Kriek, 2020). Writing tasks that are carefully designed to encourage learners to think on paper can provide an opportunity to develop critical thinking (Cavdar & Doe, 2012), and this is what this study seeks to achieve.

The study consequently seeks to investigate if writing-to-learn strategies implemented in science classes can be effective in promoting thinking and helping learners to understand and learn science content. Writing-to-learn as a teaching strategy is a process in which teachers order and represent learner experiences to make meaning of concepts through written language which helps learners shape meaning, reach deeper understanding, and develop a stronger ability to reason through evidence (Nurnberg, 2017).

To unpack writing-to-learn strategies effortlessly as described by Nurnberg (2017), one needs to take note of the three purposes of writing in education. The first purpose, which is mainly practised in the English classroom, is to teach learners to communicate well through writing. This type of writing focuses on the technical aspects of writing such as spelling and grammar. The second purpose of writing is basically what happens in examinations and tests, namely to assess learner understanding of content across all subjects, and this can be formative or summative. The third purpose, which is not popular amongst teachers, is writing for thinking and learning about the particular subject matter and is termed writing-to-learn (Nurnberg, 2017). This study focuses on the third purpose of writing which is about how teachers and learners can use writing in Physical Sciences to optimise its effects on learning.

One of the Physical Sciences topics requiring learners to explain concepts and therefore requiring proficiency in writing is intermolecular forces (Ogden, 2017). This topic, which is taught in Grades 11 and 12 in South Africa, requires learners to understand types of intermolecular forces, and to explain the physical properties of simple molecular solids, liquids and gases (Cooper, Williams and Underwood (2015). Intermolecular forces is considered one of the important topics in chemistry as it facilitates understanding of chemistry by providing a mechanism for how and why molecules interact. Learners often confuse the energy associated with intermolecular forces with the energy necessary to break bonds (Barbosa et al., 2015).

Further, Cooper, et al., (2015) agree that although the topic of intermolecular forces is important in our lives and significant in explaining the attraction between particulate matter as well as numerous phenomena in our lives such as viscosity, solubility, drug interactions, and the dyeing of fibres, the topic is often misunderstood by the majority of learners. Difficulties experienced in understanding the topic have led to numerous research studies being conducted about different methods of teaching it including the use of educational games, computer investigations and laboratory experiments (Johnson, Javner & Hackel, 2017). However, the topic requires learners to explain concepts through writing and few studies have been conducted on implementing writing-to-learn strategies in teaching this topic.

Rompayom, et al. (2011) in a study on learner understanding of intermolecular forces, conducted to assess Grade 10 learners on the topic, found that an effective way to teach it is to use open-ended questions requiring learners to do extensive writing. Open-ended questions require learners to be proficient writers since they are required to think through writing. In the case of this study, the focus was on questions requiring extended explanations and questions requiring learners to define concepts.

In the South African Physical Sciences curriculum, learners are expected to predict and explain the types and strength of intermolecular forces in organic molecules with a special focus on chain length, structural isomerism and physical properties. Most learners find it difficult to explain intermolecular forces concepts from the context of the physical properties. The inherent teaching and learning characteristics of the topic is that learners are required to do a lot of expository and argumentation writing that demands higher-order thinking skills.

1.2 Research Problem

The South African National Senior Certificate (NCS) has been characterised by poor performance in Physical Science (Bhawa & Kriek, 2020; Probyn, 2019; Charamba, 2017). One of the contributing factors to poor performance is associated with the LoLT (Charamba, 2017; Oyoo, 2017). The fact that Grade 12 learners in South Africa struggle to express themselves in questions requiring written explanations and basic concepts shows that there is a need to investigate how writing pedagogies can help learners to improve conceptual understanding for improved performance.

Writing as an important skill in schools in South Africa still needs to be developed to prepare secondary school learners for post-school education. Since very few teachers have the skills or techniques for doing so, the implementation of writing-to-learn strategies in the South African context would be beneficial in the education system. A plethora of research studies shows that inadequate academic writing abilities among secondary and tertiary science students pose a challenge, particularly in Africa where the majority of students are English second language students (Du Plessis, 2012).

Writing-to-learn strategies can be described as useful teaching strategies that help learners shape, describe, and conceptualise knowledge in content areas by engaging in writing activities (Tucel, 2016). Previous research on writing-to-learn pedagogies has proved that engaging learners in writing can help learners to synthesise scientific information and formulate scientific arguments or explanations about concepts (Nurnberg, 2017). Since writing requires learners to engage in the process of organising their thinking, evaluating and supplying evidence, and drawing connections from concepts (Nurnburg, 2017), the implementation of writing pedagogies will be beneficial in science class where learners are struggling to express themselves through scientific writing.

It is against this backdrop that the research problem of this study was to determine the relative efficacy of writing-to-learn pedagogies in the teaching of intermolecular forces for improved learner achievement. The problem was addressed by asking the following question:

- How will the performance between learners exposed to writing-to-learn strategies and those exposed to traditional teaching approaches differ with respect to:
    - overall academic achievement in intermolecular forces
    - how learners define and explain basic concepts and intermolecular forces, and
    - how learners answer questions requiring science inquiry skills.

The question was broken down into the following sub-questions:

- How will the academic performance between learners exposed to writing-to-learn pedagogies and those exposed to traditional pedagogies differ concerning overall academic achievement in intermolecular forces, science inquiry skills, and how students define and explain basic concepts in the topic of intermolecular forces?
- What will the achievement scores of girls compared to boys in the post-test be after they engaged in writing-to-learn pedagogies and traditional teaching methods?
- What are the learners' and teachers' views on the features of writing-to-learn and traditional teaching approaches?

Four null hypotheses were formulated from the first two research questions:

- $H_0 1$: There will be no significant difference in performances between the learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning overall academic achievement in the topic of intermolecular forces.
- $H_0 2$: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners define and explain science concepts in the topic of intermolecular forces.
- $H_0 3$: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to

traditional pedagogies concerning how learners respond to questions requiring intermolecular forces science inquiry skills.

- $H_0$4: There will be no significant differences in achievement between boys and girls in the post-test for the experimental group and the control group after they have been engaged in writing-to-learn strategies in the topic of intermolecular forces.

1.3 Aims and Objectives of the Study

The broad aim of this study was to explore the efficacy of writing-to-lean strategies in facilitating learner achievement in the topic of intermolecular forces. The following sub-aims emanated from the broad aim of the study:

- To investigate if there will be any significant differences in academic performance between learners who are engaged in writing-to-learn strategies and those exposed to traditional teaching approaches regarding academic achievement, science inquiry skills, and how learners define and explain basic concepts in the topic of intermolecular forces in a pre-test and a post-test.
- To examine the differences in academic performance in the pre-test and post-test, if any, between boys and girls in both the experimental and control group after the implementation of writing-to-learn strategies.
- To collect qualitative data through interviews and focus group interviews on teachers' and learners' views regarding their experiences on writing-to-learn strategies in the teaching and learning of intermolecular forces.

1.4 The Significance of the Study

In 2012, the Minister of Basic Education appointed a task team to investigate the implementation of the MST (maths, science and technology) strategies. The team revealed that few provinces have clear, comprehensive and aligned MST strategies. Most provincial strategies have recently been drafted and have not permeated the provincial education systems in districts and schools. While all strategies have clear goals, many lacks sufficient detail in respect of intended actions, scale, timelines and budgets to facilitate action, management and monitoring (DBE, 2012). These strategies have not yielded any positive results towards achieving the NDP goals.

The point of departure here is that a lot still need to be done to improve the quality of teaching and learning of Physical Sciences in order to attract more learners to the subject. Both the government and private sector invested a lot of financial resources with the aim of improving the quality of teaching and learning in these subjects. However, the focus has always been on resources, including human resources. Less attention has been paid on the main stakeholder, namely the learner. It is imperative to investigate alternative innovative teaching strategies for teaching Physical Sciences with the aim of suggesting the appropriate learning and teaching strategies to address such challenges. If new strategies are implemented it will be easier to investigate appropriate intervention strategies that can assist learners to achieve better results in the subject.

Engaging learners in writing through writing-to-learn strategies will assist in the mitigation of the challenge identified by the Department of Basic Education in the diagnostic reports (2012-2018) where it was revealed that the majority of candidates in Physical Sciences could not express themselves in questions that required explanations and conceptual understanding. The topic of intermolecular forces was identified for writing-to-learn strategies because it is a topic that contains many important concepts that need to be defined, and learners need this knowledge to facilitate understanding of organic molecules in Grade 12. Cooper et al. (2015) attest that having learners write about their understanding of intermolecular forces is important as this provides teachers with useful insight into learner thinking. The use of models and experiments to teach chemistry is therefore as important as teaching science discipline through writing pedagogies.

1.5. Context of the Study

This research was conducted in Mpumalanga Province in the Nkangala Education District. The schools involved in the study are public secondary schools situated in the rural area in this district in South Africa. The figure below shows a map of the Nkangala district and surrounding areas in South Africa.

Figure 1.2

Nkangala district and surrounding areas (extracted from google maps)

The selected schools were situated in KwaMhlanga of the Nkangala Education district. KwaMhlanga is a rural town situated about 70km from Pretoria in Mpumalanga which is often referred to as the hometown of the Ndebele tribe. The majority of learners in these schools are mainly black Africans and the everyday language for communication for the majority of them is isiNdebele with a few of the learners speaking Sepedi as the town is close to the border of the Limpopo Province which is home to the mainly Sepedi speaking population. The schools offer isiNdebele and Sepedi as home languages and English is offered as a first additional language (FAL) or second language and is the medium of instruction for all content subjects.

The majority of learners in the participating schools come from low to medium-income families and rely on the schools' feeding schemes for their lunch. Most of the learners' parents work in Pretoria as labourers with a small percentage of parents working as civil servants. This means that many of the learners have to look after their siblings because their parents leave in the early morning for work and come back in the evening; they have to travel to Pretoria which is about 70km from their homes. The learners do not have enough time for independent study as they are expected to do the chores supposed to be done by their parents.

1.6 Definitions of Concepts

1.6.1 Writing-to-learn

Writing-to-learn are teaching strategies where learners complete informal, short, and exploratory writing activities designed to enhance thinking skills to explore ideas, discover possibilities, and clarify their own thoughts (Hougen, 2015). In the context of this study this refers to engaging learners in writing tasks such as assignments, short in-class writing activities and summaries at the end of the class.

1.6.2 Writing

Ernst, Hodge, and Schultz (2015) define writing as,

> the cognitive, emotional, collaborative, and physical task of written communication. Writing is a complex, multi-faceted cognitive function that incorporates aspects of social and cultural perspectives. It involves artistic, political, spiritual, and self-expressive purposes. It is also an ‘indispensable’ tool for learning.

Writing in the context of this study refers to learners being deliberately engaged in writing activities for the purpose of learning intermolecular forces concepts.

1.6.3 Intermolecular forces

According to Everything Science (2012),

> intermolecular forces are weak forces of attraction between molecules or between atoms of noble gases. Intermolecular forces allow us to determine which substances are likely to dissolve into which other substances and what the melting and boiling points of these substances are. Without intermolecular forces holding molecules together, we would not exist.

1.6.4 Language of Learning and Teaching (LoLT)

The Department of Basic Education (2010) defines the language of learning and teaching as the language medium through which learning and teaching, including assessment, takes place. LoLT is the medium used to learn and teach content subjects such as physical sciences, mathematics and history. English and Afrikaans are the languages of instruction for content subjects in South Africa.

1.7 Chapter Outline

The report for this study comprises five chapters. Chapter 1 introduces the topic under discussion, the research problem, the aims and objectives of the study, the significance of the study, and the demarcation of the study. Chapter 2 is dedicated to the literature review and the theoretical underpinnings for the study. Chapter 3 discusses the research design and methodology of the study. Chapter 4 discusses the data presentation, interpretation, and analysis. This includes transcripts from the audio recordings of the interviews, focus group interviews, and the results of the pre- and post-test. Lastly, Chapter 5 discusses conclusions and recommendations and offers suggestions for possible further research.

1.8 Conclusion

This chapter outlined the background and orientation of the study. The research problem, significance of the study, sampling procedures and limitations were also discussed. For clarity, definitions of key concepts used in the study were included in this chapter. Lastly, the chapter outline for the study was clarified. The next chapter looks into the theoretical underpinnings of the study including a literature review on writing-to-learn strategies in science education.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

To place this study in perspective, a literature survey was conducted to present issues on language in science education in the South African context and how these issues affect how learners learn Physical Science. The chapter then proceeds to explain what writing-to-learn entails, and how writing-to-learn strategies link to the teaching and learning of intermolecular forces as a topic. The chapter also discusses issues of gender in science education and how these issues can be mitigated through writing-to-learn strategies. Lastly, the chapter offers the theoretical framework for the study.

2.2 South African Linguistic Context and Challenges

In South Africa, the LoLT has not received sufficient attention as a factor that denies meaningful access to education even though South Africa is a linguistically diverse country with eleven official languages (Lafon, 2009). Regardless of South Africa's legacy of multilingualism, many of the indigenous African languages have not been put to significant use for socio-economic development (Manyike & Lemmer, 2014). English remains the language of higher education, commerce and government as well as the medium of instruction for the majority of secondary school learners (Makoe & McKinney, 2014). The table below from Statistics South Africa (2017) shows the home language distribution in South Africa.

Table 2.1

Home language distribution in South Africa (Statistics SA, 2018)

Language	Percentage (%)
Afrikaans	12.1
English	8.1
IsiNdebele	1.6
Isixhosa	14.8
Isizulu	25.3
Sepedi	10.1
Sesotho	7.9
Setswana	9.1
Siswati	2.8
Tshivenda	2.5
Xitsonga	3.6
Other	1.9
Khoi, Nama and San Languages	0.1

Table 2.1 above shows that English is the home language to only 8.1% of South Africa's population; however, it is the language of instruction to 80% of the learner population in secondary schools (DBE, 2010). Research shows that language plays a crucial role in learning and proficiency in language contributes to academic success (Cummins, Mirza & Stille, 2012). Nevertheless, for many learners in South Africa, the challenge is twofold: first learning a second language, which is predominantly English, and second being expected to use the same language, which they have not yet mastered, to learn academic subjects like Physical Sciences (Charamba, 2017).

For many decades, the issue of the language of instruction in South Africa has been highly politicised. By the 1970s, during the apartheid era, English and Afrikaans were recognised as languages of instruction on a 50/50 basis, and African languages were recognised as non-examination languages (Manyike & Lemmer, 2014). This adoption of English and Afrikaans as languages of instruction on a 50/50 basis led to the Soweto uprising in 1976 when students protested against Afrikaans as a medium of instruction (Hlongwane, 2007). After 1994, the South African language policy recognised 11 official languages of which nine were African indigenous languages (Department of Arts and Culture [DAC], 2003). Despite the introduction of the policy, English is still positioned as the language of power and the preferred language of instruction for the majority of black learners in South Africa (Setati, 2011). Yet, the challenges of ensuring equality in South Africa have been neglected to meet the needs of black learners who are using English as the language of instruction.

In 2014 a ministerial task team was set up to look into the challenges in the implementation of the National Senior Certificate (NSC) since its introduction in 2005 which sparked a plethora of challenges. The task team identified language of instruction as one of the central factors for poor learner performance in South Africa (DBE, 2014a). In addition to the ministerial task team findings, examination reports from previous years pointed to language as a central factor for poor performance in the Grade 12 NSC. For instance, the 2015 examination report identified the following challenges associated with the language of instruction:

> There is a strong correlation between the reading skills of candidates and their inability to decode the requirements of a question. All the subject reports in this publication indicate that the poor language skills of numerous candidates are a major reason for under-achievement. This adversely affects the ability of those candidates to interpret questions and source material accurately and to frame appropriate responses to questions (DBE, 2015).

As indicated in the findings from the extract above, the diagnostic examination reports showed that learners lack the linguistic academic skills necessary for learning content subjects. If learners struggle with LoLT across all topics or subjects, they would likely find it challenging to study academically demanding subjects like Physical Sciences. One of the most critical aspects of language is writing, and all learners are expected to respond to questions through writing. The 2019 examination report as illustrated in the extract below recommends that informal writing be prescribed in the curriculum and become part of everyday classroom;

> Informal writing must be taught as per the CAPS prescripts. Learners writing skills will improve if informal writing activities become part of classroom and homework activities. A large percentage of candidates displayed a limited understanding of subject matter and specifically complicated topics. (DBE, 2019, p. 29).

In Physical Sciences the challenge in writing is aggravated by the fact that the subject have technical terms that rarely occur in learners' everyday interactions such as force, substance, mass, salt, etc which have different scientific meanings. The informal writing tasks that are referred to in the 2019 report form the basis of this study, referred to as writing-to-learn activities, which are discussed in detail in the upcoming sections of this chapter.

2.3 Writing-to-Learn

Many teachers think that incorporating writing in their classrooms involves engaging learners in formal high-stakes writing assignments which requires writing grammatical accurate products and error-free spelling (Atasoy & Kucuk, 2020). However, there is another type of writing which is informal, exploratory, and often ungraded where learners use writing to explore ideas, discover possibilities and their own thoughts as they engage in science concepts (Fry & Villagomez, 2012). This type of writing is referred to as writing-to-learn. Writing-to-learn activities as described by the DBE (2014), are brief and informal writing tasks designed to enhance creative and critical thinking skills through key concepts and ideas. Thus, the primary purpose of writing-to-learn strategies is to improve thinking and learning about subject concepts (McKenna,1991).

Writing-to-learn activities make the subject or topic clear to learners as they reason through it in writing and is a pedagogical approach that uses writing to facilitate learning (Fry and Villagomez 2012). However, writing-to-learn activities cannot be compared with traditional writing assignments in chemistry such as laboratory reports or essay writing since they prompt students to engage deeply with specific concepts through writing (Moon, et al., 2018). One of the challenges that learners are grappling with in science class is understanding basic concepts. Writing-to-learn strategies can be used as a mechanism to practice and improve science literacy skills, serving as a means for thinking and reflection, which is likely to promote students' efforts in transforming knowledge (Hohenshell, 2004).

To incorporate writing-to-learn as a pedagogical approach, teachers need to use a wide variety of writing activities in content area classes with the dual aim of supporting content knowledge acquisition and writing ability (Wright et al., 2019). In the topic under investigation, writing-to-learn activities can be used as a learning strategy to teach core concepts such as hydrogen bonds, dipole-dipole, and London forces. These strategies can be illuminative as learners engage in writing that stimulates their thinking skills, requiring them to explain the concepts. In addition, implementation of writing-to-learn strategies will also allow learners enough time to practice how to write extended explanations that promote reasoning capacity.

Writing-to-learn therefore cannot be taught by teachers of English, but should be taught by subject matter content teachers who are in the best position to teach as they are the subject matter experts in their disciplines (Hougen, 2015). In the case of science disciplines, science teachers are better placed and knowledgeable to give examples of subject-specific writing-to-learn and provide feedback to learners about content-based writing assignments. Hougen (2015) further elaborates that writing-to-learn means using writing as a tool to promote content learning; when students write, they think on paper, and therefore content teachers should assign writing activities to help students learn the subject matter, clarify and organise their thoughts, and improve retention of content.

Jager (1994) describes two categories in writing-to-learn. “Informal” writing tasks are short quick written assignments that are used every day both to spur learners’ comprehension about the subject matter and to assess their comprehension. For example, the teacher can ask learners in the chemistry class to write about what they have learned about molecular size and how it affects the melting point of substances with the same homologous series. These informal writing-to-learn tasks tend to involve fairly compact and quick methods of expressing ideas and demonstrating knowledge. Teachers assess informal writing primarily for its content, rather than its form or style.

‘Formal’ writing tasks on the other hand are a process in which learners go through the drafting and revision necessary for creating a well-developed written product (Jager, 1994). For example, teachers may ask high school chemistry learners to complete a structured lab report that lays out hypothesis, procedures, data, and conclusions. This may also include writing assignments on a particular topic. This study adopts both informal and formal writing-to-learn tasks to ensure that learners intentionally engage in a sufficient amount of writing beyond what is done in traditional science lessons.

One of the strategies related to WTL is writing intensive teaching (WIT). Based on a model developed by Woolley (2014) from Wilson College, USA:

> Writing-intensive teaching is defined as a strategy that systematically integrates the teaching of writing into the work of the discipline. It provides for a variety of assignments that introduce the nature of writing in the discipline and help learners to learn such elements as the nature of proof, persuasion, and argumentation in the field; the proper information and sources; and forms and formats appropriate to the discipline. Writing-intensive teaching offers instruction and support needed to familiarise students with the writing processes in various fields (Woolley, 2014).

There is a correlation between WTL and WIT as there is an emphasis on writing in the discipline although WTL also emphasises that as learners write, they should also be learning the subject. Even though there is an inclusion of writing assignments in this study, the purpose differs from what is emphasised by WIT, namely focus on how students write. In WTL the focus is on using the writing assignments to learn concepts in science rather than focusing on how the text is composed.

2.3.1 The benefits of writing in chemistry education

The ability to communicate ideas through writing is one of the most important skills science learners need as they are often expected to convey complex scientific ideas. There is extensive literature on the benefits of teaching writing in science to improve academic performance (Prain, 2006; Schmeiser, 2017). Van Staden, (2010) agrees with the above statements that when writing, learners reveal how they reason and think as their understanding emerges, thereby allowing the teacher to make a judgment call on the level of the student's knowledge and ability to apply acquired scientific knowledge. Writing as an integrated component in the science class thus has powerful potential to facilitate critical and creative thinking but only if learners connect new ideas to prior knowledge rather than reciting information, as often happens in the traditional science class (Koffman, Kreutz & Trenbath, 2017).

When learners reason through writing, this may translate into the construction of new ideas and contribute to good academic performance because when text is composed, there is consensus that it is neither an easy nor a spontaneous activity but requires conscious mental effort (Yayie, 2016). In particular, writing in the discipline of science requires even deeper thinking skills because science attempts to explain natural phenomena through observation, rational argument, experimental evidence and scepticism (Tala & Vesterinen, 2015). Writing about science topics helps learners organise their thoughts and questions; it allows them to be active participants in the learning process.

The chemistry profession has always promoted writing as one of the most important skills that prospective chemists should acquire (Deng, Kelly & Xiao, 2019). However, the notion of developing scientific ideas through writing in chemistry is often neglected by many chemistry teachers (Schmidt-McCormack, et al., 2019). For learners to learn chemistry, there is a need to develop their understanding of concepts (Schmidt, Kaufmann & Treagust, 2009), and writing-to-learn as a strategy is ideal for the development of conceptual understanding. Despite the increase in research on the effectiveness of writing strategies in different disciplines, its acceptance in STEM subjects has always been questionable (Finkenstaedt-Quinn, et al., 2018).

A study conducted by Shibley and Milakofsky (2001) proved that incorporating writing instruction in chemistry is rewarding, and they identified three benefits. Firstly, the authors indicate that writing in chemistry engages learners in learner-centred activities, which helps them to become active participants in their learning and to realise that learning is self-directed requiring mental effort. Secondly, as Shibley and Milakofsky (2001) contend, writing activities enhance learners' content knowledge as they discover how chemistry knowledge is applied in different contexts. Thirdly, the authors indicate that as learners engage in writing in the chemistry class they are offered an opportunity to practice writing in their discipline. This differs from writing in traditional English classrooms; in science class they practise what real scientists do, namely write and publish papers (Shibley & Milakofsky, 2001).

As indicated above, the benefits of writing in chemistry are associated with learner-centeredness, improvement of learners' content knowledge, learning to write in the discipline and consequently practising what real scientists do in their daily lives which results in the holistic development of the learner rather than only focusing on knowledge development.

In another study conducted by Cox et al. (2018) on using writing assignments as an intervention to strengthen acid−base content knowledge, the authors noted that writing assignments can promote problem-solving. A calibrated peer review (CPR) strategy was used to implement writing assignments that strongly emphasise quality. The study proved beneficial as the writing assignments aided in closing the gap in learners' abilities between honours and introductory courses meaning that it translated into good academic performance. Peer assessment is identified as one of the components in writing-to-learn strategies and this assessment strategy is beneficial because as learners engage in grading their peers; they are actually in the process of learning from each other's' writing which translates into more meaningful learning.

Jacobs, Dalal and Dawson (2015) in a study that incorporates writing in chemistry stress that engaging learners in this way is widely perceived as forcing learners to think qualitatively and effectively about problems and therefore promoting their understanding and critical thinking. Writing, when practised appropriately, allows learners to grow from dualistic thinkers to acknowledging that scientific knowledge is tentative and therefore subject to change. One of the challenges in teaching chemistry is to move learners from thinking that science is just a collection of memorised facts to a deeper understanding of scientific thinking (Taber, 2015). In the South African context, encouraging learners to be deep thinkers is important as the challenge in the current implementation of the science curriculum is focused on preparing learners to answer questions rather than emphasising understanding. When learners are engaged in writing, they are allowed to think deeper about what they are writing which will translate into deeper understanding.

Although research shows that writing is an effective tool to enhance knowledge acquisition and cognitive development in science disciplines, writing strategies are still not widely implemented in science education (Rivard, 1994). Rivard's insightful review on writing in science disciplines identified several key issues that need to be taken into consideration for the widespread implementation of writing in these disciplines. First, different types of writing tasks result in different kinds of learning, and therefore Rivard suggests that science teachers need to determine the links between writing and both critical thinking and conceptual change. Second, writing practices need to be studied in context, rather than in isolation, and it is important to examine the interactions among specific learning objectives, personal characteristics (e.g. prior knowledge), models of instruction (coverage vs conceptual understanding), and specific writing tasks. Third, the underlying metacognitive processes necessary for learning specific types of knowledge (declarative, procedural, and conditional) must also be identified and targeted by corresponding WTL strategies. Lastly, Rivard (1994) suggests that higher-order thinking involves restructuring knowledge, and therefore it is imperative to determine what types of writing activities evoke knowledge transformation.

In closing, Rivard suggests that there is a need to reconceptualise the importance of writing in science education since knowledge is no longer understood as simply the acquisition of knowledge but as a process of constructing understanding and meaning. Reconceptualisation as suggested by Rivard means that there is a need to explore new ways of engaging learners in writing in science education. In this study that focuses on writing from an African perspective where the majority of learners do not succeed due to language barriers, the implementation of writing-to-learn encourages transformative pedagogies which are crucial for transforming marginalised African learners.

Caukin (2010) identified two main views in writing-to-learn science, namely the modernist and the postmodernist view. The modernist view is that students should learn traditional forms of science writing. It is believed that constructing meaning is inefficient which implies that science is too difficult. The postmodernist view is to critique the status quo and to develop different genres for communicating scientific findings (Caukin, 2010). The latter is relevant to this study since it believes in different genres to communicate findings. Since learners have always been struggling to communicate scientific content through writing, the challenge is likely to be associated with the types of writing activities given to students (Stewart, et al., 2016). This study seeks to focus on a variety of writing genres to encourage thinking, and these types of writing tasks are discussed in detail in the next section.

2.3.2 Developing different types of WTL activities in science class

In science class learners are generally expected to produce different types of writing. However, it is important to note that different types of writing activities serve different educational purposes, do not produce the same type of text, and in the context of science may be used differently depending on the topic (Klein, Haug & Bilfell, 2019). From a language education perspective, science teachers will need to understand different types of texts produced to develop writing activities for different purposes. The types of writing genres identified in this study are argumentative writing, expository writing and narrative writing (DBE, 2015).

Argumentative writing as the first type of writing is a process whereby learners offer different reasons or opinions to support or refute claims about a particular topic (DBE, 2015). In this type of writing, the learner is expected to provide evidence and illustrate the reasoning that supports his or her claims regarding a certain subject (Fan & Chen, 2019). Reasoning through arguments may take different forms such as trying to change the opinion of others or trying to reason collaboratively with them (Klein, et al., 2019). As already mentioned, argumentative writing as a genre is about arguing a point on a particular topic meaning that when learners write argumentatively they are expressing an opinion, but they must have background knowledge on the topic under discussion so that they can provide sound reasons and good examples.

The DBE (2015) further emphasises that the purpose of argumentative writing is to convince the reader to agree with an opinion or point. The writing is subjective and strong personal opinions are sometimes expressed. In the context of science, opinions should be based on knowledge acquired from the topic. An example of questions requiring learners to write argumentatively in intermolecular forces could be: “Fully explain why the boiling point increases from methane to pentane”. For learners to attempt this question they need to have knowledge about intermolecular forces and how molecular mass affects the boiling points of substances. They will have to convince the reader by giving sound reasons based on the knowledge they have acquired about the effects of intermolecular forces on the boiling point of substances.

Argumentative writing tasks are considered higher-order questions and require independent and analytical thinking. As elaborated by Afshar, Movassagh & Arbabi (2017), there is a strong correlation between critical thinking and argumentative writing acquisition. For instance, critical thinking is defined as “disciplined, self-directed thinking which exemplifies the perfections of thinking appropriate to a particular mode or domain of thought” (Afshar et al., 2017). In a nutshell, as Afshar and colleagues maintain, critical thinking can be considered a series of cognitive skills in which learners are expected to identify and apply issues and assumptions as well as important relationships through making inferences, evaluating evidence or authority, and deducing conclusions. Likewise, as already mentioned, critical thinking is self-directed thinking, and there is a correlation between argumentative writing and critical thinking because as learners write argumentatively they have to make inferences and give personal accounts for particular arguments.

The second type of writing is expository writing which according to Sedillo (2020) is aimed at explaining and exposing a particular point or phenomenon. In this type of writing, the learner selects information from oral, written, or electronic texts and organises it to show that he or she understands a concept (DBE, 2015). Klein and colleagues (2019) agree that in expository writing, learners give a form of a summary; they engage in a challenging activity as they need to understand the main ideas behind a theory and the connections between particular ideas. For example, if they are writing about a hydrogen bond, they will have to understand this phenomenon well and draw a mental picture of the concepts, which may pose a challenging task.

The DBE (2015) points out that the purpose of expository writing is to communicate on various topics and to give objective and balanced views. The writer usually gives a summary of the main points and suggests some way forward. An example of questions on the topic of intermolecular forces would be: "Explain the difference between intermolecular forces and intramolecular forces". The learner needs to explain that intermolecular forces are usually weak electrostatic forces found between molecules and that intramolecular forces are usually forces found within molecules; they are types of chemical bonds. Contrary to argumentative writing, this type of writing is not subjective although there might be some elements of subjectivity concerning writing type and context. These types of writing activities are evident in all topics, and the diagnostic reports indicate that learners are struggling with the definitions and explanations of basic concepts. Expository writing, therefore, attempts to address the challenge of understanding basic concepts.

The third type of writing is narrative or descriptive texts, which are types of writing where learners describe an experience, a situation, an object or a person (DBE, 2015). Descriptive writing requires learners to tell a story that describes an event or relates a personal experience. A good narrative should have convincing characters, a plot, and a theme. An example of narrative writing in science class may be a response to a question asking learners to give an account of the methods or procedures for an experiment on the effects of intermolecular forces on vapour pressure. In this case, the learner will have to give a narrative explanation of the methods. It could also be a process where learners report on what they have observed from an experiment.

2.3.3 Models of teaching writing

Writing as a product

Writing can be framed both as a process and a product. Traditional approaches to the teaching of writing merely focus on writing as a product (Yayie, 2016). In this approach to writing, teachers evaluate the written text and judge its form and content according to defined criteria. Traditionally, writing is something teachers expect learners to do in the class without giving any prior thought to the meaning of the finished product (Yayie, 2016). Writing as a product is often viewed as a traditional type of writing focused on the text itself rather than the processes involved in producing that text (Kekana, 2015). In this approach, writing is seen as a linear process of plan-write-edit and the cognitive processes involved in the development of the text is often ignored (Mahdieh, 2021).

As this approach focuses on the written text, the association between writing and thinking is not considered and therefore the critical thinking aspects associated with writing are not considered. Learner attention is merely focused on conforming to and duplicating models and, in particular, on correct language (Yayie, 2016). The approach is rooted in behaviourist theory where language is seen as a system of structurally-related elements for the coding of meaning, and the product of language learning is the mastery of elements in this system (Mahdieh, 2021).

From a chemistry education perspective, this approach does not work. The purpose of this study is to show that writing can be used as an active learning process in which learners construct chemistry knowledge through writing rather than a linear process from the product approach ideologies. In the past the teaching of writing in both high school and college was criticised for its emphasis on the finished product and neglecting the process involved in writing (Lea & Street, 1998). For this reason, when teaching writing through a product approach, writing becomes thoughtless, monotonous and non-cognitive (Williams, 2003). The drawback is that writing results in mindless copies of a particular organisational plan which will not be workable in the teaching of intermolecular forces (Eschholz, 1980). The model is often viewed as microscopic since its focus is only on the product, neglecting the cognitive process involved in writing (Kekana, 2015).

Writing as a Process

While a product-based view of writing is concerned with a text, writing as a process approach is preoccupied with the cognitive process involved in producing the text (Kekana, 2015). Unlike writing as a product approach, the process approach focuses on mental activities during the writing, encouraging learners to be creative and discovering their potential (Mahdieh, 2021). The emphasis is on the writer as an independent producer of texts, and teachers are not supposed to help learners perform the writing task (Hyland, 2003). Furthermore, the process approach articulates issues of pedagogy, which is significant in teaching intermolecular forces as the cognitive processes involved in this will assist learners in conceptualising their thoughts about concepts and principles.

In the process approach, learners get an opportunity to voice their opinions about the topic since the approach is conceptualised out of the expressionist model (Mahdieh, 2021). In the expressionist model, expressive and self-actualising writing in which students discovered ideas about themselves through free writing and brainstorming, is encouraged (Bacha, 2002). Since the process approach is expressive compared to micro-product approaches, it is an effective tool for motivating learners to practise writing, to develop a positive attitude toward writing, and to teach writing skills and language structure (Fregeau, 1999). In Physical Sciences, learners are expected to analyse and evaluate theories that are already discovered and therefore through a process approach they will be in the position to identify the gaps in the theory and formulate new theories.

Engaging learners in writing on the topic of intermolecular forces can be done by applying writing process strategies. For instance, if the teacher introduces a new concept in the pre-writing or construction stage, the learners can be provided with information that explains the concepts or can be given a writing assignment to generate more information about the topic. After the completion of the assignment, learners in the classroom can peer assess each other's assignments and the teacher can develop a rubric that learners can use for the assessment. Learners can be taken through each criterion of the rubric before they assess each other. In the classroom, learners can engage in composing short writing-to-learn activities and at the end of the class can be asked to write a summary of the learning about the topic.

As they engage in the above process, they will be engaging in learner-centred activities, and writing in this approach is a process through which students can explore and discover their thoughts (Ho, 2006). The process approach is predominantly aimed at generating meaning and assessing it at the same time. This study seeks to ensure that the purpose of writing in science is for learners to organise their thoughts and regulate their learning in the process.

In the process approach, the teacher should adopt the role of a facilitator who only intervenes when necessary (Keen, 2017). However, the responsibility of a writing teacher depends on the level of the learners' writing experience. For instance, skilled writers need less guidance than unskilled writers and, most importantly, when giving writing instruction to inexperienced writers teachers are advised to explain the composition process and the fact that writing is not a matter of getting everything right with the first attempt (Duplessis, 2012). The role of the science teacher in introducing the process approach in the topic of intermolecular forces will be to guide the learner on how to organise ideas through summaries. However, learners are not expected to copy the notes and claim that they are their own ideas; they will have to paraphrase and write in their own words. In a nutshell, they will have to attach meanings to the concepts and the teachers need to ensure that they clarify this to the learners.

2.3.4 Gender, Writing and Science Education

The relationship between gender and science performance in secondary schools has always been a matter of global attention (Oon, Cheng & Wong, 2020). Empirical findings in different countries report that boys often perform better in science-related subjects than girls (Khanyane, Mokuku & Nthathakane, 2016). A study conducted by Spaull and Makaluza (2019) on girls versus boys' performance during the period of 1995-2018, revealed that girls generally perform better than boys in different examinations such as TIMSS, SACMEQ, PIRLS and Grade 12 National Senior Certificate. However, in the Grade 12 examinations, the authors revealed that out of 13 school subjects, girls generally performed better, but boys outperformed girls in Mathematics and Physical Sciences.

Contrary to the above findings, it seems that females have more advantages concerning language proficiency. Even though there is agreement that males and females do not differ much in general intelligence, a large body of research indicates that in terms of language ability, there seems to be a difference (Reilly, Neuman & Andrews, 2019). In terms of writing ability, research shows that females tend to outperform males in many aspects of writing (Wucherer & Reiterer, 2018). The reason why girls often outperformed boys in writing fluency and text quality is because of the fluency in English proficiency as girls tend to learn a new language faster than boys (Al-Saadi, 2020). If girls are more proficient in writing, the implementation of writing-to-learn strategies may be beneficial, and this may contribute to better academic performance in Physical Sciences. Implementing writing-to-learn strategies may assist in closing the gap between male performance and female performance in STEM subjects. The writing strategies are therefore inclusive and transformative for the girl child as they will have an added advantage when used in science subjects which are often problematic for them.

2.3.5 Scientific inquiry and writing

Generally, writing-to-learn activities in science classes should be able to enhance learners' conceptual understanding and enable them to organise new information in a unified conceptual framework (Self, Widmann, & Prince, 2013). Learners are not simply expected to memorise facts but must be able to apply these facts in different contexts. As they are in the process of composing the writing activities, they should be engaging in inquiry-based learning (IBL). IBL is a form of self-directed learning where learners are expected to respond to questions using data that is provided in different formats (Gholam, 2019). In the context of school science, inquiry entails learners exploring scientific data and using the data to make observations, draw conclusions and communicate the findings (Penn, et al., 2019). In the examination format, scientific inquiry could entail analysing data provided in tables and figures to make inferences and conclusions, and this requires learners to be able to communicate through writing.

Scientific inquiry includes three elements, namely the skills of the scientific inquiry, knowledge about scientific inquiry, and an educational approach for teaching scientific inquiry (Ho Yang, et al., 2017). The third element which is an educational approach to teaching inquiry could mean implementing WTL. In the topic of intermolecular forces, applying WTL as an educational approach, entails providing learners with information about a particular investigation as demonstrated by the example below from DBE (2018) Physical Sciences question paper.

Learners conduct an experiment to investigate the effects of intermolecular forces on boiling points. They use 20 mℓ of each of the following compounds in their investigation: water, sunflower oil, nail polish remover, glycerine and methylated spirits. The results are shown in the table below:

Name of the compound	**Boiling point (°C)**
Water	93
Sunflower oil	230
Nail polish remover	56
Glycerine	290
Methylated spirits	62

From the above example, learners can be asked expository writing type of questions where they define or describe a particular concept. They could also be asked to formulate an investigative question or hypothesis which will result in expository text. It can mean that they are asked to identify a compound with the strongest intermolecular forces and give a reason for that which will result in argumentative type of writing. An example of a narrative type of question could be to ask learners to describe the method used in this experiment. From a language education perspective, science teachers need to understand different types of texts to provide learners with different question types that cover all the writing genres.

The three types of writing discussed in the previous section are all noticeable when learners are engaged in scientific inquiry activities. McBride and Colleagues (2004) on teaching IBL in secondary schools emphasise that teaching science through inquiry entails taking learners through science process skills and helping them apply these skills as they learn science concepts. The learners may be provided with data for a particular experiment and asked to state the hypothesis, investigative question, conclusions or even observations. They may also be asked to identify the variables or describe the methods for the experiment. As they engage in these IBL writing activities, questions requiring explanations and the understanding of basic concepts can be included. Therefore, learners in Physical Sciences are expected to engage in the types of writing that encourage scientific inquiry and problem-solving skills.

2.3.6 Traditional science teaching approaches versus writing-to learn

The current study views traditional teaching approaches to teaching science as common approaches that rarely engage learners in writing-to-learn activities in the classroom. Abeysekera (2020) identified two aspects that teachers should consider in teaching science. First, scientific knowledge consists of experimental observations and the theories involved in explaining these observations. Second, the process that enables the generation of scientific knowledge such as scientific inquiry and science process skills (Abeysekera, 2020). Writing-to-learn teaching strategies, which are rarely implemented in the teaching of science, are concerned with enhancing the understanding of theories that explain what has been observed in an experiment or demonstration.

One way of teaching science is through practical work. Practical activities in science teaching offer several advantages such as facilitating understanding of scientific knowledge and developing scientific inquiry and science process skills (Omilani, et al., 2019). In addition to ensuring that the teaching of science is accompanied by practical activities, writing-to-learn activities are equally important as they assist learners in structuring explanations that encourage deep conceptual learning in science (Moon, et al., 2018). Learners are expected to show their understanding of scientific knowledge through writing and these skills must be practised in science class, not in the conventional English classroom.

Another common strategy that is used to teach science is problem-based learning (PBL). PBL involves engaging learners in problem-solving where they construct new ideas allowing them to reflect on what they already know (Smith & Hung, 2017). As a teaching strategy PBL is learner-centred and uses cases, projects and experiments to engage learners in problem-solving (Abbey, Dowsett & Sullivan, 2017). In PBL the teacher needs to create a problem on a particular topic based on a real-world situation and the problem needs to be complex, ill-structured and offering different possibilities that will evoke learner thinking (Golightly & Raath, 2015).

It is important to note that for PBL to be successful, the problems must be open-ended, context-specific, and the teacher must assume the facilitator role (Belland, et al., 2019). However, for learners to be successful in PBL, they will need to create evidence-based arguments to convince their peers that their claims are valid. To engage in argumentation, they will need to use different forms of communication such as verbal, non-verbal, written and visual communication. Writing is one of the important forms of communication, and they will be expected to engage in problem-solving as they write their assessments. Therefore, as they engage in writing-to-learn activities, they will be practising argumentation which promotes problem-solving.

Other common strategy related to PBL used to teach science is discovery learning. As a strategy that emanated from the constructivist approach, discovery learning advocates for learners to discover facts and relationships by themselves by exploring and manipulating objects, wrestling with questions and controversies and performing experiments (Simamora, Saragih & Hasratuddin, 2019). As they engage in exploring ideas through discovery, they engage in meaningful learning that promotes motivation and encourages active engagement which in turn can facilitate the understanding of science concepts. (In' am & Hajar, 2017). In outlining the relationship between writing and discovery learning, Azizah (2018) points to the fact that writing is a process of discovery and learners often do not know what they will write until they start writing. For this reason, writing, as a complex skill requiring learners to engage in higher-order thinking skills, if encouraged in science class can be beneficial in ensuring that learners process science content at a deeper level.

2.3.7 Assessment for learning and writing-to-learn activities

Writing-to-learn to support learners to construct new knowledge is important but depends on teachers' understanding of the various purposes of assessment (Edens & Shields, 2015). In education, assessment serves a variety of purposes which include ascertaining learner understanding before introducing a new topic (diagnostic assessment), providing judgement about student learning at the end of the term (summative assessment) and enhancing the teaching and learning process (formative assessment) (Moeed, 2015).

For many teachers, assessment is understood from the summative assessment perspective, and this is the traditional view of assessment. This traditional view has dominated the teaching and learning space rather than the formative purpose, which is meant to enhance learning (Bruner, 2016). The challenge in the summative purpose of assessment is that it usually comes towards the end of the term and hardly serves the primary purpose of assessment which is to aid learning. Teachers need to value the formative purpose of assessment since its primary purpose is to provide learners with regular feedback, and the feedback provided to learners enable them to identify the challenges in the learning and to act upon the challenges. Paul Black and Dylan Wiliam have conducted research on formative assessment for decades and below they offer a comprehensive description of what formative assessment entails.

> Assessments become formative when the inference about a student's learning is 'elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited (Black and Wiliam 2009, p.29)

The description above indicates that writing-to-learn activities can be referred to as formative assessment activities since their purpose is to improve learning because learners reason through writing (Fry & Villagomez, 2012). Moreover, WTL activities are influenced by a variety of classroom factors (Moeed, 2015).

Incorporating writing-to-learn activities in science class entails assessing the learners' ability to integrate knowledge and skills from a variety of disciplines, and this can happen if teachers understand the principles of formative assessment which are often related to how writing-to-learn activities are implemented in the classroom. One of the critical features of formative assessment is feedback. Writing-to-learn activities are also regarded as formative assessment tasks insofar as they facilitate reflections from teachers and learners feedback. Feedback in writing-to-learn involves a dialogue with the teacher and between the learners as they analyse the actions to take and identify strategies to reduce learning gaps (Villarroel, et al., 2018). Without effective feedback, it will be difficult for learners to engage in self-assessment which helps them to clarify misconceptions in their original writing (Sedita, 2013). Another way to engage learners in plentiful, immediate and individualised feedback from fellow learners is through peer assessment. In the context of writing-to-learn, peer assessment is a process where learners assess each other's writing as they generate ideas that promote discovery and understanding (Jaafar, 2016).

2.4 Writing and the topic of Intermolecular Forces

Intermolecular forces is one of the topics covered in the secondary school Physical Sciences curriculum in South Africa. Physical Sciences is taught from Grade 10 to Grade 12 and is divided into two sections, namely Physics which is often examined as paper 1 and Chemistry which is examined as paper 2. The chemistry curriculum covers the following knowledge areas:

- Matter and materials
- Chemical systems
- Chemical change

Intermolecular forces are categorised under matter and materials which include other topics such as chemical bonds, molecular shapes, electronegativity, bond polarity, bond energy and bond length (DBE, 2011). The topic of intermolecular forces covers themes such as types of intermolecular forces, states of matter, density, kinetic energy, temperature, three phases of water and the macroscopic properties related to sub-macroscopic structures (DBE, 2011). For learners to understand the topic they need to understand that matter comes in different forms such as solids, gases and liquids. Intermolecular forces are the reason why matter exists in different forms.

In definition, "Intermolecular forces can be described as forces of attraction that occur between molecules due to the distribution of electrons within the particles. These forces are sometimes referred to as noncovalent interactions" (Bindis, 2013). The types include London dispersion (induced dipole forces), ion-induced dipole, ion-dipole, dipole-dipole and hydrogen bond.

In terms of application, the topic is useful in explaining the attraction between particulate matter as well as several phenomena in our lives such as boiling point, melting point, viscosity, solubility, drug interactions, and the dyeing of fibres (Barbosa, et al., 2015). Although the topic is often associated with chemistry, the significance of the topic goes beyond chemistry as it is also applied to general biology and molecular biology (Bruck, 2016). Numerous authors have found the concept of particulate matter and intermolecular forces is always misunderstood by learners because learners confuse the energy associated with intermolecular forces with the energy necessary to break the bonds (Barbosa, et al. 2015). Ideally, as Cooper, et al. (2015) explain, learners should be able to construct and then use the structure by first understanding that the shape and electron distribution in a molecule determine molecular polarity and then make deductions about interactions between molecules that govern both physical and chemical properties. For learners to be able to connect these ideas at a different representational level including how to make predictions about properties, can prove to be daunting and difficult.

One of the identified challenges about intermolecular forces is that it is a topic that has no problem-solving algorithms and therefore is abstract with extensive new vocabulary (Da Silva Junior, et al., 2020). For learners to understand the topic, they need to have a basic understanding of chemistry at a three-dimensional level which includes microscopic (particulate), symbolic, and macroscopic levels (Johnson, Javner, & Hackel, 2017). The macroscopic level refers to things at the visible level such as experiments or objects; learners need to understand the physical properties of matter such as boiling, melting and evaporation. The symbolic (or representational) level is about the use of letters to represent elements or chemical reactions. For instance, at a symbolic level, learners need to understand the concept of Lewis structure to have a thorough understanding of intermolecular forces (Finkenstaedt-Quinn, et al., 2018). At the microscopic or particulate level, learners need to understand the concept of atomic combinations and the reason why some molecules are polar and some non-polar.

Several educational research reports have been conducted on efforts to develop different teaching strategies and tools to help learners overcome the difficulties in learning intermolecular forces. Some of the strategies include the use of board games (Da Silva, et al., 2020), inquiry-based activities (Ogden, 2017), e-learning teaching strategies and protein-based experiments (Johnson, et al., 2017) and dual gas chromatography (Cunningham, et al., 2018). However, few studies report on the teaching of this topic through writing-to-learn strategies.

In the South African Physical Sciences curriculum, learners are expected to use knowledge of IMF to predict and explain the types and strength of intermolecular forces in various organic molecules regarding chain length, structural isomerism and physical properties. Because of the abstract nature of the topic, writing-to-learn strategies are ideal for teaching it as there are many concepts that need to be understood. If they are regularly engaged in expressive writing activities they will be forced to think about what they are writing, and their vocabulary and comprehension skills in the topic will improve.

To give an example of the challenge described above, in the topic of organic chemistry learners are expected to use knowledge of intermolecular forces to predict and explain the physical properties of different organic molecules. They might be expected to explain the effects of chain length on influencing the boiling point of different alkanes. These types of questions can prove to be difficult if not practised in class through writing, and they will only attempt answering questions that require short answers rather than questions that require extensive explanations.

Teaching chemistry through language has been known and explored for many years and there is a saying that “science without literacy is like a ship without a sail” (Markic & Childs, 2016). Cooper, et al., (2015) in their attempt to incorporate writing in the topic of IMF investigated learner thinking about intermolecular forces focusing on hydrogen bonding, dipole-dipole forces and London dispersion forces. In this study on general chemistry, college students were asked to describe their understanding of intermolecular forces in writing and to draw representations of intermolecular forces. The authors found that the learners’ drawings on representations of intermolecular forces show they did not have a stable coherent understanding of the forces as interactions between molecules. Their findings are an indication that learners struggle to connect representation at a symbolic level and representation at a microscopic level.

Engaging them in activities where they can write about their understanding of the concept will facilitate their understanding of the topic of intermolecular forces. In a study which investigated the teaching of Lewis structure using peer review comments and revision from a writing-to-learn assignment, Finkenstaedt-Quinn and colleagues (2019) discovered that writing-to-learn as a pedagogy can serve as a valuable education tool for learning chemistry.

Bindis (2013) conducted a study to investigate misconceptions among secondary school learners in general chemistry, and twenty-two misconceptions were identified nine of which were related to chromatography and thirteen related to intermolecular forces. Below are some of the findings by Bindis (2013, p. 227):

- Students described attractions between molecules in terms of chemical bonding, charges present within molecules, and in terms of intermolecular forces.
- The idea that ‘opposites attract’ was a common idea among all levels of students, even though not all students understood the concept correctly.
- Students were able to identify and define types of intermolecular forces to varying degrees, but not every student was able to identify multiple examples of intermolecular forces.
- Students had misconceptions about the charges on atoms in water molecules.
- Not all students were able to describe partial charges on the molecules and some students incorrectly assigned charges on the atoms in the water molecule.
- The most frequently mentioned type of intermolecular force was hydrogen bonding which resulted from the use of water as a prompt.

- While the majority of the students could define hydrogen bonding, they overestimated the strength of hydrogen bonding compared to covalent bonding

These misconceptions are all related to learners' representations of molecules at the microscopic level which shows a deficiency in understanding IMF concepts, meaning that learners struggle to connect and draw a microscopic mental picture of the concepts. The word cloud below shows some of the concepts that learners will need to understand even before understanding the types of intermolecular forces:

Word cloud created using Mentimeter: mentimeter.com

The concepts mentioned are just a few of many concepts that learners need to understand to be able to understand each type of intermolecular force. For instance, one of the challenges identified is that they still confuse interaction between molecules with chemical bonds. This shows that they do not understand the concept of polarity and partial charges. Their confusion about intermolecular forces and chemical bonding can be mitigated by allowing them to free-write their understanding of IMF and chemical bonding. In addition, confusion concerning the strength of hydrogen bonds and the fact that they associate all intramolecular forces with hydrogen bonds is also an indication of not understanding the concepts in this topic. Through writing-to-learn learn activities they can overcome these challenges as they will be reflecting on their understanding.

A study conducted by Rompayom, et al., (2011) also revealed that learners experience difficulties in understanding intermolecular and intramolecular forces. In this study, open-ended questions were administered to sixty-four Grade 10 learners after giving normal instructions on chemical bonding topics. The authors acknowledged that making learners understand chemistry concepts and principles is not an easy task, and that chemistry is regarded as a highly abstract and complex subject. While many learners can answer questions related to chemical concepts, they completely lack understating of the concepts. Pedagogies that enable learners to practise and learn about chemistry concepts are ideal for teaching chemistry.

One of the most important topics in chemistry that applies knowledge of intermolecular forces is organic chemistry. A study conducted by Ealy (2018) showed that learners' conceptual difficulties in organic chemistry stem from a lack of prior knowledge in general chemistry. It was discovered that many chemistry teachers are faced with this challenge and are frustrated with learners not being able to perform what teachers perceive to be fairly simple tasks. Organic chemistry in the South African National Curriculum is taught in Grade 12 level which is the highest grade in the South African schooling system. However intermolecular forces as a topic is taught in Grade 11. Below is a structure of organic chemistry in terms physical properties and relationships according to the Department of Education Curriculum and Assessment Policy Statement.

Learners must be able to recognise and apply with given examples the relationships between:

- physical properties and intermolecular forces (ethanol, dimethyl ether, ethanoic acid, ethane, chloro-ethane)
- physical properties and number and type of functional groups (ethanol, dimethyl ether, ethanoic acid, ethane, chloro-ethane)
- physical properties and chain length (methane, ethane, propane, butane, hexane, octane)

- physical properties and branched chains (pentane, 2-methyl-butane; 2,2-dimethylpropane) (CAPS, 2011, p. 106).

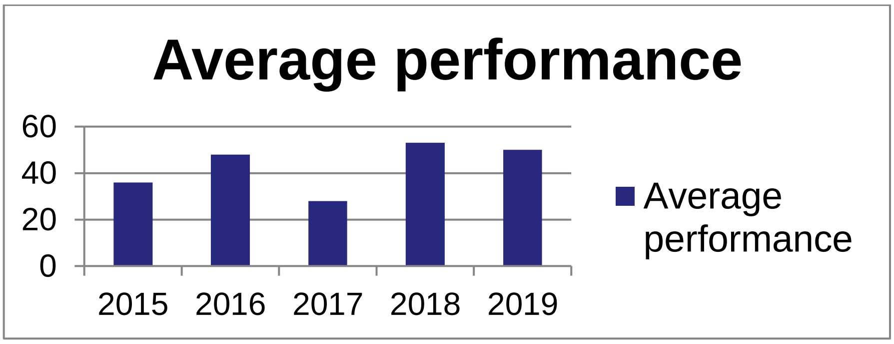
The time allocated to teaching the physical properties of organic chemistry in Grade 12 is limited. For learners to be able to understand the physical properties of organic molecules, they need to understand types of intermolecular forces which are not adequately taught in Grade 11. Therefore, it is necessary to prepare learners thoroughly in Grade 11 on intermolecular forces to cater to this transition. The Grade 12 chemistry examination covers the following topics:

- organic nomenclature
- physical properties in organic molecules
- organic reactions
- reaction rates
- chemical equilibrium
- acids and bases
- stoichiometry
- electrolytic cells, and
- fertilisers.

Physical properties are examined as a unit in the Grade 12 examination. Below is an analysis of the performance of the unit from Physical Sciences paper 2 (Chemistry) for Grade 12.

Figure 2.1

Average % organic physical properties (2015-2019)



According to the diagnostic reports (Department of Basic Education, 2015-2019), the average performance on physical properties has always been below 55%. The picture is not looking good considering that organic chemistry is a section that is considered fairly easy, and learners should capitalise on that and make sure they do well in this section. The topic requires understanding of intermolecular forces, and thus there is a need to investigate pedagogical practices that can enhance understanding of intermolecular forces. Teaching this topic through writing-to-learn strategies would provide them with an opportunity to relate the concepts learned at a microscopic level with the macroscopic level in this topic.

2.5 Theoretical Framework

The theoretical underpinnings of writing-to-learn emanate from a movement referred to as writing across the curriculum (WAC). WAC is a pedagogical movement developed in the mid-1970s by James Briton who believed that understanding the relationship between writing and thinking was an important key to understanding language acquisition as a means of understanding the world (Hodgson, 2016). The theory assumes that effective writing is a skill which is grounded in the cognitive domain and that it involves learning, comprehension, application, and synthesis of new knowledge (Defazio, et al., 2010). In simple terms, writing across the curriculum can be referred to as writing that takes place in various academic disciplines such as natural science, ICT and humanities across institutions (Diaz-Chard, 2020). Therefore, WAC as an educational movement recognises that each discipline is unique and has its own writing discourse which means that writing cannot be adequately taught as a generic mechanical skill; it should be embedded in the discipline (Harper & Vered, 2017).

Two philosophical bases are identified in WAC, namely cognitive philosophy and rhetoric philosophy. Cognitive philosophy represents the view that writing cannot only be used to show what learners have learned but can be used as a mode of learning which is referred to as writing to learn (Diaz-chard, 2020). Rhetoric philosophy on the other hand, focuses on learning how to write in a discipline and the emphasis is on formal writing assignments (Miller, 2018). However, it is important to note that these two philosophies are not mutually exclusive as they often complement each other. The current study considers writing as a valuable tool for learning which can assist learners to better synthesise, analyse, and apply knowledge in specific disciplines and therefore subscribes to the former philosophy.

Cognitive philosophy acknowledges that each discipline, including the sciences, has its own language and style and teachers should be aware that for writing to result in meaningful learning, it should not merely be the responsibility of the English department, but the entire science education community (Luthy et al., 2009). WAC cognitive philosophy is grounded in the constructivist approach to learning since writing has always been regarded as an active learning process where learners construct their knowledge because the process involves some form of thinking (Kekana, 2015). What is learned in constructivism is determined by the process of learning and therefore understanding is often developed through a combination of learning activities, the environment, and prior knowledge (Doubleday, et al., 2015). There is thus a distinct relationship between writing and constructivism as both processes involve thought processes; when learners engage in writing-to-learn activities, they are forced to think about what they are writing, resulting in the construction of knowledge.

The two WAC philosophies described above can also be termed as “transactional writing” and “expressive writing” with transactional writing referring to rhetoric and expressive writing referring to cognitive philosophy. Transactional writing is when learners write to accomplish something such as to inform, instruct, and persuade while in expressive writing we write for ourselves intending to represent our own experiences and to understand science concepts (Saulnier, 2015). As learners write for themselves, they are engaged in metacognitive processes where they get to think about their thinking. There is an association between writing and metacognition because writing has always been considered a constructive process where learners regulate their activities to produce written text (Teng, 2020). As they engage in metacognition activities through writing, they begin to understand how they learn and are able to identify gaps in their learning.

From the above assertions, it is apparent that there is a need to introduce WAC programmes such as writing-to-learn in the South African curriculum. As discussed earlier, different reports point to language as a significant contributing factor in the poor performance in the National Senior Certificate (NSC) and beyond. It is therefore imperative to study some of the important principles in the implementation of WAC programmes and to incorporate these strategies into science topics such as intermolecular forces. Many science teachers assume that learners already know how to write effectively since they are taught how to write in their English classrooms. In the South African setting where the majority of learners learn content knowledge in a second language, this is not always the case. It is noteworthy that learners might engage in writing activities in their English classes, but the challenge is that they do not necessarily apply or know how to apply these skills in a science classroom context. Woolley (2014, p. 21) provides the following questions to consider when implementing WAC programmes:

- How will writing help students to understand the content and material?
- How does writing help students learn the modes of thought in my discipline?
- How can writing help students explore their areas of interest in-depth?
- How can informal writing assignments prepare students for class discussion?
- How can writing help students connect content material to their own experience?
- What kinds of writers would we like to see in the science discipline?
- What kinds of writing do professionals scientists in this field do?

One of the theory linked to writing is Vygotsky sociocultural theory. Writing has always been regarded as a sociocultural activity because it is an act that is often shaped and directed by social context (Callow, 2015). Developed by Lev Vygotsky in the 1970s, sociocultural theory identifies the relationship between sociocultural processes taking place in society and mental processes taking place in the individual (Ornstein & Hunkins, 2004). The theory focuses on the collaborative nature of development that takes place when members of a community interact with each other (Hanjani & Li, 2014). As opposed to Piaget's cognitive development theory, Vygotsky believed that when children interact with society, they learn to perform certain cognitive activities. For example, learners begin to learn to speak a particular language before arriving at particular cognitive stages because of their interactions with society (Ornstein & Hunkins, 2004).

Vygotsky believed that culture and thinking within a particular society require learners to have certain skills or tools. These cultural tools include language, counting, writing, works of art, mechanical drawings and mnemonic techniques (Ornstein & Hunkins, 2004). As a sociocultural process in which learners are allowed to internalise concepts and principles, writing becomes a powerful cultural tool that learners use to shape their thinking at deeper levels (Moon, et al., 2018). Writing is thus regarded as a social activity that involves efforts to understand, communicate, and co-construct knowledge which in turn impacts learners' lived experiences (Moon, et al., 2018). Vygotsky identified language as the primary tool invented by humans and that if there was no language there would be no thought (Ornstein & Hunkins, 2004). One aspect of language is writing which can be used for expressive and transactional purposes.

Rish, et al., (2015) identify four tenets of conceptualising writing as a socio-cultural activity. First, the authors refer to writing as a social act and that social context shapes how learners write as well as the content of their writing. The authors imply that when learners are writing, the process does not happen in isolation, it is affected by social relationships, institutional belongings, and community interactions. This means that authorship is not a solitary activity, but that the writer interacts in multiple ways and on multiple levels, and these interactions affect the content and style of writing. Thus, the process of writing is culturally mediated, meaning that when learners write in a science context it will not be the same as when they are writing in other contexts such as in the English classroom. This also applies to writing in the context of a particular topic in science, for example, intermolecular forces where learners need to understand representation at symbolic, macro and microscopic levels.

Second, as Rish, and colleagues (2015) elaborate, writing is not a solitary activity but is distributed. As learners write, they interact in multiple ways and on multiple levels and this happens in a process of invention and transcription. Therefore, the IMF content produced and the style of writing is affected by these interactions, meaning that writing is a collaborative process that constitutes some form of co-authorship. For example, teachers can in many ways be regarded as co-authors in their learners' writing as they assist learners in identifying topics and sometimes provide advice and give feedback to aspects of the writing.

Third, writing is a mediated process of invention implying that when learners engage in writing they use several resources or tools that influence the nature and content of their writing (Slavkov, 2015, Rish, et al., 2015). In the case of the topic of intermolecular forces, the resources and tools will be the study material, fellow students, the experiments and the teacher. All of this influences the type of content and the type of writing which the learners produce.

Fourth, writing is dialogic and intertextual which means that learners borrow and lend ideas, linguistic structures and lexical material from different disciplinary contexts (Rish, et al., 2015). In the case of this study, the context is chemistry and the topic is intermolecular forces. Chemistry writing will require students to understand matter at macro, micro and symbolic levels to understand the phenomena in intermolecular forces.

Another important theory that is closely linked to sociocultural theory is Badura's social learning theory. The theory emphasises that the major part of what learners learn is learned through observing their peers and interacting with others (Bandura, 1989). This means that the environment in which learners learn should be taken into consideration. The environment can be both the physical setting, in this case the classroom, and the elements within the setting in which the learner interacts and observes - which could be the teachers and their comments, other learners and their comments (Black & Allen, 2018). In the writing-to-learn context, several elements will influence how learners compose their writing. If the teaching of writing only happens in the English classroom, learners will have difficulties in engaging with writing in other subjects such as Physical Sciences. Learners' writing is also influenced by personal characteristics which Black and Allen (2018) refer to as cognitive and affective characteristics which may include previous content knowledge, literacy skills, self-efficacy beliefs, motivational levels, attitudes, values, and emotions. All of the aspects mentioned will affect the learner's writing process and have to be taken into consideration.

Social learning theory focuses mainly on observational learning, and this is considered a cognitive form of learning since learners are expected to pay attention, construct and remember mental representations from what they have observed (Connolly, 2017). In the context of writing on the topic of IMF, this happens when learners are engaged in the process of peer reviews and through the process learn from what their peers have written. This also takes place when the teachers model good explanations by writing and guiding learners.

Accordingly, when learners are writing they emulate good writing skills from cultural tools such as textbooks, study guides and teachers. In addition, as they engage with readings and writing in class they engage in a learning process through the drafting these ideas. However, their behaviour needs to be reinforced by giving them regular feedback as reinforcement. Another important feature outlined by Bandura (1977) is learning by direct experience which means acquiring knowledge, skills and attitudes by observing the behaviour of others. In the topic of IMF, learners learn how to write in the science classroom and are directly involved in the writing which can be regarded as learning through direct experience.

2.7 Conclusion

A central goal in education is for learners to be able to teach themselves and become self-directed learners. This can only be possible if they are taught how to learn by engaging in WTL activities. This chapter explored all the aspects of writing in science education by emphasising the urgency of developing students' language abilities in South Africa, especially their writing skills. Noteworthy was that there are several theories about the process of writing; it is not an isolated process. Several approaches to teaching writing were discussed and how the approaches were modified to develop a scientific writing process. Studies that investigated the teaching and learning of intermolecular forces with a specific focus on writing-to-learn strategies, were also explored. Writing across the curriculum (WAC) and Vygotsky's sociocultural theory as representative of pedagogic theories, were explored as the theoretical underpinnings of this study.

CHAPTER 3: RESEARCH METHODS AND DESIGN

3.1 Introduction

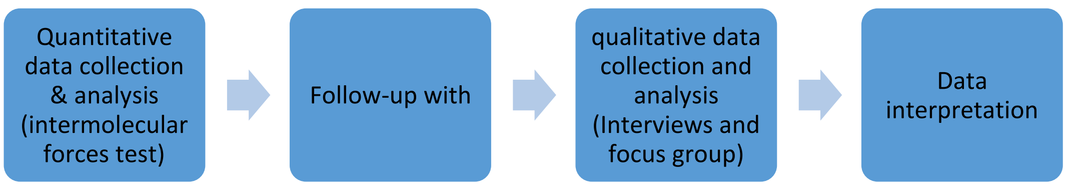
In this chapter, I discuss the research procedures that were followed to investigate the effectiveness of implementing writing-to-learn strategies for improving the achievement of Grade 11 learners in the concepts of intermolecular forces in school Physical Sciences. It includes the research methods and design, study sample and sampling procedures, development and validation of instruments and data analysis procedures. The ethical issues, validity, reliability and how the writing-to-learn materials were developed in the study are also discussed.

3.2 Research method and design

Research methodologies are categorised into three approaches, namely; quantitative, qualitative or mixed-method, and all these methodologies depend on the nature of the study and what the researcher seeks to achieve. In the current study, a mixed-methods approach in a form of an explanatory sequential design was employed to investigate the effectiveness of writing-to-learn pedagogies in enhancing learner academic performance. An explanatory sequential design is a type of mixed-methods design where the researcher first collects quantitative data and later qualitative data to elaborate on the quantitative data and to provide the general picture of the problem (Creswell, 2012). The flow chart below shows how the explanatory mixed-method design is used.

Figure 3.1

A flow chart for an explanatory research design



This research design assumes that utilising both types of data provides a better understanding of the problem under investigation. Furthermore, the use of a mixed-method approach was necessary because it enabled the use of different kinds of data-collection instruments with quantitative data used as primary data collection method followed by qualitative methods used to complement the quantitative data.

McMillan and Schumacher (2014) indicate that there has been an increase in the use of mixed-method design in recent years as many scholars are now realising that the best approach to answering questions is to use both quantitative and qualitative methods in the same study. In the current study, I wanted to follow up the quantitative part of this study with a qualitative study, referring to the intermolecular forces test which was administered both as a pre-test and a post-test followed by interviews. The purpose was to get a sense of how teachers and learners experienced the writing-to-learn intervention.

The philosophy behind mixed methods research is pragmatism which is the primary purpose of this study (Johnson, Onwuegbuzie, and Turner, 2007). This approach is regarded as 'practical' in the sense that researchers are free to use all methods possible to address a research problem as well as the fact that they combine inductive and deductive reasoning (De Vos, et al., 2017). To determine the practicability and efficacy of writing-to-learn strategies, it was necessary to use both inductive and deductive reasoning to gather more information from the participants about what the strategies entail and what the strategies look like during implementation.

3.3 Quantitative research methods

Quantitative research is used to answer questions about relationships amongst measured variables; about testing hypotheses to explain, predict, and control phenomena (Leedy and Ormrod 2005). It has roots in logical positivism and mainly focuses on measurable aspects of human behaviour (Brink (2006). The quantitative aspect of this study involved an intermolecular force test which was administered as a pre-test and a post-test to Grade 11 Physical Sciences learners of the sampled schools. A pre-test is essential as it provides a measure of some attributes of the participants that are assessed in an experiment before they receive treatment, while a post-test measures some attributes of the participants after treatment (Creswell, 2012). The main purpose of using pre- and post-tests was to investigate how writing-to-learn strategies influenced academic performance in intermolecular forces with a special focus on conceptual understanding and scientific inquiry skills. The process of how the intermolecular forces test was developed is discussed in the upcoming sections.

3.4 Qualitative research methods

Qualitative research is an unstructured approach to inquiry that is flexible with regards to the objectives, design, sample, and questions asked to explore the nature of a problem, issue, or phenomenon (Kumar, 2002, Van Staden, 2010). This methodology is not concerned with generating statistical data or attempting to generate numerical data that the researcher will use to prove a hypothesis as in the case of quantitative methodology; the focus is on describing and understanding the problem within a natural setting (Maree, 2010).

The qualitative part of this study involved interviews conducted with teachers who participated in the WTL in Physical Sciences and focus group interviews conducted with the learners who participated in the intervention. Interviews are necessary when researchers ask one or more participants general open-ended questions and record their answers as this allows participants to voice their experiences unconstrained by the perspectives of the researcher or past research findings (Creswell, 2012).

To discover the experiences of teachers in engaging learners in the writing strategies, I decided to conduct interviews that investigated their views about extensive and meaningful learner writing. The interviews were also meant for teachers to offer suggestions on how writing-to-learn strategies can be effectively implemented in science classes. The focus group interviews conducted with the learners who participated in the intervention were essential as I wanted to find out how they experienced the WTL learning material so that they could offer suggestions for improvement.

3.5 Development of writing-to-learn materials

The writing-to-learn materials comprised a study guide on the topic of IMF which was a resource that integrates writing-to-learn strategies and the topic of intermolecular forces. Learners in the experimental group used this handout together with normal learning and teaching materials used in their school. To understand how the study guide was developed it is important to understand some principles that guide writing-to-learn teaching strategies. Two approaches need to be considered: first, the expressive (cognitive) writing approach which involves ungraded in-class writing tasks that help students think on paper, and second, the transactional approach often referred to as rhetorical, which is concerned with how learners learn how to write in a particular discipline. The current study was based on the first approach but not necessarily ignoring the value of learning to write in the science discipline. In addition to summarised notes on the topic of intermolecular forces, the WTL study guide comprised the following writing tasks:

- writing assignments
- in-class writing activities
- inquiry-based learning writing tasks; and
- summaries.

The writing assignments were completed before the beginning of each sub-theme and were limited to 500 words. These were not the short writing-to-learn activities included in the study guide, but extended writing assignments that learners had to complete before the teaching of the topic. The types of writing assignments were expository as they enabled the learners to communicate knowledge of the topic in a meaningful and coherent manner (Peretz, 1986). In expository writing, learners can discover that they understand more (or less) than they thought, meaning that through this writing they are engaged in discovery learning (Braun, 2014). Learners must be able to demonstrate that they have gained knowledge on the topic of intermolecular forces and this is only evident if they can argue and express their viewpoints on the topic which is what expository writing is all about. In the South African Physical Sciences curriculum writing assignments are not included as part of the continuous assessment tasks. Below is the assessment plan for Grade 11 Physical Sciences which does not include writing assignments as part of the formal assessments extracted from the DBE (2011) curriculum document:

Table 3.1

Grade 11 assessment plan (DBE: 2011)

Term or period	Assessment tasks
Term 1: January –March	• Experiment • Test
Term 2: April-June	• Experiment • Mid-year exam
Term 3: July-September	• Project: either the construction of a device/ building a model/practical investigation
Term 4: October-December	• Final examination

Table 3.1 shows that writing assignments are not encouraged as forms of assessments in science disciplines; experiments, tests and projects are given preferences. The assessment types outlined above are relevant to the science discipline, but writing assignments in the form of essays can be given to learners since informal formative assessment tasks enhance the understanding of concepts. Even as part of informal assessment, essay writing assignments are not mentioned in the curriculum document. The only informal assessments mentioned are observations, discussions, practical demonstrations, learner-teacher conferences, and informal classroom interactions although these are important in improving conceptual understanding (DBE, 2011).

Learners completed two writing assignments focusing on the topic of intermolecular forces. The first assignment required learners to write an essay on their understating of intermolecular forces. The purpose was to orient learners in the topic through writing before the topic was taught. They were required to explain the meaning of intermolecular forces by giving applications of intermolecular forces in everyday life. They were also supposed to differentiate between intermolecular forces and intramolecular forces. Lastly, they were expected to explain types of intermolecular forces with examples. The second assignment focused on the relationship between physical properties and intermolecular forces. These were boiling point, melting point and molecular mass, and the learners had to explain how the strength of intermolecular forces affects these physical properties.

The second type of writing tasks included in the WTL study guide were in-class writing activities. These were given to the learners at the beginning of each lesson on intermolecular forces and were limited to 5-10 minutes of class time. Since learners engaged in writing assignments before, it was assumed that they should have gained some knowledge of concepts from the writing assignments. Before a new concept was introduced learners were provided with terms that they had to explain through free writing. They were expected to continuously write down their thinking about particular concepts for a few minutes without stopping. The teachers provided the learners with writing cards; small pieces of paper on which the learners had to write their ideas about given concepts. After they have engaged in the freewriting exercise, learners randomly exchanged writing cards with their peers. The teacher then randomly selected learners to read out what their peers have written in the exchanged card. After the learners had read a few cards, the teacher provided a summary of the given concepts.

The third type of writing task involved Inquiry-based learning tasks where the learners were provided with the scenario of an experiment or a situation. For example, they were told that carbon dioxide is a non-polar molecule and were expected to explain the interactions of the intermolecular forces between two or more carbon dioxide molecules. They could represent this situation first as a diagram, followed by an explanation through writing. Other IBL activities could be providing learners with different substances and their boiling points and asking learners to identify the ones with the strongest or weakest intermolecular forces and provide reasons for their choices. This could also mean providing them with different molecules of different chain lengths and asking them how chain length affects the boiling or melting points of the substances. All these explanations are done through writing. The teacher can either grade the tasks or they can be graded through peer assessments by exchanging books.

The fourth type of writing is where learners have to write a summary of what they had covered in each section. In this case, after the end of each unit they were expected to complete a summary and to share this with the rest of the class. The teacher then randomly selected a learner to share their learning journey on a particular topic. This can sometimes be referred to as a learning journal after completing a particular section of a topic. Learners can represent their learning journey through writing a paragraph or two or through a mind map. For the activities that were completed in class, learners received immediate feedback from the teachers and their peers. For activities completed as homework, the learners were given feedback by the teacher or their peers on the following day. The purpose of these informal writing activities was to ensure that learners completed a substantial amount of writing.

Table 3.4 below shows the content of intermolecular forces covered in Grade11 Physical Sciences as illustrated in the Gauteng Department of Education (GDE) Grade11 Physical Sciences work schedule (2016).

Table 3.2

Grade 11 intermolecular force content

Intermolecular forces	In a liquid or a solid, there must be forces between the molecules causing them to be attracted to one another, otherwise, the molecules move apart and become a gas. These forces are called intermolecular forces (forces between molecules).	
	Intermolecular and interatomic forces (chemical bonds). Physical state and density explained in terms of these forces. Particle kinetic energy and temperature.	❑ **Name** and **explain** the different **intermolecular forces**: i. **ion-dipole** forces ii. **ion-induced dipole** forces iii. **dipole-dipole** forces, with **hydrogen bonds** a special case of dipole-dipole forces - explain hydrogen bonds iv. **dipole-induced dipole** forces v. **induced dipole** forces (The last 3 forces (involving dipoles) are also called **Van der Waals forces**) ❑ (Revise the concept of a covalent molecule) ❑ **Describe** the difference between: ♦ **Intermolecular forces** and **interatomic forces**, using

		♦ a **diagram** of a group of small molecules - represent a common substance, made of small molecules, to show microscopic representations of ice, $H_2O(s)$, water liquid $H_2O(\ell)$ and water vapour $H_2O(g)$ ♦ and **words** ● Illustrate the proposition that intermolecular forces increase with incr**easing molecular size**, e.g. He, O_2, C_8H_{18} (petrol), $C_{23}H_{48}$ (wax). (Only for van der Waals forces.) ❑ Explain: ♦ the relationship between the **strength** of intermolecular forces and **melting points** and **boiling points** of substances composed of small molecules ♦ Contrast the melting points of substances composed of small molecules with those of large molecules where bonds must be broken for substances to melt

Table 3.4 identifies five intermolecular forces, namely ion-dipole forces, ion-induced dipole forces, dipole-dipole forces with the inclusion of a hydrogen bond, dipole-induced dipole and induced-dipole forces. The developed WTL study guide focused on the three main intermolecular forces, namely; dipole-dipole, induced-dipole forces (London forces) and hydrogen bonds. These are the types of intermolecular forces included in the Grade 12 content. Therefore, the WTL study guide focused on the five themes shown below:

Unit 1: Introduction to intermolecular forces

Unit 2: Induced-dipole forces

Unit 3: Dipole-dipole forces

Unit 4: Hydrogen bonds

Unit 5: Physical properties and intermolecular forces

The main focus of the study guide was on learners explaining and justifying these concepts through writing. To design the WTL study guide, a principle of constructive alignment was used; a curriculum design principle which holds that what it is intended for students to learn (learning outcomes), how they should learn it (learning activities), and how the teachers will know that students have learned (assessment), are clearly stated before teaching takes place (Biggs, 2014). See the illustrated diagram below.

Figure 3.2

Constructive alignment process

This means that the teaching and learning activities and assessment strategies have to be designed to achieve intended learning outcomes. The study guide was thus designed in a way that the intended outcomes in each topic are stated, followed by learning activities which were mainly informal WTL activities, and lastly information on how learners would be assessed through writing assignments and the intermolecular forces test. Since assessment is continuous, learners were engaged in writing activities and given feedback by their teachers and peers in class. Contrary to traditional methods of teaching, WTL pedagogy ensures that learners complete writing activities in class every day.

3.6 Data collection instruments

3.6.1 Intermolecular forces test

An intermolecular forces test was administered both as a pre- and post-test covering the chemistry topic of intermolecular forces which is currently taught in Grade 11 Physical Sciences in the South African National Senior Certificate (NSC). The test was developed by the researcher and was moderated by the heads of department from the participating schools. Teachers were also given the chance to look at the test and to make comments. The topic which is in the knowledge area of matter and materials is taught in the first quarter (January-March) of the South African school calendar. The test focused on the following sub-topics:

- Introduction to intermolecular forces
- Induced dipole forces
- Dipole-dipole forces
- Hydrogen bonds
- Physical properties and intermolecular forces

In Grade 12 chemistry content learners are expected to apply knowledge of the three intermolecular forces which include induced-dipole force, dipole-dipole forces and hydrogen bonds in organic molecules. It was necessary to interrogate how these types of intermolecular forces are explored and understood by the learners through writing. Most learners struggle to construct meaningful explanations to account for intermolecular forces in different organic molecules. To give an example of how the topic is examined, see the extract below from the Western Cape 2014 preparatory exam of questions on physical properties which show the types of questions that were asked.

QUESTION 3 [START ON A NEW PAGE]

A learner conducts a scientific investigation to compare the boiling points of organic compounds belonging to different homologous series. Propan-1-ol, ethanoic acid and propanal are used for the investigation. His results are shown in the table below.

Compound	Boiling Point (°C)
Compound A	48
Compound B	97
Compound C	118

3.1 For this investigation, name the ...

3.1.1 independent variable. (1)

3.1.2 dependent variable. (1)

3.2 Will the vapour pressure of propanal be LOWER or HIGHER than the vapour pressure of propan-1-ol? Explain your answer by referring to the type of INTERMOLECULAR FORCES present and ENERGY. (4)

3.3 Identify:

3.3.1 Compound A (1)

3.3.2 Compound B (1)

3.3.3 Compound C (1)

3.4 Will the boiling point of butan-1-ol be HIGHER or LOWER than the boiling point of propan-1-ol? Explain the answer referring to the INTERMOLECULAR FORCES. (2)

Most learners can easily attempt answers to questions 3.1. and 3.3 as they are only expected to identify the compounds and give short answers of one word. However, most of them struggle to answer questions 3.2 and 3.4 as the questions require learners to provide written responses. To be able to do this, they need to practice how to construct explanations through writing in class, and the majority of learners struggle with this type of writing. Another challenge identified in the examination reports is that learners lack understanding of basic concepts. To prepare tests or examinations, the Department of Basic Education provides guidelines using Bloom's taxonomy. The following table illustrates how a question paper or a chemistry test should be prepared considering the cognitive levels of questioning:

Table 3.3

Guidelines on preparing chemistry test according to DBE (2011)

Cognitive level	Description	% for chemistry paper
1	Remember	15%
2	Understand	40%
3	Apply and analyse	35%
4	Evaluate and Create	10%

The first level requires learners to be able to recall facts and scientific concepts. Examples of action verbs that are used include define, list, identify, repeat, choose, label, etc (Wilson, 2016). According to DBE (2016), the majority of learners in Physical Sciences struggle with definitions of concepts and stating scientific laws. These questions require learners to write one or two sentences, and for many second language learners this can pose a serious problem. In the second level learners are expected to demonstrate understanding of facts such as organising, comparing, interpreting and giving descriptions. Action verbs that are used include explain, describe, discuss, differentiate, and many more. These types of questions prove to be problematic as they also require learners to construct meaning from scientific concepts. When they are describing, discussing, explaining, for example, they are expected to do this through writing and to comprehend scientific concepts.

For level 3, which includes analysing, learners are expected to break down concepts into parts and to determine how the concepts are related. This is important in intermolecular forces as they are expected to relate the concepts to physical properties in real-life situations. The last level on which this study focuses is evaluation; the learner must be able to make a judgement using particular criteria and action verbs such as conclude, criticise, decide, estimate and many more. The diagnostic reports indicate that learners struggle with these questions as they are not able to reason by critiquing or judging the value of something.

Therefore, in this study, the majority of questions were based on level 1, 2 and 4 questions. However, the main focus was on how learners demonstrate understanding of basic concepts which are covered by level 2. Table 3.4 below illustrates how question types were distributed in the intermolecular forces test.

Table 3.4

Cognitive levels of the intermolecular forces test

Cognitive level	**Description**	**% for chemistry paper**
1	Remember	18%
2	Understand	52%
3	Apply and analyse	9%
4	Evaluate and create	21%

The main aim was to include questions which required learners to write argumentative and expository texts; 73% of the questions focused on such questions and these types of questions appear in all Physical Sciences question papers. The focus was on how they explain different intermolecular forces in different contexts. The table below unpacks the question types and their cognitive levels.

Table 3.5

Cognitive levels for chemistry pre/post-test for each question

Questions	**Cognitive level 1**	**Cognitive level 2**	**Cognitive level 3**	**Cognitive level 4**
Question 1				
1.1	2			
1.2.1	2			
1.2.2	2			
1.2.3	2			
1.2.4	2			
Question 2				

2. 1		4		
2.2.1		4		
2.2.2		4		
2.2.3		4		
Question 3				
3.1		2		
3.2				5
3.3		3		
QUESTION 4				
4.1			4	
4.2		2		
4.3				4
Total:	**8**	**23**	**4**	**9**
Percentage	**18**	**52**	**9**	**21**

The test was marked out of 44 points. Question 1 consisted of multiple-choice questions which covered eight marks covering 18% of the test. The multiple-choice questions were recall-type questions to check if learners could recall and recognise main concepts, mainly types of intermolecular forces, and whether learners could identify types of intermolecular forces in different types of compounds. A standard Physical Sciences question paper must at least start with multiple questions to assess basic understanding of concepts. Question 2 was made up of explanation questions (expository) where learners were required to explain concepts according to their understanding. These questions were worth 16 marks covering about 36% of the question paper. The main purpose of these questions was to assess how learners structure scientific explanations. Question 3 was made up of contextual questions where learners were provided with different compounds and different boiling points, and they had to identify the compounds with stronger or weaker intermolecular forces relative to their boiling points and provide reasons for their choices. The question was worth 10 marks covering 23% of the question paper. Question 4 was also a contextual question where learners were given compounds of different molecular mass or sizes and had to identify compounds according to molecular size and how they affect intermolecular force strengths. The question was worth 10 marks covering 23% of the paper.

An investigation was done to identify how many explanation questions are included in a chemistry question for the 2013-2018 question papers, and it was found that on average a total of 21 marks out of 150 accounted for explanation and reasoning questions, which is 15% in Grade 12 chemistry papers. This excludes definitions and comprehension questions. If explanation, reasoning, definitions and comprehension questions are included these would account for 60% of all the questions in the chemistry question papers. If learners can answer these questions that require some form of extended writing, it would not only improve their academic performance but also their understanding of the subject, which is a basic requirement in higher education.

The tests were administered under standardised conditions for both groups, and the learners were not allowed to refer to any reading materials while writing the test. The researcher and the teachers in each school were the invigilators. The duration of the test was 1 hour and added up to 44 marks in total.

3.6.2 Interviews and focus group interviews

The teachers who participated in the study were interviewed to discover their views and experiences about the WTL project on the topic of intermolecular forces. According to McMillan and Schumacher (2010), an interview is a flexible and adaptable technique used to engage with many problems and different types of people. In this study, the interviews encouraged a wide range of responses concerning the teachers' social identities and also encouraged debates and discussions about appropriate writing pedagogies in science education. The interviews were also meant to identify challenges and barriers that impede teachers to integrate writing into their classes. In a nutshell, the focus was on listening to teachers' reflections regarding their teaching practices while engaging learners in writing sessions.

Learners who participated in the WTL project were interviewed through focus group interviews. According to Leedy and Ormond (2010), in a focus group interview the researcher gathers several participants (not more than 10) to discuss a particular issue. The researcher must ensure that no one dominates the discussion and keep participants focused on the topic. The focus groups were aimed at finding out learners' experiences about WTL in Physical Sciences classrooms and to reveal how they have benefited from the intervention.

Both the interviews and focus groups were audio-recorded using a smartphone audio recorder. The practical advantage of using a smartphone is that it is easy to place a smartphone between the interviewer and participants. Another advantage is that it has ample data storage that is extendable using a memory card and you can audiotape each question individually which makes it easier to transcribe. You can also easily transfer data from a smartphone to a laptop or play it on a device like an MP3 OR USB player.

3.6 Sampling

The population of this study comprised Physical Sciences Grade 11 learners and their teachers in public schools in the Nkangala District in the Mpumalanga Province South Africa. The district was chosen because the researcher resides in the area and it was cost-effective to collect data in this area. The district was also chosen because it has a variety of high and low performing schools. Many of the schools in the area are semi-rural. In addition, the participation rate in Physical Sciences for the district has always been lower compared to other districts in Mpumalanga. Mpumalanga has four education districts, namely Bohlabela, Enhlanzeni, Gert Sibande and Nkangala. Table 3.6 below shows the participation rate and pass rates for the four districts for the academic years from 2015 to 2019 extracted from the DBE (2015, 2016, 2017. 2018 and 2019) diagnostic reports.

Table 3.6

Districts performance and participation rate in Physical Sciences in Mpumalanga

Year	2015		2016		2017		2018		2019	
District	Number wrote	Pass rate	Number wrote	Pass rate	Number wrote	Pass rate	Number wrote	Pass rate	Number wrote	Pass rate
Bohlabela	**3575**	55.0	4478	55.0	4714	55.5	5072	64.6	4995	63.4
Ehlanzeni	**4876**	63.8	5187	64.2	5313	62.6	5524	72.0	5187	70.9
Gert Sibande	**4645**	62.1	4558	68.0	4661	66.1	5149	71.9	4954	74.0
Nkangala	**4432**	68.2	4694	67.0	4618	62.4	4642	72.5	4543	75.6
Total	**17527**	62.6	18917	63.6	19306	61.6	20378	70.2	19679	70.9

There has not been a steady increase in the number of learners who participate in Physical Sciences for the district compared to other districts where the participation rate has reached more than 5000 learners. Even though the district has been performing well in terms of pass rates, the number of learners who wrote the subject was low meaning that the district attracts few learners in science subjects.

Multistage cluster sampling was used to select the schools and participants for the study. McMillan and Schumacher (2014) describe cluster sampling as a technique where the researcher identifies naturally occurring groups such as neighbourhoods, schools, districts, and regions and then randomly selects units for the study. Since Nkangala district is a huge district with 148 secondary schools it was not possible to randomly select schools; certain criteria had to be followed, which means the researcher opted to focus on a particular cluster; in this case, an area in Nkangala district called KwaMhlanga. KwaMhlanga comprises 12 secondary schools with representative numbers of high and low performing schools in Physical Sciences. Out of the 12 schools, the researcher used a random stratified sampling technique to select the schools and participants for the study. According to De Vos, et al., (2017) stratified random sampling is used to ensure that different groups of a population acquire sufficient representation in the sample. Schools that meet the following criteria were selected:

- Schools with Grade 12 pass rates between 50% and 80% in Physical Sciences in the past three years.
- Schools with more than 50 Grade 11 Physical Sciences learners.
- Schools comprising qualified Physical Sciences teachers with a minimum of three years' teaching experience.
- Schools in which the home language of the majority of learners is IsiNdebele.
- Schools with Physical Sciences teachers who were voluntarily willing to participate in the study.

Out of the twelve schools, three schools with 317 Grade 11 learners and 5 teachers met the above criteria and voluntarily agreed to participate in the study in the Nkangala region. There were 149 learners from school A, 98 learners from school B, and 70 learners from school C. In terms of gender representations, 194 females and 123 males participated in the study. In school A there were 88 females and 61 males, in school B 69 females and 29 males, and in school C 37 females and 33 males. Ideally, learners who are in Grade 11 should be between the ages of 15-17, and a large proportion of the learners were around these ages. Five teachers from the schools who teach Physical Sciences were interviewed: two males from school A, one male and female from school B, and one female from school C. The main purpose of selecting the schools from a particular cluster was that the researcher could have enough time to monitor and support the teachers in implementing the intervention and to reduce any chance of contamination in the results.

3.7 Pilot study

For the researcher to be able to test the practical aspects of the research study, a pilot study was conducted. Brink (2006) defines a pilot study, sometimes referred to as a preliminary study, as a small-scale study conducted before the main study; preferably performed with a limited number of participants from the population at hand. A pilot study gives the researcher ideas, approaches, and clues that may not have been foreseen before conducting the main study (Mugenda & Mugenda, 2003).

The pilot study was conducted in a school in Mpumalanga province with 32 learners. It was aimed at determining the effectiveness and appropriateness of the interventions and instruments. The specific aims for the pilot study were the following:

- to gather relevant information about the research instruments (intermolecular forces test, interview guide and focus group interview guide) for further review
- to determine the reliability and validity of the instruments
- to collect data about the approximate duration of the study, and
- to identify and check logistical challenges and errors before conducting the main study.

The learners were taught through the study guide which incorporated writing-to-learn strategies and after teaching of the topic they wrote the test (pre/post-tests). After the implementation of the pilot study, changes were made to the study guide, pre- and post-tests and interview questions. After a month, the same test was administered to the same learners. The teacher who implemented the intervention was interviewed, and a focus group interview was conducted with randomly selected learners from the group. Learners also completed two writing assignments to check if there were challenges with these instruments. The results from the first and second administration of the pre/post-tests were used to determine the reliability of the pre/post-tests which is further discussed in the validity and reliability section.

The data from the administration of the other instruments (interviews, focus group interviews, study guide, writing assignments) were used to check logistics, time constraints and challenges associated with the tools. Improvements and amendments to the instruments were made before the implementation of the main study.

3.8 Data collection process

The data collection process took place in the first week of the 2019 academic year from mid-January until the end of April 2019. The first part involved visiting the participating schools and building relationships with different stakeholders: the principals, heads of departments, teachers and learners. The participating teachers were individually trained as the researcher could not locate a specific date for the training of all the teachers. They were trained one-on-one at the beginning of the term before the teaching of the topic of matter and materials which includes intermolecular forces.

Matter and materials as a topic is taught over 4 weeks: the first week is dedicated to the teaching of atomic combination and the last 3 weeks to intermolecular forces. The intervention had to start 2 weeks before the teaching of intermolecular forces. The actual data collection comprised the following four phases:

1. Pre-test and introduction of the first writing assignment. (two weeks before the intervention)
2. Feedback on the first assignment, teaching the IMF topic, and introduction of the second writing assignment (the first week of teaching IMF)
3. Feedback on the second assignment and teaching Physical Properties (the second week of teaching IMF)
4. Summative assessment through the post-test and interviews (following

   The week after teaching the topic of IMF).

The stages are discussed in the upcoming subsections. The Physical Sciences teachers in the participating schools were responsible for teaching both the experimental and control groups. During the data collection process, the researcher visited the schools on a daily basis to ensure that the intervention was implemented and that there were no threats to validity.

3.8.1 Pre-test and introduction of the first writing assignments

In this phase, the pre-test was administered to the learners, and after the pre-test they were provided with the first writing assignment. This was done two weeks before the actual teaching of the topic of intermolecular forces. Learners were given two weeks to complete the first writing assignment. After the writing assignment was handed in, the grading of the assignment was completed through peer assessment on the first day of teaching the topic of IMF. The idea was to provide the learners with formative feedback before the actual teaching of the topic.

Writing assignments are not new in chemistry and have been implemented for decades. In this study, the purpose of the first writing assignment was to enhance understanding of the basic concepts of intermolecular forces (Rhoad, 2017) and to foster critical thinking (Chamely-Wiik, Haky & Galin, 2012). According to Van Orden (1987), for writing assignments to be of real value, they need to be more than the traditional end of the chapter activities which can be answered by copying appropriate sentences from the textbook. In the study, the writing assignments were essay type questions requiring learners to discuss how the concepts of intermolecular forces apply in real-life situations as illustrated in Figure 3.3 below:

Figure 3.3

Extracts for instructions of the first writing assignment

Assignment 1

Understanding of Intermolecular forces

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1. Discuss in not more than TWO handwritten pages, your understanding of intermolecular forces. In your essay, include the following.

Introduction

In the introduction, first, explain what are intermolecular forces and give a background about the importance of intermolecular forces in our daily lives. You must also explain how intermolecular forces are different from intramolecular forces with examples. (10)

Types of intermolecular forces

Briefly explain different types of intermolecular forces with examples. Give examples where necessary and also outline how the polarity of the intermolecular forces affect the strength of the intermolecular forces. (25)

Conclusion

In your conclusion provide own your views about what you discussed in this essay and how you will apply this knowledge in your everyday life and in the community where you live. (5)

TOTAL: 40 MARK

In the society we live in, acquiring knowledge that is disconnected from real-life situations is no longer relevant; learners need to know why they have to study a particular topic and how it applies to their daily lives. The inclusion of real-life situations in this assignment was to encourage authenticity and engagement in writing the assignment.

3.8.2 Feedback for the first assignment, the teaching of IMF and administration of the second writing assignment

The first day of teaching intermolecular forces started by giving learners feedback on their first writing assignment. The scripts of the writing assignments were marked by learners through peer assessment. The learners were not allowed to mark their own assignments, and the teacher ensured that this did not happen. Below is the rubric used to grade the assignment:

Table 3.7

Rubric for writing assignment 1

RUBRIC: Writing assignment 1

CRITERIA	Excellent	Good	Average	Fair	Poor
Introduction (10)	Define intermolecular forces (IMF) (2) Describe the importance of IMF in daily lives (4) Outline the difference between intermolecular forces and intramolecular forces (4) **Total: 10 marks**	Does not define intermolecular forces (IMF) (2) **BUT:** Describe the importance of IMF in daily lives (4) Outline the difference between intermolecular forces and intramolecular forces (4) **Total: 8 marks**	Define intermolecular forces (IMF) (2) **BUT either does not** Describe the importance of IMF in daily lives (4) OR Outline the difference between intermolecular forces and intramolecular forces (4) **Total: 6 Marks**	**Get one of the following:** define intermolecular forces (IMF) (2) Describe the importance of IMF in daily lives (4) Outline the difference between intermolecular forces and intramolecular forces (4) **Total: 2-4 marks**	Does not: Define intermolecular forces (IMF) (2) Describe the importance of IMF in daily lives (4) Outline the difference between intermolecular forces and intramolecular forces (4) **Total: 0**
Types of intermolecular forces (25)	Describe the 5 intermolecular forces (2x5 marks) Discuss 5 examples and application of each intermolecular forces in daily lives (3x5) **Total: 25 marks**	Describe the 4 intermolecular forces (2x4 marks) Discuss 4 examples and application of each intermolecular forces in daily lives (3x4) **Total: 20 marks**	Describe the 3 intermolecular forces (2x 3 marks) Discuss 3 examples and application of each intermolecular forces in daily lives (3x3) **Total: 15 marks**	Describe the 2 intermolecular forces (2x2 marks) Discuss 2 examples and application of each intermolecular forces in daily lives (3x2) **Total: 10 marks**	Describe 1 intermolecular force (2x1 marks) Discuss 1 example and application of each intermolecular forces in daily lives (3x1) **Total: 5 marks**
Conclusion (5)	Own views about IMF in everyday lives (2) How it applies within own community (3) **Total: 5 marks**	**Does not describe:** Own views about IMF in every day (2) But explain: How IMF's apply within own community (3) **Total: 3 marks**	**Describe:** Own views about IMF in everyday lives (2) But does not explain: How IMF's apply within own community (3) **Total: 2 marks**	**Replicates** definition of IMF without prior context **Total: 1 mark**	No conclusion **Total: 0**

Each learner was provided with a rubric to grade their peers. The peer assessment was anonymous; each learner was allocated a number that was only known to the teacher. The teacher went through the rubric with the learners, and they were allowed to ask questions if they did not understand anything. During the process, the learners engaged in dialogical feedback even before the scripts were marked. The marking encouraged peer learning as learners had to read each other's assignments. The marking was also scaffolded across three levels as illustrated in the rubric above. First, the introduction was marked and when everyone was happy with the marking, they commenced on the intermolecular forces section and then the conclusion section was marked. Afterwards, the teacher collected the assignments, moderated them, and returned the scripts to the learners.

After this marking of the first assignment, the actual teaching of the topic started, and the WTL study guide was used as part of the learning and teaching material. Learners completed in- and out-of-class writing-to-learn activities daily. During the first week of teaching of the topic, the learners were also given a second writing assignment which they were supposed to complete within a week.

3.8.3 Feedback on the second assignment and teaching of physical properties

The third phase involved peer assessment of writing assignment 2 which was based on the learners' understanding of how the strength of intermolecular forces affects the physical properties of substances. This is illustrated by the extracts from assignment 2 below:

Figure 3.4

Extracts instructions of the second writing assignment

Assignment 2

Physical properties and intermolecular forces

1. Describe in not more than TWO hand-written pages, how intermolecular forces affect the physical properties of materials and substances.

Introduction

First, explain what are physical properties and provide background about the relationship between physical properties and intermolecular forces. Give examples of physical properties. (10)

Physical properties in relation to intermolecular forces

Discuss the following physical properties and describe how the strengths of intermolecular forces affect these physical properties with relevant examples. (15)

- Boiling point
- Melting point
- Molecular mass

Conclusion

In your conclusion give your own views about what you discussed in this essay about applications of physical properties in relation to intermolecular forces. (5)

TOTAL: 30 MARKS

The physical properties discussed in the second assignment were boiling point, melting point and molecular mass. The learners were provided with the rubric shown below to assess their fellow learners.

Table 3.8

Rubric for assignment 2

RUBRIC: Writing assignment 2

CRITERIA	Excellent	Good	Average	Fair	Poor
Introduction (10)	Define physical properties (2) provide a brief background about the relationship between physical properties and intermolecular forces. (5) Give some examples of physical properties not mentioned in the assignment (3) **Total: 10 marks**	Does not define physical properties (2) **BUT does:** provide a brief background about the relationship between physical properties and intermolecular forces. (5) Give some examples of physical properties not mentioned in the assignment (3) **Total: 8 marks**	Define physical properties (2) provide a brief background about the relationship between physical properties and intermolecular forces. (5) **But does not:** Give some examples of physical properties not mentioned in the assignment (3) **Total: 7 Marks**	**Get one of the three right:** Define physical properties (2) Provide a brief background about the relationship between physical properties and intermolecular forces. (5) Give some examples of physical properties not mentioned in the assignment (3) **Total: 2-5 marks**	**Does not:** define intermolecular forces (IMF) (2) Describe the importance of IMF in daily lives (4) Outline the difference between intermolecular forces and intramolecular forces (4) **Total: 0**
Types of intermolecular forces (25)	Describe the 3 physical properties in relation to intermolecular forces with examples (5x3) **Total: 15 marks**	Describe the 2 physical properties in relation to intermolecular forces with examples (5x2) **Total: 10 marks**	Describe the 3 physical properties in relation to intermolecular forces **without** relevant examples **Total: 7marks**	Describe the 1 physical properties in relation to intermolecular forces with examples (5x1) **Total: 5 marks**	Does not show understanding of intermolecular forces in relation to physical properties. Replicates definitions **Total: 2 marks**
Conclusion (5)	Own views about physical properties in everyday life (2) How it applies within own community (3) **Total: 5 marks**	Does not describe: Own views about physical properties in everyday life (2) But describe: How the knowledge applies within own community (3)? **Total: 3 marks**	Describe: Own views about physical properties in everyday life (2) But does not explain: How the knowledge applies within own community (3) **Total: 2 marks**	Replicate definitions without prior context **Total: 1 mark**	No conclusion **Total: 0**

After the grading of the second assignment, the teacher moderated the marked assignments and the learners received the feedback. The actual teaching of physical properties and intermolecular forces continued using the WTL study guide.

3.8.4 Summative assessment through the post-test and the interviews

The last phase was the implementation of summative assessment, often referred to as assessment of learning. On the distinction between summative assessment (assessment of learning) and formative assessment (assessment for learning) Bloom (1969) states that formative assessment is aimed at providing feedback and remediation at each stage in the teaching and learning process, and summative assessment is employed to judge what the student had achieved at the end of a course or programme.

The two writing assignments and the informal writing-to-learn activities in the study guide were formative assessment tasks aimed at giving learners feedback so that they could improve their understanding of intermolecular forces. On the other hand, the post-test served a summative assessment purpose to determine the effectiveness of writing-to-learn strategies in improving learner academic performance. The implementation of the post-test was followed by interviews conducted with the teachers and focus group interviews conducted with the learners. At the end of data collection process, learners in the control group received the WTL study guide as supplementary study material. As the researcher is a former science teacher by profession, afternoon classes were organised for the control group to clarify the IMF concepts for the learners using the same WTL study guide.

3.8.5 Traditional teaching approaches for the control groups

The control group was taught at the same period of the intervention, along with the experimental group. These learners were at the same school but in different classes taught by the same teachers who taught the experimental groups. The control group learners used the normal traditional textbook used in the school, and the activities were taken from these textbooks. On the other hand, the experimental group used the WTL study guide which included in-class writing activities and writing assignments which were not included for the control group. The teachers ensured that the control group did not have access to the WTL study as it was part of the intervention. The control group only participated in the Intermolecular forces tests in the form of a pre- and post-test. They were only exposed to the WTL materials after the intervention was implemented.

3.8.6 Potential threats to validity

Threats to validity in this study refers to the extent to which the researcher would be certain that the findings of the research were solely due to the comparative effects of the WTL strategies and the traditional teaching approach (Owusu, 2015). Possible threats to validity can include experimental mortality where learners withdraw from participating in the study (Kazeni, 2012) as well as contamination. Contamination can happen where learners from different groups borrow each other's study materials. To avoid experimental mortality the researcher outlined expectations and the importance of participating in the study.

During the first month of the intervention the researcher spent time visiting the schools and building relationships to ensure that the learners and teachers took ownership of the study. One reason for using cluster sampling in this study was to ensure that the researcher could regularly visits the schools and attend classes with the teachers as much as possible. Regular visit to the schools addressed the internal validity issues that can contaminate research. The reason for having both the control groups and the experimental groups in one school was to ensure that learners in each of the three schools were exposed to a similar environment. The learners had an opportunity to be taught by the same teacher from the same textbooks used in each school, and the same resources such as classroom environment and laboratories.

3.9 Data analysis

In this section, I report on how the quantitative and qualitative data were analysed. The quantitative data was drawn from the pre- and post-test achievement scores while the qualitative data was drawn from the interviews conducted with teachers and the focus group interviews conducted with the learners. The participants in this study were 317 Grade 11 Physical Sciences learners and their five teachers responsible for teaching the learners in the participating schools.

3.9.1 Quantitative data analysis

The quantitative data of this study comprised pre- and post-test achievement scores which were drawn from the intermolecular forces test, and the data was analysed using both descriptive and inferential statistics. For descriptive statistics, the data was analysed by comparing frequencies, percentages scores, means, standard deviations, for both the pre- and post-tests. For inferential statistics, analysis of variance

(ANOVA) was used to compare the mean scores of the pre-test for both the experimental group and the control group. The aim was to investigate if there was a difference in performance between the two groups before the intervention. According to Miller et al., (2002), ANOVA is concerned with comparing whether the average values or levels of one variable differ significantly across all categories from another variable. This is calculated by observing how the values that make up the means in each category are dispersed. This was necessary as it assisted in determining the significant differences between the academic performance of the control group and the experimental group before the intervention. It also assured that the control and experimental groups from the three schools performed at the same level before the implementation of the intervention.

An analysis of covariance (ANCOVA) was then implemented to investigate the extent to which extent the treatment affected the academic performance of the learners. According to McMillian and Schumacher (2014), ANCOVA serves two purposes. First, it helps to adjust the initial group differences statistically for one or more variables that are related to a dependent variable. Second, it helps to increase the possibility of finding the significant differences between the mean of the group. Furthermore, in examining the conditions for using an ANCOVA, McMillan and Schumacher emphasise that it can be used with two groups and one independent variable in place of a t-test. Alternatively, it can be used with one independent variable that has more than two groups instead of a one-way ANOVA. Lastly, it can be used for the factorial analysis of variance. The study implemented the third alternative where there were two independent variables in the study as illustrated in Table 3.8 below:

Table 3.9

Study variables

	Variable type	Variables
1	Independent variable	1.1 WTL strategies 1.2 Traditional approaches
2	Depended on variables	2.1 Overall achievement in the topic of intermolecular forces 2.2 Achievement in questions requiring an understanding of basic concepts. 2.3 Science inquiry skills 2.4 Achievement of boys versus girls
3	Control variable	3.1 School environment

The purpose of the ANCOVA was to address the four null hypotheses identified in the study, as illustrated below:

- $H_0$1: There will be no significant difference in performances between the learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning overall academic achievement in the topic of intermolecular forces.
- $H_0$2: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners define and explain science concepts in the topic of intermolecular forces.
- $H_0$3: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners respond to questions requiring intermolecular forces science inquiry skills.
- $H_0$4: There will be no significant differences in achievement between boys and girls in the post-test for the experimental group and the control group after they have been engaged in writing-to-learn strategies in the topic of intermolecular forces.

In a nutshell, the ANCOVA was implemented to adjust initial experimental and control group differences statistically through using the pre-test achievement scores as covariance. It was also used to analyse the tests since it enables one to reduce contamination and covariates. For all the testing of all the null hypotheses in this study, a p-value of equals to or less than 0.05 ($p \leq 0.05$) was considered statistically significant at a 5% significant level. This means that any value greater than 0.05 was considered not statistically significant.

3.9.2 Qualitative data analysis

Qualitative data analysis involves beginning with a large body of information and through inductive reasoning, sorting and categorising the data (Leedy & Ormond, 2010). Devos et al., (2017) define qualitative data analysis as non-numerical examination and interpretation of observations to discover underlying meanings and patterns in relationships. Qualitative data analysis is considered a process of inductive reasoning and theorising and is treated as both an art and a science.

In analysing the data from both the interviews and focus group interviews, the audio recordings were transcribed and converted into written texts. Then the researcher established categories or themes from both interviews and focus group interviews. The extracted raw data was processed to further consolidate the research information base. Since the interviews were semi-structured with pre-determined questions, the researcher ensured that each response to a specific question was put into a category so that patterns could be identified in the categories.

Each of the themes comprised several texts which were carefully examined to establish the general views of the participants. The transcribing process was labour-intensive requiring careful examination of what the participants meant. What was notable was that some learners and teachers code-switched as they responded to the questions and in these instances, the text had to be translated into English. Most of the learners code-switched to isiNdebele and the teachers to IsiZulu.

3.10 Issues of validity and reliability of the instruments

Validity is the extent to which an instrument measures what it claims to measure. An instrument needs to be valid for the results to be accurately applied and interpreted. Reliability describes the overall consistency of an instrument; it is said to have high reliability if it produces similar results under consistent conditions. To ensure that the study guide, writing assignments and intermolecular forces were valid and covered the concepts of intermolecular forces, the researcher used the Curriculum and Assessment Policy Statement (CAPS) document for Physical Sciences. Work schedules provided by the Department of Education were used to determine the scope and content that should be covered. Physical Sciences textbooks approved by the Department of Basic Education were used as references in developing the instruments. The instruments were given to a Physical Sciences curriculum implementer in the district plus three heads of department from the participating schools, to validate if they covered the content of intermolecular forces. Further changes were made to the instruments after the consultations.

The instruments were also piloted with 32 learners from a school in Mpumalanga province to ensure that they were reliable. To test the reliability of the intermolecular forces test, the researcher utilised the test-retest reliability procedure with participants from the pilot study. According to Creswell (2012), test-retest reliability is a procedure that looks into the extent to which learner marks are stable over time after applying an instrument twice. The first test was administered to the learners, and after a month the same test was given to the same group of learners. The Pearson correlation coefficient was used to calculate the relationship between the two sets of marks and the results yielded a coefficient of 0.72. Researchers recommend a Pearson correlation coefficient of 0.7 or more for the instruments to be regarded as reliable (Kazeni, 2012). The data from the pilot study was used to check if the instruments measured what they were supposed to measure and to check if it would yield the same results if used with different groups of learners.

3.11 Ethical considerations

Ethical consideration is concerned with the fact that a researcher must be ethically responsible for protecting the rights and welfare of participants in a study. It includes informing participants about the purpose of the study, refraining from deceptive practices, being respectful of the research site, using ethical interview practices, maintaining confidentiality, and collaborating with the participants. The researcher complied with the above, informed consent was requested from the teachers, and permission was granted by the Education Department and the principals.

The learners had an opportunity to choose whether they wanted to participate in the study throughout the data collection. The researcher outlined the purpose of the research and indicated that participation was voluntary and that they could withdraw at any time. Consent was obtained by asking the parents of the participants to sign a form that indicated an understanding of the research and their consent. The participants agreed in writing after being informed of and understanding the risks that could be involved. Since most of the learners who were taking part in this research were under the age of 18, their parents were required to co-sign the consent forms

Like in all social science research, the researcher was mandated to protect the privacy of all the participants (Babbie, 2010). This means that access to the participants' information such as characteristics, responses, behaviour, and any other information that could make them identifiable would not be made public (Cohen et al., 2011). Booyse et al., (2011) state that confidentiality in research means that those studying or reading the research results will not be able to establish the identity of the participants based on their responses. In this research, numbers were used to represent the participants who were allocated numbers from 01 to 317. The same procedure was applied with the teachers who were also not identified by name or school name. This ensured that confidentiality was protected. The study was cleared by the UNISA research ethics committee and an ethical clearance certificate was issued.

3.12 Conclusion

This chapter described the research design used in the study to investigate the effectiveness of WTL pedagogies in the topic of intermolecular forces. It was done by giving a detailed description and justification of the selection as well as the use of the various data collection methods. These included selecting and locating the subjects, and data gathering via pre and post-test methods as well as a WTL study guide. The researcher highlighted the differences between qualitative and quantitative approaches and explained why he opted to use both approaches instead of just one.

The following chapter presents the findings obtained from each of the research instruments. From these findings, a profile of the investigation was created so that conclusions could be drawn and recommendations made.

CHAPTER 4: STUDY RESULTS

4.1 Introduction

The current study was aimed at investigating the effectiveness of writing-to-learn pedagogies to enhance academic performance and science inquiry skills in the topic of intermolecular forces. This chapter focuses on the analysis and presentation of quantitative and qualitative data. The quantitative data was collected through the intermolecular forces test in a form of the pre- and post-tests. The qualitative data were collected through interviewing individual Physical Sciences teachers in the participating schools and focus group interviews were conducted with learners.

4.2 Quantitative Data analysis

The first research question looked into how effective WTL is in improving academic performance compared with traditional pedagogies. To be able to answer this question an intermolecular force test in the form of pre- and post-tests was administered to learners. The pre-test was aimed at assessing the learners' prior knowledge before the topic was taught. The post-test which was identical to the pre-test was administered after the interventions. Table 4.1 below shows the structure and description of the test.

Table 4.1

Pre/post-test question types and descriptions

Question	Type	Description	Weight
1	Multiple choice	Generally, focus on how learners identify types of intermolecular forces from a compound/molecule	18% (8 marks out of 44)
2	Open-ended (explanation questions)	Open-ended questions requiring students to explain basic concepts with some examples.	36% (16 marks out of 44)
3	Question focusing on scientific inquiry skills	Contextual questions requiring students to interpret data from an experiment and to give an account	23% (10 marks out of 44)
4	Question focusing on scientific inquiry skills	Contextual questions requiring students to interpret data from an experiment and to give an account	23% (10 marks out of 44)

The first two questions in the pre-test were based on an understanding of the basic concepts in intermolecular forces content knowledge. The first question which was a multiple-choice question comprised four questions where learners were expected to identify different intermolecular forces in different molecules. These forces were induced-dipole forces, dipole-dipole forces and hydrogen bonds. The Department of Education Curriculum and Assessment Policy Statement indicates that Physical Sciences promotes knowledge and skills in scientific inquiry and problem-solving, the construction and application of scientific and technological knowledge, and an understanding of the nature of science and its relationships to technology, society and the environment. Therefore, the focus of these multiple-choice questions was on enhancing knowledge of the topic. Multiple-choice questions were included to follow the basic structure of the Physical Sciences question paper, which ensured that the control group would not be disadvantaged. The DBE examination papers for Physical Sciences start with multiple choice questions followed by open-ended questions. This was also necessary as the study aimed to compare the overall performance of both groups after the intervention.

The second question which comprised open-ended questions required learners to explain concepts using their own words with examples. The first question, for example, required learners to differentiate between intermolecular and intramolecular forces and to give examples. Making comparisons is one of the science process skills identified in the CAPS document. The purpose of this question was therefore specifically to enhance this skill because students need to be able to differentiate between concepts and make comparisons. The other questions required learners to explain dipole-dipole forces, induced-dipole forces, and hydrogen bonds. The focus was on strengthening their knowledge of basic concepts. According to the Natural Sciences CAPS document for the senior phase (Grades 7-9) learners are required to be able to access and recall information, be able to use a variety of sources to acquire information, to remember relevant facts and key ideas, and to build a conceptual framework.

The third and fourth questions focused on developing science inquiry skills. Scientific inquiry is an important concept in science, and although closely related to science process skills it goes beyond the latter by combining process skills with scientific knowledge, scientific reasoning and critical thinking (Luderman, Antink, & Bartos, 2014).

Inquiry skills were addressed in an integrated way and addressed in different questions. For example, in question 3.1, learners were asked to write down an investigation question for the stated experiment. To write an investigation question, learners need to identify independent and dependent variables. Question 3.2 required students to explain why some compounds have higher boiling points than others with reference to intermolecular forces. They were expected to fully explain their answers based on the investigation provided in the explanation. This means they were expected to use their knowledge of intermolecular forces to make decisions and draw conclusions. In question 4.1 learners were expected to formulate a hypothesis for a scenario of compounds with different molecular masses. Notably, there were two questions in which students were expected to fully explain and give reasons for their answers. These questions required extended explanations and higher-order skills and were identified as problematic in the diagnostic reports. Four null hypotheses were formulated for the first two research questions:

- $H_0$1: There will be no significant difference in performances between the learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning overall academic achievement in the topic of intermolecular forces.
- $H_0$2: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners define and explain science concepts in the topic of intermolecular forces.
- $H_0$3: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners respond to questions requiring intermolecular forces science inquiry skills.
- $H_0$4: There will be no significant differences in achievement between boys and girls in the post-test for the experimental group and the control group after they have been engaged in writing-to-learn strategies in the topic of intermolecular forces.

4.2.1 Attainment of intermolecular forces content knowledge

Research question 1

- How will the academic performance between learners exposed to writing-to-learn pedagogies and those exposed to traditional pedagogies differ concerning overall academic achievement in intermolecular forces, science inquiry skills, and how students define and explain basic concepts in the topic of intermolecular forces?

Null Hypothesis

- $H_0$1: There will be no significant difference in performances between the learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning overall academic achievement in the topic of intermolecular forces.

The results for the research question and hypothesis in the pre- and post-tests are provided by in a summary of the results. There were 154 learners in the control group and 163 learners in the experimental group. In total 317 learners, participated in the study, 194 were females and 123 males, taught by five teachers from the three schools. There were 149 learners from school A, 98 learners from school B, and 70 learners from school C. Table 4.2 presents a summary of the results for both the control group and the experimental group.

Table 4.2

Summary of results for the pre-test and post-test

Control Group					
Tests	N	Mean*	Std deviation	F-Value	Sig
Pre-test	154	4.53	2.37	0.337	0.564
Post-test	154	14.45	12.031	65.54	0.000
Experimental Group					
Tests	N	Mean	Std deviation	F-Value	Sig
Pre-test	163	4.58	2.38	0.334	0.554
Post-test	163	24.96	11.388	65.54	0.0012

*Marks calculated out of 44

Key: N: Number of learners

Table 4.2 shows that the mean scores for the control group and the experimental group for the pre-tests were 4.43 and 4.58 respectively. The results from the analysis of variance (ANOVA) of the pre-test mean scores which compare learner performances before the interventions, are presented in Table 4.3 below.

Table 4.3

Pre-test results

Groups	ANOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	154	4.53	2.37	0.334	0.564
E	163	4.58	2.38		
Total	317	4.51	2.37		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

Table 4.3 shows that the results for comparing the pre-tests of the control and experimental groups were not statistically significant (F=0.334 and p=0.564). This indicates that there were no differences in the academic performance of the learners in the control and experimental groups before the intervention. The results of the pre-test were also compared according to schools.

Table 4.4

Pre-test results School A

Groups	ANOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	74	4.28	2.187	0.284	0.595
E	75	4.45	2.591		
Total	149	4.39	2.393		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

Table 4.4 indicates that there was no significant difference in performance between the control and experimental groups before the intervention (F=0.284 and p=0.595) for School A. This is similar to the results for the overall performance in all three schools. A similar trend is evident in the results for school B illustrated in Table 4.5.

Table 4.5

Pre-test results School B

Groups	ANOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	48	4.31	2.442	0.551	0.460
E	50	4.64	1.903		
Total	98	4.48	2.179		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

The results for school B as indicated in Table 4.5 show that there was no significant difference in performance between the control and experimental groups with mean scores of 4.31 and 4.64 respectively (F=0.551 and p=0.460). This indicates that before the intervention there was no significant difference in performance between these groups. Table 4.6 shows similar results for school C.

Table 4.6

Pre-test results School C

Groups	Pre-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	32	4.94	2.675	0.163	0.687
E	38	4.68	2.559		
Total	70	4.80	2.597		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

Out of the three schools and the overall performance for the schools combined, the results indicate similar performances which shows that there were no significant differences between the groups before the learners were taught this topic. Figure 4.1 below compares the mean scores of the three schools for the pre-test.

Figure 4.1:

Pre-test comparison per school

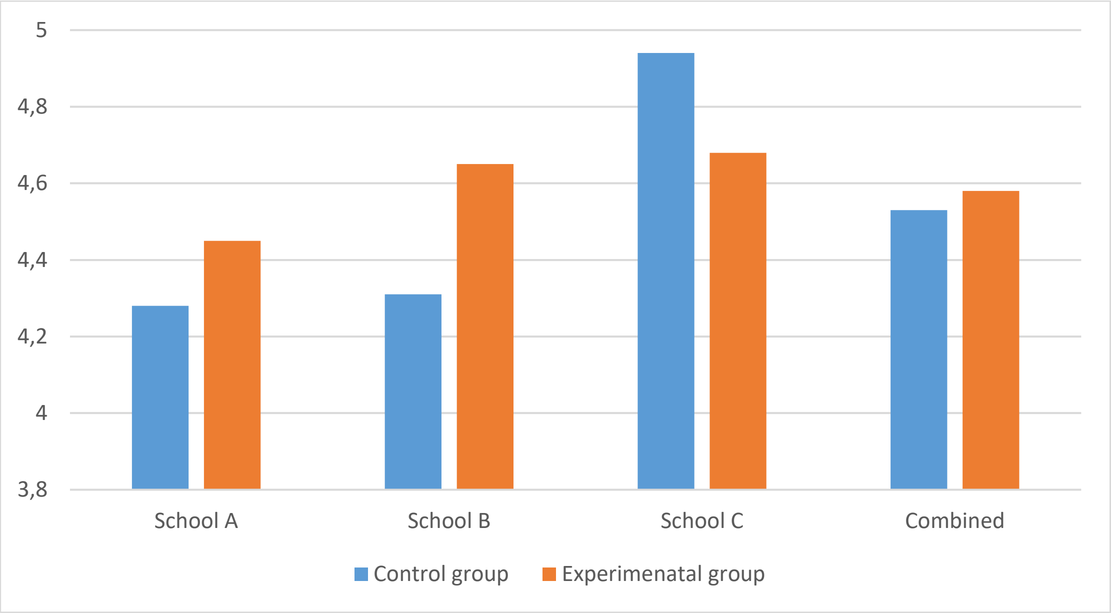


Figure 4.1 indicates that the mean scores for the pre-test in the three schools ranged from 4.28 to 4.95 (9.73% - 11.38%). This indicates that learners were not familiar with the topic before the intervention. The pass rate for Physical Sciences in FET was 30%. The figure below indicates the overall performance in the pass rates.

Figure 4.2

Pre-test Learner performance according to the pass rate

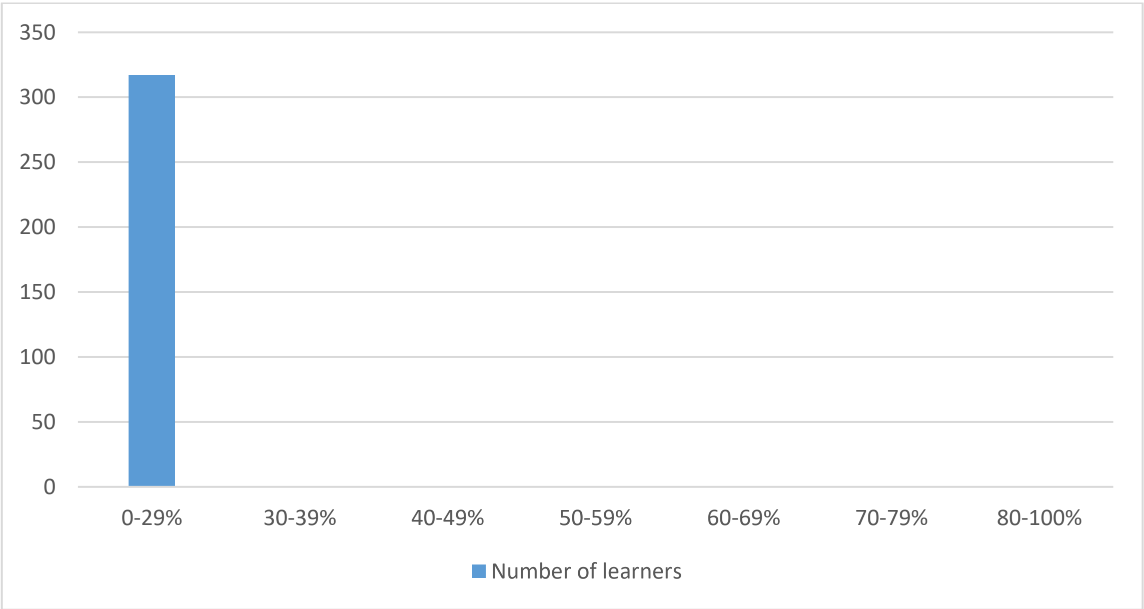


Figure 4.2 shows that all 317 learners performed below 30% indicating they had little or no prior knowledge before the intervention. However, after they were taught, Figure 4.3 shows that the mean scores for the control group improved from 4.53 to 14.45 and for the experimental group from 4.58 to 24. 96.

Figure 4.3:

Comparison of the pre-test and post-test mean score

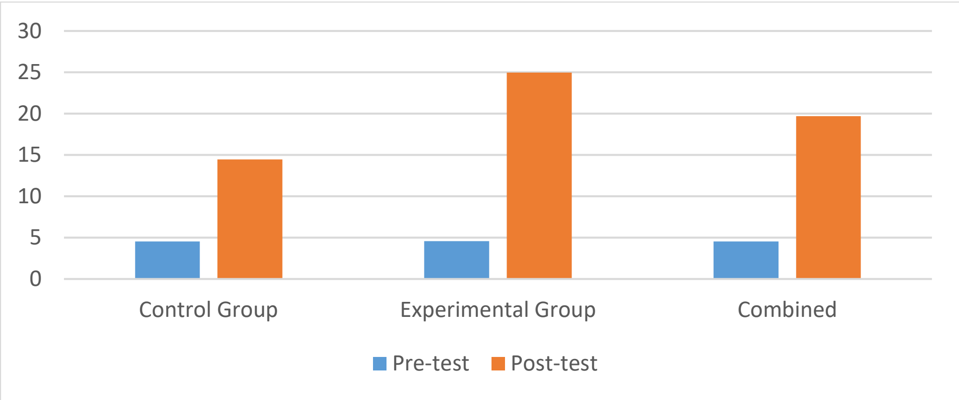


Figure 4.3 compares the pre- and post-test results for both groups and shows that there was an improvement after they had been exposed to the topic although the control group was taught through traditional pedagogies while the experimental group incorporated writing-to-learn strategies. Table 4.7 compares the results for the control group and the experimental group through the ANCOVA results.

Table 4.7

Overall post-test results

Groups	ANCOVA Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	154	14.45	12.031	65.54	0.0012
E	163	24.96	11.388		
Total	317	19.85	12.814		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

Table 4.7 shows that after the intervention there were significant differences between the mean scores and standard deviations of the experimental and control groups (F= 65.54 and $P<0.05$) in favour of the experimental group. The mean scores for the post-test in the control group and the experimental group were 14.45 and 24.96 respectively in favour of the experimental group ($p<0.05$). The results were further analysed according to schools using the ANCOVA. Table 4.8 shows the results for school A.

Table 4.8:

Post-test overall results School A

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	74	14.16	11.644	29.142	0.00132
E	75	24.21	11.101		
Total	149	19.22	12.406		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

Table 4.8 still indicates statistically significant results for school A in favour of the experimental group with mean scores of 14.16 for the control group and 24.21 for the experimental group (F=29.42, $P<0.05$). The results indicate that after the intervention, the experimental group outperformed the control group in terms of performance in the topic of intermolecular forces. This trend is also evident as indicated in Table 4.9 for school B.

Table 4.9

Post-test overall results School B

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	48	15.27	12.155	16.747	0.001
E	50	25.12	12.285		
Total	98	20.30	13.127		

*Marks calculated out of 44

Key:

C: Control group

E: Experimental group

N: Number of learners

The results for school B show similar results to School A. The mean score for the control group was 15.27 and 25.12 for the experimental group (F=16.747 and p<0.05). This shows that the results for school B were statistically significant in favour of the experimental group for school B. School C showed similar results: see Table 4.10.

Table 4.10

Post-test results School C

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	32	13.91	13.022	18.545	0.0012
E	38	26.21	10.895		
Total	70	20.95	13.340		

*Marks calculated out of 44

Key:

C: Control group

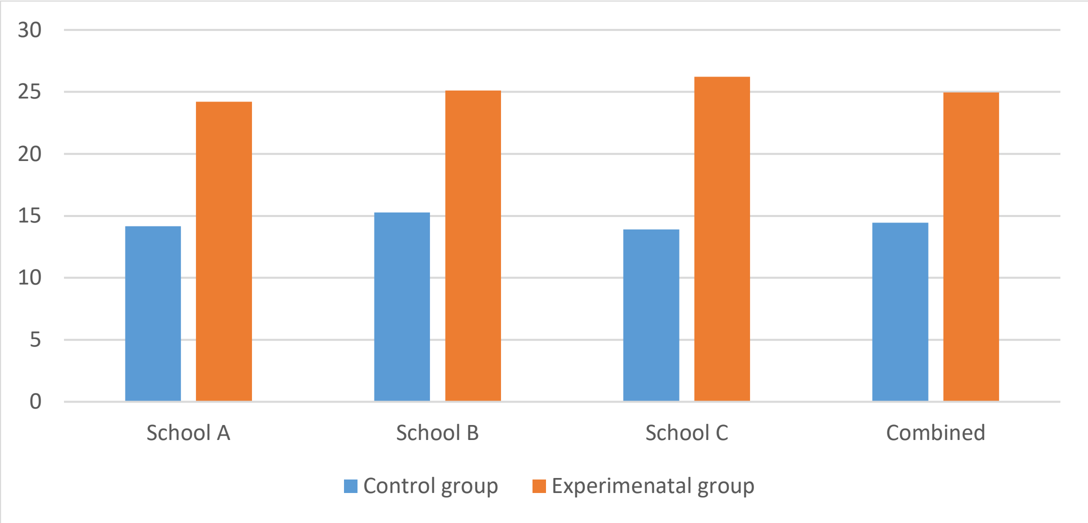
E: Experimental group

N: Number of learners

Table 4.10 indicates statistically significant results for school C in favour of the experimental group (F=18.545 and p<0.05). This indicates that the experimental group outperformed the control group regardless of school. The summary of school performances for the three schools and the combined mean scores are shown in Figure 4.3 below.

Figure 4.4

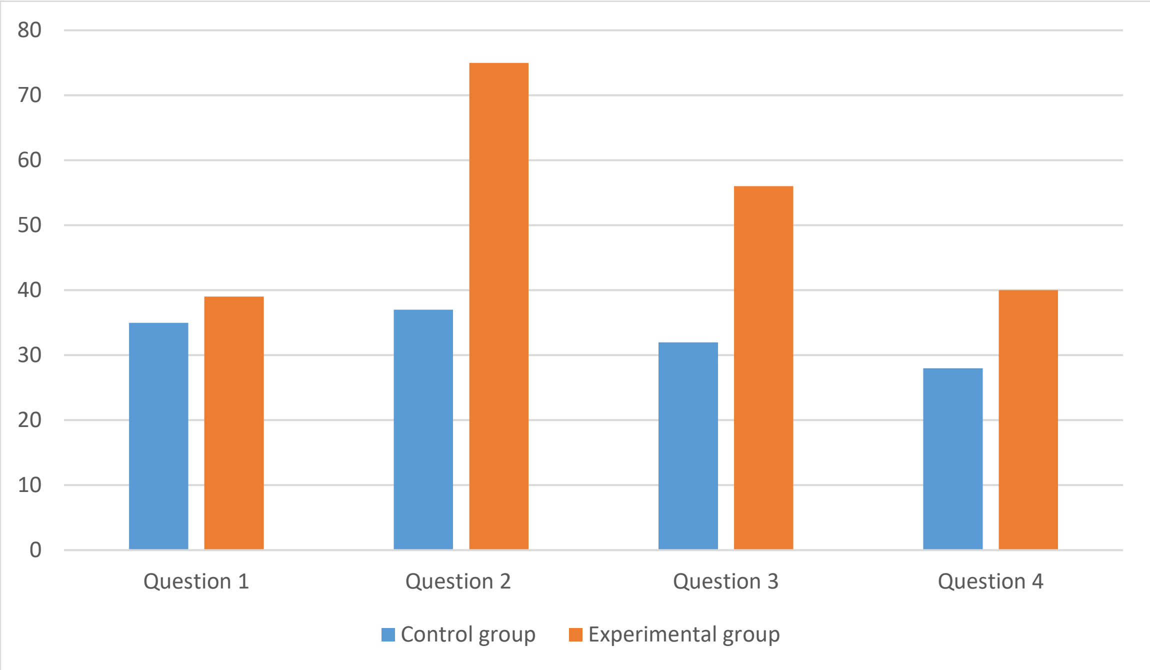
Summary of post-test mean scores per school



The summary in Figure 4.4 shows that the experimental group outperformed the control group in overall performance and per school. This shows that learners who participated in writing-to-learn teaching strategies performed better than the learners who participated in traditional teaching methods. Incorporating writing strategies in the teaching of intermolecular forces can thus have positive effects.

Figure 4.5

Item analysis per question for the control group and experimental group



*Mean scores calculated in percentage

For question 1 which consisted of multiple-choice questions, the control group obtained a mean score of 35% and the experimental group 39%. Here both groups achieved comparable results. For question 2, which comprised conceptual questions requiring explanations and understanding of basic concepts, the control group scored 37% and the experimental group scored 75%. This shows the benefits of writing-to-learn strategies as these questions required students to write scientific explanations in which they explained the concepts in their own words with some examples. The diagnostic reports indicate that students do not understand basic concepts well, and it was hoped that encouraging them to write would strengthen conceptual understanding. This is supported by Shibley and Milakofsky (2001) who submit that writing assignments help to enhance learner content knowledge as they discover the application of content themselves through engaging in the assignments.

In questions 3 and 4, which were contextual questions, the experimental group outperformed the control group. These required problem-solving and inquiry skills.

4.2.2 Comparing overall performance according to gender

Research question 2

- What will the achievement scores of girls compared to boys in the post-test be after they engaged in writing-to-learn pedagogies and traditional teaching methods?

Null hypothesis

- $H_0 4$: There will be no significant differences in achievement between boys and girls in the post-test for the experimental group and the control group after they have been engaged in writing-to-learn strategies in the topic of intermolecular forces.

The second research question looked into the performance of girls and boys in the control and experimental groups. There were 194 girls and 123 boys who participated in the study. Table 4.11 shows the overall performance of girls and boys in the post-test. An ANCOVA was used to analyse the results.

Table 4.11

Post-test Gender

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
F	194	20.36	13.022	0.821	0.365
M	123	19.06	10.895		
Total	317	19.85	12.814		

*Marks calculated out of 44

Key:

F: Females

M: Males

N: Number of learners

Table 4.11 shows that the mean score for girls was 20.36 with a standard deviation of 13.022 and the mean score for boys 19.85 with a standard deviation of 12.814. The table indicates that there was no significant difference between boys and girls with a p-value greater than 0.05 (F=0.821 and p=0.365). The results mean that the null hypothesis was accepted; there was no significant difference between the two groups. Table 4.12 compares the performance of girls and boys in school A.

Table 4.12

School A Post-test Gender

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
F	88	20.05	13.022	0.947	0.336
M	61	18.30	10.895		
Total	149	19.22	12.406		

*Marks calculated out of 44

Key:

F: Females

M: Males

N: Number of learners

For school A, the performance of girls was 20.05 with a standard deviation of 13.022 (n=88), and for boys the mean score was 18.30 with a standard deviation of 10.406 (n=61). The results also show that there was no significant difference between the performance of girls and boys (F=0.947 AND p=0.336). Table 4.13 shows the performance of girls and boys.

Table 4.13

School B Post-test Gender

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
F	69	20.16	13.166	0.035	0.851
M	29	20.62	13.260		
Total	98	20.30	13.127		

*Marks calculated out of 44

Key:

F: Females

M: Males

N: Number of learners

Similar results as school A are indicated for school B in Table 4.12. Mean scores of 20.16 and 20.62 are indicated for girls and boys respectively. There were no significant differences between the performance of girls (n=69) and boys (n=29) in school B (F=0.035 and p=0.851). Table 4.14 shows the results for school C.

Table 4.14

School C Post-test Gender

Groups	Post-test				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
F	37	21.49	12.829	0.616	0.435
M	33	19.58	14.020		
Total	70	20.59	13.340		

*Marks calculated out of 44

Key:

F: Females

M: Males

N: Number of learners

Similar results can be observed for School C as in School A and School B in Table 4.13. There was no significant difference in performance between girls (n= 37, M=21.49) and boys (n=33, M=19.58) with a p-value greater than 0.05 (F=0.616, p=0.435). The comparison indicates that there was no disadvantaged group in terms of gender. Both groups had equal opportunity regardless of the teaching method employed.

4.2.3 Attainment of science inquiry skills

An analysis of learner performance in science process skills was undertaken using ANOVA and ANCOVA. The purpose of the ANOVA used in the pre-test was to investigate learners' prior knowledge of science inquiry skills. The following null hypothesis was used to assess this:

- $H_0 3$: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners respond to questions requiring intermolecular forces science inquiry skills.

Science inquiry skills are important as they focus on the practical aspects of science, and are examined as experimental scenarios or experimental case studies. This was covered in questions 3 and 4 of the intermolecular forces test. Table 4.15 shows the performance of the learners in science inquiry skills before the intervention.

Table 4.15

Pre-test results for Science Inquiry skills

Groups	ANOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	154	2.18	1.888	0.007	0.966
E	163	2.17	1.911		
Total	317	2.17	1.897		

*Marks calculated out of 20

Key:

C: Control group

E: Experimental group

N: Number of learners

The results from the pre-test show that the performance of the learners before the intervention concerning science inquiry skills for both groups was non-significant. This means that their science process inquiry skills in the topic of intermolecular forces before the intervention were similar; the null hypothesis was not rejected. This is indicated by a p-value greater than 0.05 and a very small F value (p=0.996 and F=0.007). Table 4.16 shows the results after the intervention.

Table 4.16

Post-test results Science Inquiry skills

Groups	ANCOVA				
	N	Mean	Std deviation	F-value	Sig
C	154	5.87	5.313	40.600	0.001
E	163	9.83	5.723		
Total	317	7.91	5.865		

*Marks calculated out of 20

Key:

C: Control group

E: Experimental group

N: Number of learners

Table 4.16 shows statistically significant results in favour of the experimental group. The mean score for the control group was 5.87 and for the experimental group 9.83, which is statistically significant (P<0.05 and F=40.600). This shows that the experimental group performed well in questions that required science inquiry skills in the topic of intermolecular forces. The results were further analysed according to schools. Table 4.17shows the results for school A.

Table 4.17

School A Post-test Science Inquiry skill

Groups	ANCOVA				
	N	Mean	Std deviation	F-value	Sig
C	74	5.19	5.189	22.814	0.0012
E	75	9.37	5.572		
Total	149	7.30	5.763		

*Marks calculated out of 20

Key:

C: Control group

E: Experimental group

N: Number of learners

There were 74 learners in the control group and 75 learners in the experimental group for school A. The results show statistically significant results in favour of the experimental group. The mean scores for the control and experimental groups were 5.19 and 9.37 respectively with a statistical significance of less than 0.05 ($P < 0.05$ and $F=22.814$). Table 4.18 for school B shows similar trends.

Table 4.18

School B Post-test Science Inquiry skills

Groups	ANCOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	48	6.08	5.027	11.272	0.014
E	50	9.37	6.144		
Total	98	8.04	5.919		

*Marks calculated out of 20

Key:

C: Control group

E: Experimental group

N: Number of learners

The results for science inquiry skills in the topic of intermolecular forces for school B shows statistical significance with a mean score of 6.08 for the control group and 9.37 for the experimental group. This indicates that for school B, the experimental group outperformed the control group in science process skills. Table 4.19 shows the results for school C.

Table 4.19

School C Post-test Science Inquiry skills

Groups	ANCOVA				
	N	**Mean**	**SD**	**F-value**	**p-value**
C	32	7.12	5.901	6.852	0.003
E	38	10.63	5.499		
Total	70	9.03	5.912		

*Marks calculated out of 20

Key:

C: Control group

E: Experimental group

The results for school C show similar trends to schools A and school B. The table shows statistically significant results in favour of the experimental group with mean scores of 7.12 and 10.63 for the control group and experimental group respectively.

4.2.4 Understanding IMF basic concepts through scientific explanations

Attainment of basic concepts through scientific explanations focus on how learners define basic concepts using their own words and was covered in question 2 of the intermolecular forces test. This is referred to as conceptual knowledge, which is about knowledge of principles, theories, and generalisation in the topic. The open-ended question covered a total of 16 marks, and learners had to show their understanding of the basic concepts. At the same time, the questions were focused on how learners structure scientific explanations. Below is the null hypothesis:

- H_02: There will be no significant difference in performances between learners who are exposed to writing-to-learn strategies and those who are exposed to traditional pedagogies concerning how learners define and explain science concepts in the topic of intermolecular forces.

Table 4.20 shows the ANOVA results for the pre-test.

Table 4.20

Pre-test results on understanding of basic concepts

Groups	ANOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	154	4.97	3.471	0.244	0.622
E	163	4.79	3.079		
Total	317	4.87	3.280		

*Marks calculated out of 16

Key:

C: Control group

E: Experimental group

N: Number of learners

Table 4.20 indicates non-significant results for the understanding of basic concepts. This means that there was no significant difference between the experimental and control groups before the interventions; the groups performed at the same level with mean scores of 4.97 and 4.79 for the control group and the experimental group respectively ($p=0.622$ and $F= 0.244$). Table 4.21 shows the ANCOVA results after the intervention.

Table 4.21:

Post-test results on understanding of basic concepts

Groups	ANCOVA				
	N	Mean	Std deviation	F-value	Sig
C	154	6.05	6.428	79.798	0.001
E	163	12.67	5.917		
Total	317	9.24	6.905		

*Marks calculated out of 16

Key:

C: Control group

E: Experimental group

N: Number of learners

The ANCOVA results for the understanding of basic concepts show that there was a significant difference between the control group and the experimental group after the implementation of the writing-to-learn pedagogies for the experimental group, and traditional teaching methods for the control group. This means that the null hypothesis was rejected in favour of the experimental group with mean scores of 6.05 and 12.67 for the control group and experimental group respectively ($p<0.05$ and $F=79.798$). The results were further analysed according to schools to show the performance of the experimental group and control group in each school. Table 4.21 shows the results for school A regarding the understanding of basic concepts and how learners construct scientific explanations.

Table 4.22

School A Post-test on understanding of basic concepts

Groups	*ANCOVA*				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	74	5.88	6.277	33.708	0.004
E	75	11.84	6.213		
Total	149	8.88	6.245		

*Marks calculated out of 16

Key:

C: Control group

E: Experimental group

N: Number of learners

The results for school A are similar to the overall results for the understanding of basic concepts and writing ability. There was a significant difference in performance concerning the understanding of basic concepts through scientific explanations in favour of the experimental group. The mean score for the control group was 5.88 and the mean score for the experimental group 11.84 ($p<0.05$ and $F=33.708$). Similar results are observable in the results for school B.

Table 4.23

School B Post-test on understanding of basic concepts

Groups	**ANCOVA**				
	N	**Mean**	**SD**	**F-value**	**Sig**
C	48	6.08	6.493	23.041	0.003
E	50	12.22	5.913		
Total	98	9.19	6.903		

*Marks calculated out of 16

Key:

C: Control group

E: Experimental group

N: Number of learners

The results for school B results regarding the understanding of basic concepts indicate that there was a significant difference in performance between the control group and the experimental group. The mean for the control group was 6.08 and the mean score for the experimental group 12.22. This means that the experimental group outperformed the control group, and the results were statistically significant ($p<0.05$ and $F=23.041$). Table 4.24 shows the results for school C.

Table 4.24

School C Post-test understanding of basic concepts

Groups	ANCOVA				
	N	**Mean**	**Std deviation**	**F-value**	**Sig**
C	32	6.13	6.795	22.354	0.00
E	38	13.18	5.342		
Total	70	9.96	6.971		

*Marks calculated out of 16

Key:

C: Control group

E: Experimental group

N: Number of learners

The results show similar trends to school A and school B. There was a significant difference in performance for school C in both groups regarding the understanding of basic concepts and writing ability. The mean score for the control group was 6.13 and for the experimental group 13.18 ($p<0.05$ and $F=22.354$).

4.2.5 Discussion of quantitative results

The first research question interrogated the effectiveness of writing-to-learn pedagogies in improving academic performance compared with traditional pedagogies. To be able to answer this question, an intermolecular forces test was written by the learners focusing on overall performance, science inquiry skills, and understanding of basic concepts.

The ANOVA pre-test results showed that learners had little knowledge about the topic of intermolecular forces before the teaching of the topic, and their performance in all aspects was below average. The results thus indicated a non-significant difference in performance between the control group and the experimental group in the pre-test. This means that the learners from both groups were on equal footing before the teaching of the topic. However, after the teaching of the topic, both groups recorded a significant improvement. The ANCOVA results showed that there was a significant difference in performance between the groups in favour of the experimental group. This means that learners who were exposed to writing-to-learn pedagogies showed significantly better content knowledge in the topic of intermolecular forces. As indicated by Fry and Villagomez (2012), WTL strategies are beneficial when learners are exposed to writing tasks that promote metacognition. The writing tasks that learners were exposed to in this study promoted metacognition as discussed in previous chapters.

The trend of better performance by the experimental group continued when an analysis was done for each school. The experimental group showed a significant grasp of content knowledge and attainment of science inquiry skills in each school even though the students were from different environments and taught by different teachers. This was also evident when an item analysis was done. The item analysis indicated that the experimental group performed significantly better in questions requiring conceptual understanding and extended explanations.

For learners to understand Intermolecular forces, they need to understand that the microscopic mental model of matter is composed of particles that are in constant motion; atoms, molecules and ions. When they think about intermolecular forces, they need to be able to relate them to physical properties such as boiling points, melting points and viscosity. Involving them in writing enhances their content knowledge in the subject. The findings of Shibley and Milakofsky (2001) indicated that when learners are engaged in writing in chemistry class, they become actively involved in learning and realise that they need to take ownership of the process. This means that learners are actively involved in building mental models for intermolecular forces at microscopic, macroscopic and symbolic levels.

Science inquiry skills are not explicitly taught in science classes, but most of the time questions requiring science inquiry skills are incorporated in the teaching of the topics. What is interesting is that these questions form the bulk of the questions in physical science question papers. For example, learners may be asked to write an investigative question or a hypothesis, or to summarise the findings in a particular scenario. Learners struggle with these types of questions as they require language facility, particularly writing skills. The study guide provided to learners included examples of questions that focus on inquiry skills. The results indicated that there was a significant difference between the performance of the two groups in favour of the experimental group. The science inquiry skills of the learners engaged in writing-to-learn in science class, also improved.

The second research question interrogated the performance of learners in the topic of intermolecular forces by gender. The results indicated that there were no significant differences between the performance of boys and girls in the topic. Although there was a slight difference with girls performing one mark higher than boys, the ANCOVA results show that there was no significant difference in performance between the two groups.

This indicates that girls and boys have more or less the same interpretation of the topic of intermolecular forces. Notably, in this study there were more girls than boys indicating that more girls are taking science subjects than boys. Gender nevertheless has nothing to do with how learners perform in chemistry, and the thought processes in both groups are the same. Transformative pedagogies such as WTL have the power to close the gender gap on learner performance. Girls have always been underrepresented in disciplines like science, especially in African culture where the role of girls is associated with caregiving and looking after children (Ansell, 2002) However, the advent of democracy in South Africa has ensured that girls are given equal opportunities to boys by encouraging them to participate in economic activities.

4.3 Qualitative Data analysis

Qualitative data was drawn from the teachers' interviews and learners' focus group interviews. The purpose of both these was to discover teachers' and learner's views and experiences about the implementation of the WTL in the Physical Sciences classroom. Five teachers participated in the interviews: two each from school A and B and one from school C.

Five groups were interviewed from the three schools for the focus group interviews. In school A, two interviews were conducted, in school B also two, and in school C one focus group was conducted. The reason for one interview in school C was that few learners in the school participated in the study. The groups ranged from 7-9 learners in each school and a total of 39 learners participated in the focus group interviews. The learners were randomly selected; and the groups had a fair distribution concerning gender.

4.3.1 Teachers interviews

The five teachers who were involved in the study were interviewed. The interviews were audio-recorded and later transcribed. In some cases, the teachers code-switched to their home languages for explanations which were then translated into English. Six themes were established from the qualitative data and are as follows:

- Intermolecular forces is a difficult topic with many concepts to define
- Many learners struggle with questions requiring extended explanations
- Language, especially English as an LoLT is still a challenge
- Writing as an aspect of language is a big challenge for most of the learners
- Learners benefitted from the WTL programme
- The WTL programme can be implemented in other Physical Sciences topics and other subjects

Intermolecular forces is a difficult topic with many concepts to define

This theme focused on teachers' views about teaching intermolecular forces and the nature of learning the topic that contains many concepts requiring definitions and extended explanations. The aim was also to discuss the nature of the topic and how best it can be taught. Below are extracts from the teachers:

Teacher B

Intermolecular forces is difficult to the students, because it requires students to do the explanations, is not the same as other topics like stoichiometry. I don't like teaching this topic because it requires that I explain a lot to students and as scientists we are not good at that. The sad part is that the topic continue in grade 12 when they do organic chemistry and they still struggle especially with the physical properties of *organic compound. Our learners are not good in writing explanations, they are good in calculating and this creates a problem for us as we are not prepared for this like they do in the social studies and other subjects.*

Teacher B stated that intermolecular forces is a difficult topic for learners as it contains many terms that they have to explain. He indicated that he does not like teaching the topic since it is conceptual, and scientists are not used to explaining concepts. He confirmed the importance of the topic and its applications in organic molecules which is a topic taught in Grade 12. Teacher E had similar views:

Teacher E

Hey my brother its difficult indeed. For teachers we find it easy, but for this generation of students they are not good in learning this topic. What makes it worse is that the topic needs students to explain concepts in relation to physical properties and they seem not to understand and therefore it makes matters worse. I always tell them that it is important for them to understand scientific concepts but few of them do as I say and do what I tell them to do. At the university, they have modules like academic literacy and English for specific purpose. In high school we do not have, I don't know what they are doing in the English class. Because they do not prepare them enough for our subject. Therefore, as teachers, we will just drill them to pass, but they are not doing well in intermolecular forces.

The majority of the teachers agreed that teaching intermolecular forces is not easy because the topic is highly conceptual, and learners struggle to construct meaningful scientific explanations. For learners to understand the topic they need to have factual and conceptual knowledge of the topic and therefore they need to be proficient in the LoLT.

Many learners struggle with questions requiring extended explanation

Teacher D

Intermolecular forces is a topic for intelligent student who are good readers. To explain these abstract concepts, learners find it difficult, especially because they are not good in English, it makes it difficult to explain although as a teacher is easy, but for the topic to penetrate their minds is always difficult. I always spend a lot of time trying to make them understand but if they can't read after class it become a useless exercise to explain too much.

The teacher explained that the topic needs learners who are good readers. He indicated that he always try to make them understand, but they still struggle. This means that out-of-class writing tasks can assist learners to research the topic and also to learn how to be good writers in this topic.

Teacher A

> *As I have indicated, when we do practical they understand better, but when they write in exam they fail because they have to explain concepts. Other teachers in the lower grade they use local language and eh this become a problem to us when they come to grade 11 because they have to learn for understanding especially in exam and they suffer because of that. Intermolecular forces for them is difficult because the content need explanation and that is not easy for the learners.*

Teacher A agreed that the topic of intermolecular forces requires language facility but also stressed the importance of practical work. The teacher also indicated that other teachers use the language spoken in the community which is mainly IsiNdebele and Sepedi and the use of these languages to teach Physical Sciences will contribute to learners' poor performance.

All five teachers agree that the topic of intermolecular forces requires language ability, especially for second language learners. This means that it is important for learners to develop not only BICS but also CALP skills, which are necessary for learning subjects like Physical Sciences. Learners can benefit from practising writing in the context of science and becoming more scientifically literate. Teacher C indicated the importance of learners learning in their mother tongue:

Teacher C:

> *As a Ndebele, I will recommend that they learn other subjects in their mother tongue because explaining concepts like intermolecular forces and intramolecular force is not easy for the second language learners that we are teaching. The concepts are very difficult because they cannot see them in real life. How do you explain that there are forces between molecules when they cannot even see the molecules? Some of them they do not even believe when you say matter has got particles that are always in constant motion, now we have to convince them and sometimes because of their traditional and religious believe they do not accept. They believe in the ancestors and now if you say to them matter is made up of small particles, they will say why because everything is created by God and the ancestors.*

Another interesting issue raised by teacher C is that there are learners who believe in ancestors and the content knowledge in science conflict with their current beliefs. As mentioned by teacher C, learners do not believe that matter is made up of small particles since they believe that God has created everything and there is no way that matter be made-up of particles. It seems language challenge here is the difference between “made of” and “made by” This is an indication that English language is still a challenge and the theme that follows clearly outline this concern.

Language, especially English as an LoLT is still a challenge

This theme was meant to probe teachers on the language issue in science and how writing contributes to language challenges.

English is not our mother tongue. yes, English is a contributing factor. With intermolecular forces is even worse because they have to explain concepts like hydrogen bonds, dipole-dipole forces which are Greek to them.

The language issue in South Africa will always be a problem as English is regarded as an important language that is spoken internationally, and learners who are fluent in English are regarded as intelligent learners. Teacher B was supported by teacher D that language in South Africa is a big issue:

Teacher D

English is big problem in South Africa. In my country (Zimbabwe) *is not a problem because they start with English from foundation phase. This thing of mother tongue does not apply in my country. That’s why we don’t have a language problem, in South Africa even the teachers are struggling because they did not have a good foundation. For the topic of intermolecular forces, they are expected to explain, how they will do it if they don’t understand the English.*

Teacher D is originally from Zimbabwe, and he indicated that they do not condone teaching in local languages in his country. Leaners study in English from an early age in school. But he confirmed that in South Africa English is a barrier to learning for many learners. Teacher A held the same views as Teacher D:

Teacher A

Yes, because is problem to them because when they start from other grade they don't they don't start with the English they start with on when start teaching them the those language when they come to us we speak English, then become problem to them, but as times goes on when we start teaching them small small, they get used to the language, especially the scientific terms.

Teacher A also stressed the fact that since students learn in their mother tongue in the foundation phase, it creates a problem because when they go to the higher grades they struggle. It was clear that teachers from foreign countries agree that English needs to be taught well from the foundation phase as it will be the language of instruction in the higher grades. Even South African teachers agree that English is a problem for them as teachers.

Teacher E:

English language is difficult. Even for us teachers but because we are used to the language of the subject we are able to cope. In the lower grades, the learners are not prepared well so that they can do explanations and to speak. I can't even mention reading which is also the most contributing factor. They are not even aware that they need to read previous notes before they come to class. When you ask them about what we did yesterday they just look at you as if they were not in class yesterday. Hey that's what we have to deal with every day. But we are surviving against all odds.

The teacher stressed the fact that English is a problem as learners are not well prepared in the lower grades, and it becomes a burden when they move to secondary school where teachers have to intervene to ensure that learners understand the concepts well. The teachers continued to mention specific aspects of language that are problematic to learners Below are extracts from teachers:

Teacher A

They find it difficult when it comes to reading and writing, yah those two.

Teacher B:

Reading is my number one problem with these learners because I expect them to look at previous work before they come to class, mara (but) when you come to class kubamnyama tshuu (they can't say anything). I cannot even mention writing because how will they write if they can't even read, hey.

Teacher C:

I think that it has to be reading and writing. You can see that when they come to class that they did not read enough. When they study they do cram and pass (rote learning). When you bring the problem in another situation they cannot even remember that it is the similar problem we tackled yesterday. But they expect us to teach these learners science which need them to have a deep understanding.

Teacher D

Reading is a problem in South Africa. I am wondering what they are doing in Primary school if they are not well prepared for the language. That is why we have the poorest education system in the world, they are not well prepared when they come to us. Reading and writing must be the basic skills.

Teacher E

For me I think writing is a problem. When I mark their scripts, they can't even explain basic concepts. They are good with simple calculations but to interpret those calculations they struggle. If you ask them how did you get to this answer, they can't even explain. For the topic such as intermolecular forces what do you expect, they will get zero.

It seems that the majority of the teachers identified reading and writing as a challenge. Three teachers identified both reading and writing, one teacher identified reading as a challenge, and another identified writing as one of the challenges. It is expected to identify writing as a challenge as learners are expected to present assessments in writing, and it is the most important form of communication between learner and teacher.

Writing as an aspect of language is big challenge for most of the learners

This theme was a follow-up from the previous theme but focused on writing in learning specific to Physical Sciences. Below are extracts from teachers:

Teacher A

Writing is a big problem. because eh, one when they normally, other teachers teach them, they use the local language to explain when they teach the other subject they use the local the local language to explain to them but when they come to the scientific to us, we don't use the local language, we speak English and it become difficult for them.

Teacher A still emphasised that the use of a local language creates a problem for learners as they will always struggle with writing. It will be difficult for them to practise the language of science if they always converse in a local language in class. Teacher B was in support of teacher A.

Teacher B

It is a big problem, if you see what they are writing in their script you will be surprised even if it is not a matter to laugh about. Especially where they are supposed to explain, you will be amazed.

All five teachers shared the same view that writing is a problem. One teacher indicated it is especially important in science as it is a subject with its own language. They mentioned that learners do well in practical reports compared to exams because in practicals they copy from each other. They also mentioned of the lack of foundation as a problem.

Learners benefitted from the WTL programme

This theme was specific to the writing project, and whether teachers thought that learners benefitted from the programme. Below are their views about their experience of the writing-to-learn project in teaching the topic of intermolecular forces.

Teacher D

The programme is good but need at least two more weeks to cover everything. I especially like the idea of giving them assignments before we start with the topic.

Teacher A:

Yes, yah they benefited from it.

Teacher E:

I enjoyed the programme and my learners benefitted and I am planning to do that in grade 12 to prepare them in advance. Those marks where they are required to fully explain, they will nail them next year.

The teachers indicated that their learners benefitted from the programme although most of them thought the time factor might be an issue in the implementation of the programme. They mentioned that Grade 12 learners can benefit from this initiative as most of them do not attempt questions where they have to fully account through explanations and even when they do, they do it poorly. The theme also extended to the benefits and challenges of the WTL programme. Extracts from teachers are presented below:

Teacher A:

Yah the, what could be the strength is that the teacher must always show them how to answer those questions, how to write it. If the teacher fail to teach them they cannot answer them, the teacher must always be teaching them how to write those questions, those eh answers yah if he continue to do that, they become used to but he fails, then those learners cannot answer those questions.

Teacher B:

The problem is time, if enough time is given, they will benefit. The strength is that it prepares them to deal with the explanation questions in exams and tests

The time factor seems to be an issue in the implementation of the programme. Another issue concerning time is the preparation and planning of these activities which may be time-consuming for the teacher. But if the questions are prepared by the departmental officials like curriculum implementers, then this would not be a problem.

This theme also focused on whether other teachers can benefit from the programme if it is implemented nationwide and on the resources that will be needed for the implementation. These were the responses:

Teacher C:

I believe it's a good programme, I will share this with my cluster leader.

Teacher C indicated that he is willing to share the WTL programme at the cluster level. A cluster is a community of practitioners who teach the same subject in a circuit. A cluster is often made up of 5-7 schools depending on the number of schools in the circuit. The teachers meet quarterly and write the same continuous assessment tasks, especially those who are included in the year mark for students. When they meet they moderate each other to ensure that students benefit from the standardisation of assessment. This is to ensure accountability in teaching, learning and assessment.

Teacher E:

Yes, they can benefit. Only if they can get time to come for training and we get assistant teachers to assist with the implementation.

Another issue that was raised was the training which I believe is important. Professional development is important for teachers' growth. You will find that professional development programmes often focus on understanding content knowledge rather than on the pedagogical aspects of the topic.

Teacher A:

Yes, only if I get more training and it is implemented in other topics. This can be good for grade 12 topics like chemical equilibrium. Also in Physics, my learners are struggling in explaining concepts such as momentum, Newton's laws and Ohm's law.

The teachers indicated that they are willing to train other teachers if they are given support and training. They also mentioned the relevance of the programme in other physical science topics.

The WTL programme can be implemented in other Physical Sciences topics and other subjects

This theme focuses on the implementation of the writing programme in other topics. Below are the teachers' responses.

Teacher A:

Mining in grade 11 is difficult to teach as it is like teaching history as it is more conceptual and it is only taught at the end of the year.

Teacher B:

Yes, it should apply in all Physical Sciences topics, izo banceda ukuunderstanda ama (it will help them to understand…) concepts.

Teacher C:

I am struggling to teach Le chatelier's principles, I can give them writing assignments on this topic

Teacher D:

My learners struggle with the topic of electromagnetism, if they do research in advance by submitting an assignment it can help.

The topics chosen by the teachers are the topics considered conceptual in nature requiring students to have a thorough understanding of many unfamiliar concepts. For example, the topic of mining in Grade 11 which focuses on understanding the lithosphere is one of the topics that Grade 11 learners find difficult to learn as it contains many unfamiliar concepts that they have to learn. Teaching this topic through WTL by giving learners a series of writing assignments will facilitate the learning of this topic. The theme also extended to what teachers will need to implement the WTL strategies. These were the responses from the teachers:

Teacher A:

Training is important and good salary

Teacher B:

Commitment to go an extra mile

Teacher C:

Enough time to do the planning

Teacher D:

Less workload so that they can have iskhathi (time) sokuplanna (to plan)

Teacher E

Support from all stakeholders and a lot of commitment and motivation. Most teachers are demotivated by the system and there are no incentives that comes with innovation and going an extra mile. We just work to uplift our community

It is also apparent that teachers will need to be supported by all stakeholders such as school management teams (SMTs), parents, school governing bodies (SGBs), and the DBE to implement the programme well. For the programme to work it will need to be a national initiative not only in terms of recognition but also to receive support for implementation and monitoring the outcomes. The diagnostic reports always make recommendations but there are few planned initiatives to address the problems identified.

4.3.2 Learners' focus group interviews

Focus group interviews were conducted with learners from the experimental group. Five groups were interviewed: two from school A, two from school B, and one from school C. The purpose of the interviews was to interrogate the learners' views and experiences about writing in science class. The transcribed texts from learners' responses were translated into English as the majority of them code-switched to IsiNdebele and Sepedi. Code-switching into local languages shows that writing is not the only challenge that these learners are struggling with; English language fluency is also a challenge. The researcher allowed them to use their mother tongue or the language that is most often spoken at home, to get a real sense of what they meant. Six themes were established as follows:

- The WTL study guide contained questions that challenged thinking
- The WTL strategies facilitated understanding of the topic of intermolecular forces
- The writing assignments were helpful as they prepared learners to research the topic prior the teaching of the topic
- The study guide was well-designed and easy to read and navigate.
- Learners were positive about their performance in the post-test
- The incorporation of language requires that textbooks include keywords to enhance understanding of scientific concepts

The WTL study guide contained questions that challenged thinking

One of the themes that emerged in the study is that questions in the study were more challenging than questions in their textbooks. They mentioned that the questions in the WTL study guide prepared them for examination since the examination includes questions that cover different levels of Bloom's taxonomy. Below are the extracts from learners:

Leaner 18:

Yes, it was different. The material contained hard questions as compared to our textbooks. Therefore, when we wrote the examination were able to answer as compared to questions that appear in the textbooks where the questions are simpler but for the study material, it was challenging so that we can understand better.

Learner 19

It was different because we did a lot of writing and this compelled us to think critically and we did not understand why we were doing this but now we see that it is important.

The study material provided had questions that were challenging to the learners as mentioned above. WTL means that when they write exams they will be able to answer questions as they have learned how to deal with challenging questions. The questions they refer to are questions that require them to explain concepts; in other words, questions that encouraged higher-order thinking which is necessary for the learning of science. The writing activities were cognitively challenging as they had to put their thoughts in writing.

The WTL strategies facilitated understanding of the topic of intermolecular forces

Most of the learners in this theme mentioned that the WTL strategy facilitated understanding of the topic. What they mentioned is that most of their time was spent on writing. Below are some of the extracts from the learners:

Learner 8

Most of the learning time was spent on writing. I thought that my teacher did not want to teach us, she is lazy but later I realised that the study guide explains concepts better.

Learner 23:

I thought that the assignments were difficult but the study guide made it easier and they were easy. I was compelled to read through the study guide as I complete the assignments. When the teacher was teaching it was like I can teach for her because I understood the concepts already. Now I do the same with other subjects like mathematics and biology. The strategy works for me.

The learners indicated that they did not understand why they were doing a lot of writing in science. Initially, there was resistance to the idea but they later realised that it was helpful. What was also observed here is that the writing assignments encouraged critical and creative thinking. Learners indicated that the material compelled them to think, which is a notion of writing as thinking. One of the features of writing-to-learn strategies is that learners should be doing a lot of writing and the learner confirmed this. The approach teaches learners to be self-directed since most of their learning depends on their commitment to the writing activities.

The writing assignments were helpful as they prepared learners to research the topic prior the teaching of the topic

Writing assignments seemed to be the most popular in the WTL strategy. Many learners indicated that an opportunity for them to go and research the topic before it is even taught was valuable and prepared them well prior to the teaching of the topic. Below are some of the extracts from learners:

Learner 20:

I think it was different especially because we started with assignments, in Physical Sciences they like practicals they do not like giving us assignments. I was able to understand intermolecular forces better through assignments.

Learner 7

I did not understand why we have to write assignments if they are not included in continuous assessment but when I finished writing them, then I understood intermolecular forces better.

Learner 5

I enjoyed doing assignments because most of the concepts I was able to find from the study guide. I managed to get more information about intermolecular forces on the internet especially applications of intermolecular forces.

Learner 23:

I thought that the assignments were difficult but the study guide made it easier and they were easy. I was compelled to read through the study guide as I complete the assignments. When the teacher was teaching it was like I can teach for her because I understood the concepts already. Now I do the same with other subjects like mathematics and biology. The strategy works for me.

The learner indicated that the tests including the assignments and the study guide were helpful as most of the concepts were familiar when they started writing exams. Learners 5 and 7 spoke about the relevance and importance of writing assignments, which are the most important aspects of writing-to-learn pedagogies. The learners above indicated the value of the writing assignments even though some were initially resistant to the idea since it would not form part of continuous assessment.

Learners tend to only complete tasks that will form part of their year mark. In the South African curriculum; continuous assessment constitutes 25% of the year mark and is made up of mainly practical work and tests in Physical Sciences. Learners do not have to do writing assignments other than in a project that they submit in the third term for 10th and 11th graders. For Grade 12, continuous assessment is mainly based on tests and experiments. At the end of the year, they have to write a final exam which counts for 75% of the final mark. The introduction of writing assignments will strengthen learners' understanding of basic science concepts if implemented well. The only problem is that teachers will complain about the marking workload as they would not be able to give learners feedback regularly and on time. In the context of this study, peer assessment proved to be a solution to the problem.

It is clear from the learner responses that the writing assignments encouraged self-directed learning because the assignments encouraged them to learn the material in advance. In higher education, this is called flipped classrooms; learners have to prepare for a particular activity before coming to class. The learners indicated that the idea of writing assignments in science class is a good idea as the assignments prepare them in advance for the topic. This is unusual in physical science since learners are rarely given writing assignments where they are expected to write in essay format. This was also supported by the learner below.

The study guide was well-designed and easy to read and navigate through

Learner 3

The material was helpful because the concepts in science are challenging to us because some of the concepts are difficult because we need to do research to look for their meanings. Some of these words you cannot find in the dictionary. But in the study material provided, they were there.

Learner 1

Yes, the material helped us because the test that we were given before, some of the questions were in the exam, therefore it was helpful because it was not a long time we wrote the test when we wrote the exam we were able to remember a lot of stuff that was familiar, the study guide was also helpful so that when we write exam a lot of stuff were familiar.

Learner 3 indicated that the study material provided were beneficial since understanding basic concepts in science can prove to be difficult. The basic concepts in science are one of the bigger issues, and providing study material that is accessible in terms of language and clarification of concepts is important.

Learners were positive about performance in the post-test

The theme was about learners' views about their performance in the post-test. This was to investigate their self-efficacy after engaging in the writing project.

Learner 25

The pre-test was difficult but after the completion of assignments and the engagement with the study guide the post-test was easier.

The learner indicated that engagement with the assignments and study guide made things easier for them. They believed that they did not perform well in the pre-test but performed well in the post-test. They attributed this to the engagement with the study guide and writing assignments. This was also mentioned by the learner below:

Learner 13:

Yes, I thought that the post-test was easier especially when we learned through the writing assignments and from the study guide I understood better.

The learner above agrees with learner 25 that the study guide and the writing assignments helped them to understand the material and that it contributed to good performance in the post-test. The learners below also supported this.

Learner 3

We started by writing the pre-test and the pre-test was difficult because we had not started with intermolecular forces, then the teacher gave us a study guide and she taught us through the study guide and then we understood intermolecular forces, then when we wrote the post-test and we understood.

Learner 14:

The post-test was easier for me but the pre-test was difficult. The assignments prepared me for the post-test.

This is also an indication that the learners believe they performed well in the post-test compared to the pre-test because the study guide and the teaching came in handy. The writing assignments were acknowledged as contributing to performance.

The incorporation of language requires that textbooks include keywords to enhance understanding of scientific concepts

This theme focused on the strategies for incorporating language in science classes. The theme was important as learners' opinions are also valued in the curriculum development process.

Learner 15:

I think that in the study guide if we can have keywords. The keywords will help us to know the meaning of words and what the words mean so that we can understand better.

The learners agreed that a study guide similar to the one developed would help. They also mentioned the inclusion of keywords, however, if they are not given a chance to practise how to write and explain concepts, the keywords would not serve any purpose. The mentioning of keywords also shows that many learners are struggling to understand science concepts. To summarise the results, it is clear that the learners were positive about the incorporation of writing in the science class. They were also confident about their performance in the post-test after the implementation of writing-to-learn activities.

4.3.3 Discussion of Qualitative results

The qualitative results of this study were covered by the third research question which is about the learners' and teachers' views on features of the writing-to-learn pedagogies versus traditional teaching approaches.

The teachers' interviews revealed that the topic of intermolecular forces is not easy to teach as it is conceptual and requires language facility from the learners. Other chemistry topics were identified by the teachers like mining in Grade 11 and chemical equilibrium which are also problematic in terms of language. The teachers acknowledged that the LoLT is a challenge to many learners and this contributes to poor results. They also mentioned that reading and writing are major issues that challenge the majority of learners. It was indicated that most of the learners hardly attempt questions requiring extended explanations and if they do, most of them do not perform well in such questions. However, one teacher indicated that if they are taught how to attempt explanation questions, they will do well. This means that engaging them in extended writing during teaching can assist.

The teachers acknowledged the benefits of the writing-to-learn project and indicated that it was beneficial to the learners. The only challenge identified was time constraints since the strategy will require more time to be well implemented. They indicated that physical science teachers can benefit from the writing project but will have to undergo training.

The focus group interviews with the learners yielded positive results regarding the writing-to-learn project. The learners indicated that the writing assignments prepared them well for the topic before the topic was taught, and the feedback provided was valuable. They also felt that the study guide came in handy as concepts were simplified, and this was not the same with conventional textbooks.

The learners asserted that during the teaching a lot of writing was done, and they initially thought that the teachers were lazy and did not want to teach them. However, they later realised that the writing-to-learn pedagogy was effective. The fact that the questions in the study guide were challenging, encouraged thinking skills, and this was helpful as they found the post-test easier. They reported that the pre-test was difficult as they had not yet learned the topic.

The learners recommended the inclusion of keywords in the textbooks as some of the terms in science cannot be found in traditional dictionaries, and they found this challenging to them as they do not always have data to search for information on the internet. It was encouraging to note that the writing programme encouraged learners to be self-directed and that the activities encouraged them to read further about the topic.

4.3.4 Summary of both quantitative and qualitative results

The first research question of this study investigated how the academic performance of learners engaged in writing-to-learn activities would differ from those exposed to traditional pedagogies in terms of overall academic performance, science inquiry skills, and how they define concepts in the topic of intermolecular forces. The findings from the IMF tests revealed statistically significant results in favour of the learners were engaged in WTL activities. The teachers who were interviewed agreed that IMFs as a topic is difficult to teach and leaners find it hard as it has many concepts to define. They all agreed that teaching through WTL strategies facilitated understanding of the concepts.

There was a special mention about the writing assignments by learners who participated in the focus group interviews. Learners indicated that the assignments were valuable as they managed to research the topic before it is taught. One of the learners even indicated that she wished she could teach the topic even before it was taught as the assignment orientated her to the topic. That means the qualitative results which addressed the second research question agreed with the quantitative results in the sense that both were positive about the WTL strategy.

The second research question compared the performance of boys and girls after the implementation of the WTL strategy. The results were not statistically significant, meaning that there was no difference between the performance of boys and girls after engagement in the strategies. Learners (both girls and boys) in the focus group interviews also felt that they did well in the post-test after engaging in the WTL strategies. The fact that there was no statistical difference between boys and girls is an indication that WTL as a strategy can be regarded as a transformative pedagogy since the strategy does not favour any group.

Conclusion

In this chapter, I presented the data from the study on the effects of writing-to-learn strategies in the topic of intermolecular forces. The conclusion that can be made from the results is that the intervention had a positive impact on the academic performance as well as science inquiry skills in the majority of the learners. This was proved beyond doubt by the statistically significant results obtained from the study. The responses from the Physical Sciences teachers also provided insightful positive data regarding the effectiveness of writing-to-learn strategies in the topic of intermolecular forces. The results from the focus group interviews were positive since learners acknowledged the benefits of the programme. The interviews brought a human element to the quantitative data and provided more insights on what transpired during the intervention which was useful for making the conclusions and recommendations covered in the next chapter.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

The previous chapter presented the research results and findings of the study. This chapter draws conclusions from which recommendations are made. The proposed framework for the implementation of writing-to-learn pedagogies and suggestions for further research are discussed.

5.2 Summary of key findings

The study aimed to investigate whether writing-to-learn pedagogies will be effective in improving academic performance in the topic of intermolecular forces, which is a topic that is considered difficult to learn and teach. The diagnostic and examination reports from past years reported that in Grade 12 learners struggle to answer questions that require extended explanations and understanding of basic concepts. To address this problem, the research was conducted with 5 teachers and 317 learners in 3 schools in Mpumalanga province. The aim was to probe if learners' academic performance and their science inquiry skills as well as their ability to construct scientific explanations, would improve if they engaged in writing-to-learn activities in the topic of intermolecular forces. The study provides supporting data that writing-to-learn strategies were without a doubt effective in improving learners' overall academic performance including science inquiry skills and ability to construct scientific explanations.

The first research question investigated whether there would be significant differences in overall academic performance between learners who are exposed to writing-to-learn pedagogies and learners exposed to traditional pedagogies. To collect data, an intermolecular force test in the form of pre- and post-tests was administered to the learners. The results showed statistically significant differences which indicated that learners who were exposed to writing-to-learn pedagogies showed academic improvement in their conceptual understanding of the topic, science inquiry skills, and ability to construct scientific explanations.

The statistically significant findings are an indication that there is a need to consider writing pedagogies in the teaching of Physical Sciences. For chemistry, the inclusion of writing-to-learn activities can assist learners in exploring and clarifying scientific concepts which will improve their retention of chemistry content knowledge (Logan & Mountain, 2018). In topics that have many concepts to define and require a thorough understanding of basic concepts, the writing activities will even be more beneficial as they encourage self-directed learning which prompt learners to be deep thinkers as they engage with these concepts. In chemistry classes, learners are rarely encouraged and prompted to construct scientific explanations, however, in this study, it was evident that the strategies that encourage learners to draft scientific explanations were effective in facilitating understanding of chemistry concepts.

What was also notable in the study was the effects of free-writing activities. These types of writing activities were different from those usually found in traditional textbooks, as they encouraged metacognition and reflections. Many textbook activities are succinct and straightforward and encourage learners to memorise facts and content. However, writing activities that were presented in the study encouraged students to generate scientific explanations and proved to be powerful conceptual learning tools especially for understanding chemistry at the microscopic level which is often a challenge to many learners.

The inclusion of formal writing assignments was important in this study because they provided learners with information before learning a particular section of the topic and ensured that they take ownership of their learning. They also encouraged learners to realise that learning is something that must be done by themselves not by the teacher, meaning that the teaching and learning process is learner-centred rather than teacher-centred. The writing assignments also ensured that the learners discovered the applications of intermolecular forces as they engaged in research on the topic outside the classroom. As they engaged in research about the topic, they even discovered content that is not covered in the textbooks and by so doing it helped to elicit learners' interest in the topic. The inclusion of writing assignments also engaged learners in disciplinary writing, meaning that they were writing in the context of science rather than the type of writing they do in traditional English classes which are disconnected from the science discipline. In a nutshell, they were practising what scientists do which is to do research and write for publications.

As novice scientists, the learners took initiative in the learning process, were able to diagnose their learning needs and goals and were able to identify resources that they would need to learn the topic of intermolecular forces. Effective feedback practices were also notable in the study through writing-to-learn activities into which the learners were socialised. They were provided with feedback that was sufficient, timely and could be acted upon. Gibbs and Simpson (2004) identify conditions under which assessment contributes to student learning. On feedback, the conditions indicate that learners should be provided with sufficient and timely feedback and it should be received by learners while it still matters (Gibbs and Simpson, 2004).

In the current study, enough detailed feedback was provided to the learners, and the feedback focused on their performance. The learners were provided with feedback on both the assignments and the short writing activities. Other forms of feedback were dialogic; received in class through discussions between the learners, teachers, and peers. The feedback was timely; provided through peer assessment before the commencement of a new sub-topic. For freewriting activities, feedback was immediate through summaries and discussion. The writing-to-learn strategies influenced the students' learning about assessment and feedback which means that if these conditions are adhered to, the practices contributed to effective learning.

The writing tasks given to learners were formative. Mooed (2015) emphasises the importance of formative assessment and asserts that it is a form of assessment that is learner-centred and situated in the classroom with the main purpose of enhancing teaching and learning. Black and Wiliam (2018) corroborate the significance of the relationship between assessment and pedagogy and that it will be difficult to understand this relationship if the context within which assessment takes place is not considered. This means that how learners are assessed is influenced by how they are taught (pedagogy).

In the context of this study, the pedagogy was writing-to-learn and therefore it influenced how the learners were assessed. For instance, the assessments were mainly done on writing activities and writing assignments. The argument is that writing-to-learn strategies contributed to the students' learning as the assessments were formative. What was also notable in this project was that while the learners were engaged in writing activities, they were actively constructing their learning which means that writing-to-learn can be considered to be a constructivist approach to learning. In constructivism, understanding is developed through a combination of learning activities which in this case were writing activities.

The second research question was about the comparison between the performance of girls and boys in the intermolecular forces test. The results were not statistically significant in the sense that there was no difference between the performance of boys and girls. Research shows that female learners have always been underrepresented in science, technology, engineering, and mathematics (Conner & Danielson, 2016). Historically, the reason for the underrepresentation of girls is that males have commonly been perceived as scientists and females as not having an interest in the sciences (Conner & Danielson, 2016). The results showed that engaging learners in writing-to-learn activities can help to close the gaps between the academic performance of boys and girls. Therefore, we can consider the writing-to-learn strategies as appropriate inclusive teaching and learning practices.

The third research question investigated teachers' and learners' views about the implementation of writing-to-learn pedagogies in science classes. The majority of the teachers were positive about the incorporation of writing in science class and all of them corroborated that the intermolecular forces topic is difficult to teach due to its conceptual nature. Unlike the majority of chemistry topics that contain many computational questions, intermolecular forces require learners to construct scientific explanations, which can be challenging. What makes the topic even more difficult is that knowledge of intermolecular forces is applied in other topics such as organic chemistry and biology, and the majority of learners find it challenging to apply the knowledge in different contexts.

There was consensus that language is one of the contributing factors to the poor performance of many learners in South Africa. The teachers who were interviewed were experienced and the majority of them are appointed as markers which means that the information provided was based on their personal experience and active involvement in the teaching of Physical Sciences. Writing as one of the literacy skills was identified as one of the key challenges to the learning of Physical Sciences together with reading. One of the teachers indicated that writing is more problematic especially during marking as they do not perform well in questions requiring scientific explanations and knowledge about basic concepts.

The teachers also cited challenges such as time constraints and that they would need the training to be able to implement the strategy well. Other challenges were teacher motivation; most of them indicated that the department does not reward them for innovations in teaching and learning. Therefore, many teachers resort to spending most of their time drilling learners on how to answer examination questions rather than focusing on the long-term effects of learning such as conceptual understanding and the critical skills that are required by society, namely writing and reading and acquiring information.

It was also apparent that there is a need to implement writing-to-learn strategies in other science topics such as mining in Grade 11, and momentum and chemical equilibrium in Grade 12. One of the challenges with the implementation was human resources as many teachers indicated that they are overworked and if there was more capacity they would be able to adopt the writing strategies in their classes. They indicated that they would need extra time to be able to implement the writing strategies. Support from all stakeholders such as the school governing body (SGB), school management team (SMT) and parents is necessary for the successful implementation of the writing programme.

The learners agreed with the teachers about the implementation of writing pedagogies in the Physical Sciences class. Most of the learners seem to have benefitted from the writing assignments as they were given before teaching and this prepared them well and familiarised them with many of the concepts during the teaching of the topic. They mentioned that the writing activities were challenging as they prompted them to think about the intermolecular concepts but this was aligned to how examinations are prepared. It was clear that there was no alignment between the activities provided in textbooks and the assessments in examinations. They also indicated that they learned about the applications of intermolecular forces as they were compelled to do research when completing writing assignments.

5.3 Framework for implementing WTL in Science Education

The results from this study proved beyond doubt that there is a need for science teachers to implement WTL pedagogies in their classes. Physical Sciences teachers need to assume an agentic role by ensuring that WTL strategies are implemented in selected topics that require language facility and writing ability. Assuming that the language, specifically writing, will take care of itself is not an option in this regard and therefore science teachers have a responsibility to narrow the language gap in their classes by implementing writing pedagogies.

The components of the framework align with how the intervention and the principles underpinning the study according to Woolley's (2014) ideas on the features of WTL. These ideas were implemented as follows:

- Identification of the topic to incorporate WTL.
- Writing assignments given to learners before teaching of the topic.
- Sufficient and timely feedback provided to learners.
- Learners engaged in writing activities in class.
- Pre-test and post-test used by teachers to reflect on performance.

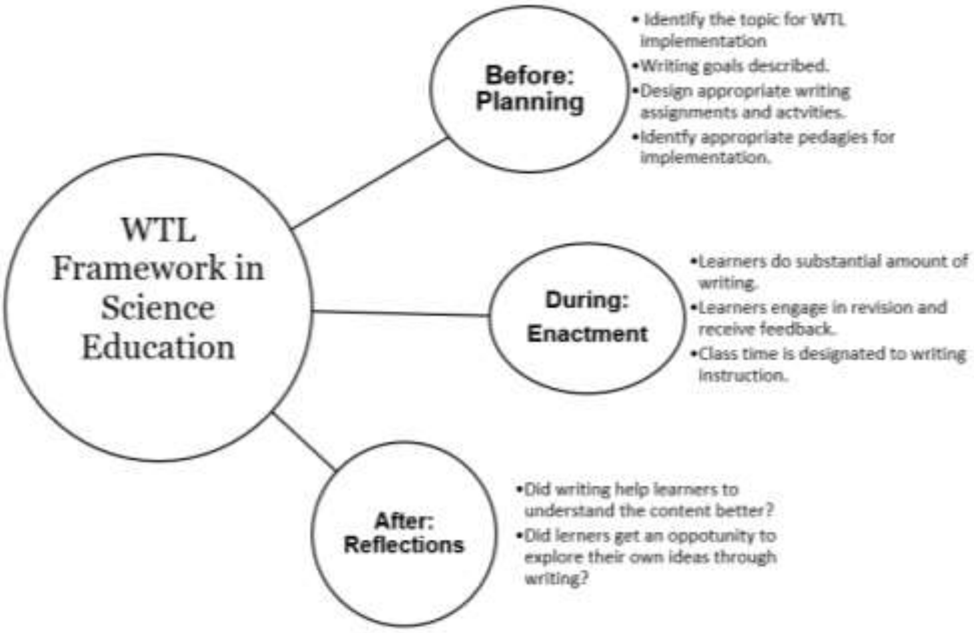
The above process led to the development of the framework for the implementation of the WTL process. The quantitative results proved beyond doubt that WTL strategies are efficacious which resulted in the development of the framework. Learners and teachers were also positive about how the project was implemented which was a positive indication. The writing assignments specifically, had a special mention from both learners and teachers.

Based on feedback from teachers and the principles by Wolley (2014), the researcher proposes a framework presented in figure 5.1 below that science teachers can use as a guide for the implementation of WTL in their classes. Woolley (2014) posits that for writing to be integrated in content subjects, focus should be in the following:

- Writing assignments and writing goals are described.
- Students do a substantial amount of writing.
- Students have the opportunity to engage in revision and receive feedback.
- Class time is designated for writing Instruction.

Figure 5.1:

The framework for the implementation of WTL in science class



The first stage which is the planning phase takes place before the topic is taught, the second stage is the implementation phase where the teacher is now implementing WTL in the science class, and the final phase is the reflection phase where the teacher reflects on how the incorporation of WTL benefitted the learners so that the practice can be improved in future. Details on each stage are provided below.

Before: Planning the implementation of WTL in science class

In this phase, the teacher needs to think about the purpose of the implementation of WTL on a particular topic. In each topic, the teacher can identify the sections that need to be writing intensive. The sections where learners have to describe and explain many concepts can be identified as requiring writing strategies. The teacher then thinks about the core concepts and what he/she intends learners to learn about the topic. It is also important to think about why learners need to know about these concepts and what the purpose of the writing tasks on these concepts is.

The next step involves designing appropriate writing activities which can include in-class writing tasks and summaries. Extended writing assignments can also be designed and be given to learners before teaching the topic so that learners can do research about the topic and learn about applications of the topic. The teacher can also think about the strategies that will be used in achieving these learning outcomes, which include describing how the lessons will unfold and when and how writing activities will be incorporated into the class. The writing activities designed must ignite wonder and passion to inspire learners, which means that the teacher will need to collate and refer learners to interesting sources that they can use in class without having to wonder what they are writing about.

During: the implementation of WTL in science class

During implementation, the teacher needs to make sure that most of the class time for the section identified in a particular topic is designated for writing instruction. The writing activities designed will be put into practice as learners engage with them and interact with their peers. This process also takes into consideration the sociocultural theory that writing is a social and cognitive act. For instance, as learners write, they need to think about the context in which they are writing, meaning the context of science. The role of the teacher will be to provide resources and direct them to relevant content that will ensure that they engage in meaningful writing.

Feedback is one of the important aspects in stage 2 since learners will need to be provided with feedback by the teacher and their peers. The feedback must be timely and must be acted upon by learners through dialogue and discussion. Formative assessment tasks to ensure that the writing tasks are efficacious and address the intended learning outcomes are necessary. The role of the teacher is to facilitate the learning and to be observant and tactful so that he/she can point learners in the right direction.

Understanding the learners' prior knowledge is important. Understanding learners' common misconceptions in each topic will help the teacher to give appropriate feedback and timeously identify errors that learners have committed in their writing. The role of the teacher also involves eliciting interest in the topic by probing learners about their sense-making in the topic and relating the topic to real-life situations to encourage authentic learning.

The role of the learners involves solving real-world problems through writing and thinking. Learners need to be independent thinkers and be able to monitor their own learning. However, teamwork is also important especially during brainstorming sessions before they start composing their writing. Interactions are equally important during the feedback session where learners share their writing with the teacher and fellow learners.

After: Reflection stage

Engaging in reflective practice allows teachers to think deeper about their practice by questioning their approaches, engaging with their feelings, questioning their assumptions, and gaining greater self-awareness (Bassot, 2016). At this stage, the teacher becomes a reflective practitioner by thinking about what did not go well and what learners were struggling to understand when they were engaged in the writing activities. The question that can probe this reflection stage is whether writing assisted the learners to understand the topic and if not, what could be done differently in the next lesson? Did the learners get an opportunity to explore their ideas through writing and did the activities promote critical and creative thinking? Other questions could include whether the writing assignments given before teaching assisted in facilitating learner thinking and understanding of the topic. What is also important is whether the in-class formal writing activities encouraged discussions in class and if learners were able to connect these writing tasks with their own experiences.

Considerations for improving the framework

In line with advances in technology in learning, an alternative or additional approach to engage learners in substantial writing as suggested by stage 2 of the framework is to develop mobile Apps; application systems that run on a mobile device to promote understanding of science concepts through writing. The Apps can be designed in a way that they prompt learners about concepts in a particular topic and learners get an opportunity to write their ideas on the App about their understanding of such concepts. An artificial intelligence system can be included in the App to provide learners with immediate feedback.

The first step in developing an App according to Blogline (2020) is to identify a concept for your App. Identifying a concept means that you need to know the purpose, the target audience, and how many users your App can accommodate. The purpose of the writing App would be to teach learners scientific concepts through writing. Learners select a concept that they want to learn, and the App will ask the learner to write their own meaning. After the learners have written their own meaning, the App will give learners the correct meaning of the concept. The correct meaning could be in written or audio format depending on learner preferences. Learners will be given an opportunity to practise as much as they can. The App should be able to host more than a hundred thousand of learners at a time and the target audience will be Grade 10 -12 Physical Sciences learners.

5.4 Suggested Principles that guide WTL Strategies

Teachers need to understand the principles that guide the implementation of writing-to-learn strategies to know what kind of writing activities they need to develop to encourage deep learning. The activities need to follow the characteristics of assessment design that promotes deep learning. One of these characteristics is authenticity. Studies have proved that authentic assessment activities have a role to play in impacting the quality and depth of learning that need to be achieved in the development of higher cognitive skills (Ashford-Rowe, Herrington & Brown, 2014). Villarroel, et al., (2018) identified three components of authentic assessment which are discussed from the writing-to-learn perspective.

The three components are: realism, cognitive challenge and feedback. Realism is associated with principles of social learning theories discussed in this study and relates to what learners can apply in real-life situations. Cognitive challenge is related to constructivism and social cognitive theory as they are concerned with transferable skills such as critical thinking which is associated with writing skills. Feedback is the crucial component that frames writing-to-learn strategies since learners need to be provided with regular feedback from peers and teachers to construct meaningful knowledge.

The three principles are significant in the development of writing-to-learn activities as they encourage learners to compose authentic writing reflections rather than just regurgitating concepts in science. For learners to develop a deep understanding of science concepts they need to authenticate their understanding by asking questions about the relevance of science knowledge in their contexts. For example, learners need to know about the application of intermolecular forces in their daily lives, such as why some substances dissolve easily in water while others cannot. If the writing activities are based on authenticity, they will be beneficial in eliciting thinking.

Realism

According to Villarroel, et al., (2018), realism is linking knowledge and concepts with everyday life and work. This means it is important for teachers to ensure that there is rich context in the writing activities and that the writing tasks are similar to what learners will encounter in their real or professional lives. The activities designed for this study were based on these principles and required learners to explain concepts in their own words and from their own experience. In particular, the writing assignments that learners completed required them to explain concepts in intermolecular forces and to think about the relevance and application of these concepts. Realism must therefore form the basis for the development of writing assignments and activities. Realism also came into play in the science inquiry writing activities that were included in the WTL study guide.

Cognitive challenge

What emanated from this study was the inclusion of a variety of questions from basic recall questions to higher-order thinking activities. One of the learners in the focus group interview stated that the questions in the study guide were challenging compared to the ones in the traditional textbooks, and therefore the questions elicited higher-order thinking. According to Villarroel et al., (2018), authentic tasks must involve knowledge building thereby promoting higher-order cognitive skills, meaning that the tasks must promote problem-solving, application of knowledge and decision making. This was notable in the study because as the learners were engaged in writing, they were actually in the process of creating knowledge since each learner produces a different kind of writing. The writing produced by learners went beyond textual reproduction of knowledge (Villarroel et al., 2018, p. 845) and moved towards understanding and establishing relationships between concepts in the topic of intermolecular forces. The learners were also engaged in problem-solving especially in science inquiry writing tasks.

Feedback

Feedback is the most integral component of writing instruction. For learners to be able to improve in scientific explanations, they will need to be provided with regular and prompt feedback. However, learners also need to develop self-regulation skills as they engage in writing to understand what good writing means. This will mean that they have to revise their writing and engage in self-evaluation. According to Villarroel et al., (2018), learners must be able to develop skills which enable them to understand what good performance means and must therefore be able to judge their own performance and regulate their learning. If they can regulate their learning, they would be able to assess the performance of their peers. In the current study, peer assessment was at the centre of the project as learners were provided with feedback on their writing assignments by their peers and during in-class discussions. Dialogic feedback was at centre stage of the WTL classes.

5.5 Recommendations for policy and practice

This study uncovered language-related challenges particularly writing in science education. These challenges can be addressed by the implementation of writing-to-learn pedagogies in selected topics in Physical Sciences. The study contributed to a framework that teachers can use to address the challenges related to writing in science classes. The study has also contributed to the principles that guide the implementation and design of writing assignments and activities in the context of science education. However, it is important to note that systems must be put in place at national, provincial and district levels of education. The solutions for the identified challenges are grouped into three categories, namely development of writing-to-learn workbooks, supplementary instruction that focuses on learners' writing in science subjects, and professional development needs.

Development of Writing-to-learn workbooks

As much as textbook publishers are tasked with the development of learning and teaching materials that cover curriculum concepts as suggested in examination guidelines, the DBE through its district and provincial officials from chief education specialists to senior education specialists have a responsibility to narrow the language gap in science education, with particular reference to writing in science education. This can be done by developing additional teaching and learning materials that focus on the development of language capabilities of the learners who take science subjects.

In the lower grades, learners are provided with DBE workbooks in addition to textbooks. However, in the FET phase, this is not the case, and therefore the workbooks can focus on writing-to-learn activities and assignments for learners to engage with. By so doing, the DBE will be providing additional resources that can be beneficial to learners and teachers. Teachers will not need to develop additional tasks that elicit learner writing skills; these tasks can be used as in- and out-of-class writing activities. The workbooks can also help to clarify concepts that are difficult for learners and can facilitate understanding in particular topics.

Supplemental instruction that focuses on literacy skills in MST subjects

To address language-related challenges, supplemental instruction (SI) can be offered to learners to develop specific literacy skills in the discipline of science. Leaners can be allocated two hours per week where they engage in supplemental instruction in the discipline. SI is a form of instruction that is mainly used in different disciplines which entail peer instruction, small group activities, worksheets, practise tests and guided discussions outside the classroom to teach a particular skill (Musah & Ford, 2017).

Currently, South Africa has many unemployed graduates with STEM degrees, and these graduates can offer their service to the department by signing up as tutors and offer SI to learners in language-related challenges in STEM subjects. The graduates can be offered a stipend and do not even need to be full-time staff members as they can provide these services on a part-time basis, particularly after school and weekends. Learners can benefit from these after school programmes which can translate into good academic performance if implemented well. The tutors can even offer services beyond language-related challenges such as conducting practical work with learners and therefore becoming an additional resource to the overworked teacher workforce.

Professional Development

The teachers who participated in the study were positive about the introduction of WTL in the science class. However, they thought that for teachers to implement WTL, they would need some sort of training. Most of the professional development provided by education district officials are content-related rather than focusing on pedagogies in selected disciplines. Although it is important for teachers to engage in content- related professional learning opportunities, it is also important to empower teachers with new pedagogical strategies that can improve learners academic performance. If learners are struggling to answer questions that require scientific explanations and to understand basic concepts, there is a need to engage teachers in pedagogical practices that enable them to implement the strategies in their classes.

5.6 Limitations of the Study

In any research project, limitations have to be taken into consideration. To get to the root of the problem investigated in this project and to study the participants in-depth, Grade 11 learners were selected in one education district. Only three schools from the district volunteered to participate in the study due to limited financial resources and the unavailability of teachers. It is therefore difficult to generalise the findings of this research. The research data collection was a painstakingly slow process because the researcher had to visit each school every week and ensure that the teachers were trained before the implementation of the intervention. This in itself limited the number of schools which could be included in this study.

Other limitations of the study were having a control group and an experimental group in each school. Although this may raise issues of contamination of the results, it also had merits. The researcher considered it important to compare learner performance from each school by ensuring that both the control and the experimental groups experienced similar environments. The teachers were notified that the WTL materials were mainly for the experimental group. During the intervention, the teachers were regularly visited, and the researcher accompanied them to class for both the control group and experimental group to ensure that there were no learners in the control group who could have access to the materials used by the experimental group. To further check, the researcher also ensured that a comparison of the results was made within each school, and the results proved to be significant in favour of the experimental group in each school.

5.7 Suggestion for further research

This study focused on one aspect of literacy which is writing. There are other aspects that still need to be studied, for example, digital literacy skills to facilitate learner understanding in science. Teaching and learning in the twenty-first century require learners to be digitally literate as they must be able to source content that comes in different digital forms. The theory that speaks to this is connectivism which encourages learners to be self-directed where knowledge connects to different nodes. The theory encourages learners to collect information from sources like videos, simulations, online articles and many more to create knowledge collaboratively with peers. I am writing this thesis in the era of a communicable disease, namely the Coronavirus (COVID-19) which is life-threatening and has resulted in the shutdown of educational institutions across the world including South Africa. For this reason, learners need to be digitally literate to learn on their own. For teachers, it means new dimensions of teaching and learning as they now have to facilitate learning via digital platforms.

Other literacies that still need attention are reading and comprehension. These are some of the aspects mentioned by teachers that the majority of learners find challenging. There is a need to develop more research on these literacies as they contribute to the poor performance of the majority of learners in South Africa.

The results from learner and teacher interviews also revealed that WTL strategies can be applied in other topics such as in chemical equilibrium, the lithosphere in Grade 11 and many other topics. Further research is necessary to apply WTL strategies in these topics. Examination reports also indicate that learners across all content subjects in South Africa struggle with understanding basic concepts. Therefore, there is an opportunity for more research on WTL in other subjects such as Life Sciences and Agricultural Sciences where understanding of basic concepts is crucial to facilitate understanding of the subject matter.

5.8 Concluding remarks

In South Africa, education is regarded as a human right, and society, particularly parents, and the government have invested in education to address the historical inequalities brought about by apartheid. The majority of learners, particularly in black society, are struggling on a daily basis with the language of instruction which is often not their home language. The challenge for these learners, particularly science learners, is twofold: they have to struggle to learn the LoLT and simultaneously learn the language of science.

The present study adds to the limited research on the role that writing pedagogies play in improving the academic performance of Physical Sciences learners in South Africa and across the globe, in particular, those whose home languages are different from the language of learning and teaching in schools. This research project has proved that there is an opportunity for teachers to use writing-to-learn strategies to improve learner understanding of IMF concepts. There is a further contribution of a framework for the implementation of WTL strategies that can be utilised by teachers in their science classes. The study also identified key principles that should be considered when designing writing tasks for the implementation of WTL in science classes. There are also suggestions for the DBE on policy implementation regarding WTL projects in STEM subjects. The study implies that as a science education community, it is up to us to assume agency and ensure that writing pedagogies are fused with their teaching.

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Appendices

Appendix 1: Participant information sheet

Title of the research: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Date: ....

Title: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Dear Prospective Participant

My name is Mr Alfred Sipho Hlabane and I am doing research under the supervision of Prof N. Nkopodi, a Chair of Department in the Department of Science and Technology Education towards a D.Ed. at the University of South Africa. We have funding from UNISA Postgraduate Bursary. We are inviting you to participate in a study entitled "The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces".

What is the purpose of the study?

This study is expected to collect important information that could improve learners writing skills and academic performance in chemistry topic of intermolecular forces which is considered to be one of the difficult topics in Physical science.

Why am I being invited to participate?

You are invited because your school is conveniently stationed closer to where the researcher is residing and the investigation is based on the grade 11 Physical Sciences topic that you are currently doing or teaching. I obtained information about you from your school Principal.

What is the nature of my participation in this study?

The study involves a pre-test and a post-test as well as focus group interviews with participating learners and one on one interview with teachers. The Writing-to-learn project, which include the pre-test and the post-test, will require learners' commitment until the end of the programme. Teachers' interview will require a minimum of 20 minutes.

Can I withdraw from this study even after having agreed to participate?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent / assent for. You are free to withdraw at any time and without giving a reason. However, it will be difficult to identify your completed questionnaire prior to withdrawal.

What are the potential benefits of taking part in this study?

The study investigates the effects on embedding writing pedagogies in teaching the topic of intermolecular forces. Intermolecular forces is considered to be one of the most difficult topics in chemistry and it is applied in many chemistry topics (Chemical equilibrium, rates of reactions, electro chemistry and organic chemistry) in grade 12. Therefore, your participation will enhance learners understanding of the topic and their academic writing skills will improve.

Are there any negative consequences for me if I participate in the research project?

There will be no possible risks that are associated with the collection of data whatsoever. The researcher will ensure that none of you experience any form of abuse or intimidation.

Will the information that I convey to the researcher and my identity be kept confidential?

Your name will not be recorded anywhere and no one will be able to connect you to the answers you give. Your answers will be given a code number or a pseudonym and you will be referred to in this way in the data, any publications, or other research reporting methods such as conference proceedings.

Your answers may be reviewed by people responsible for making sure that research is done properly, including the supervisors, language editors, transcribers, external coder, and members of the Research Ethics Review Committee. Otherwise, records that identify you will be available only to people working on the study, unless you give permission for other people to see the records.

A report of the study may be submitted for publication, but individual participants will not be identifiable in such a report.

How will the researcher(s) protect the security of data?

The researcher will store hard copies of your answers for a period of five years in a locked cupboard/filing cabinet in KwaMhlanga for future research or academic purposes; electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. After five years, hard copies will be shredded and/or electronic copies will be permanently deleted from the hard drive of the computer through the use of a relevant software programme.

Will I receive payment or any incentives for participating in this study?

No payment or incentives will be received by participants during the study.

Has the study received ethics approval?

This study has received written approval from the Research Ethics Review Committee of the college of Education, UNISA and the Mpumalanga Department of Education. A copy of the approval letter can be obtained from the researcher if you so wish.

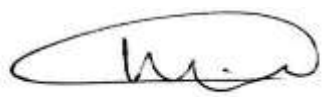
How will I be informed of the findings/results of the research?

If you would like to be informed of the final research findings, please contact Mr. Alfred Sipho Hlabane on 011 717 1485 or email hlabaneas@gmail.com .

Should you have concerns about the way in which the research has been conducted, you may contact my supervisor Prof Nkopodi at 012-429-4731 or Email nkopon@unisa.ac.za

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.



Hlabane Alfred Sipho

Appendix 2: Request Letter for permission to conduct research in Mpumalanga

Title of the research: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Date: …………………………………………

Mpumalanga Department of Education representative, Circuit managers, School Principals of Nkangala Region Secondary Schools
Department of Education (Mpumalanga Province)

Dear Provincial Department official

I, Mr. Alfred Sipho Hlabane am doing research under supervision of Prof N Nkopodi, a Chair of Department in the Department of Science and Technology Education towards a D.Ed. in Curriculum Studies at the University of South Africa. We have funding from UNISA Post Graduate bursary. We request permission to conduct research in your schools. The study entitled "The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces". Permission has been granted by the Mpumalanga Department of Education.

The general aim and objective of this study is to critically analyse and investigate the significance of academic writing skills in the learning of Physical Sciences and to examine the extent to which Physical Sciences teachers engage learners to expository and argumentative writing. Your region and the schools have been selected because they are located where the researcher is stationed. The study will entail investigating the effects on embedding writing pedagogies in teaching intermolecular forces. Learners will participate in the writing-to-learn programme, where learners will be pre-tested and post-tested as well as participating in focus group interviews. Teachers who participated in the study will participate in one on one interview and these teachers will be the one responsible for implementing the programme.

The benefits of this study are that learners' academic writing skills will improve and this may translate to better academic performance in Physical Sciences.

There are no potential risks in this study. There will be no reimbursement or any incentives for participation in the research. Feedback procedure will be through an information session that will be held after data has been analysed.

Yours sincerely

Alfred Sipho Hlabane (Mr)

UNISA Doctoral student

Appendix 3: A letter to the school Principals

Title of the research: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Date: ……………………………………….

To: The School principals

Department of Education (Mpumalanga Province)

Dear Principal

I, Mr. Alfred Sipho Hlabane am doing research under supervision of Prof N Nkopodi, a Chair of Department in the Department of Science and Technology Education towards a D.Ed. in Curriculum Studies at the University of South Africa. We have funding from UNISA Post Graduate bursary. We request permission to conduct research in Nkangala District (KwaMhlanga North east and South West Circuits) secondary schools. The study entitled "The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces".

The general aim and objective of this study is to critically analyse and investigate the significance of academic writing skills in the learning of Physical Sciences and to examine the extent to which Physical Sciences teachers engage learners to expository and argumentative writing. Your region and the schools have been selected because they are located where the researcher is stationed. The study will entail investigating the effects on embedding writing pedagogies in teaching intermolecular forces. Learners will participate in the writing-to-learn programme, where learners will be pre-tested and post-tested as well as participating in focus group interviews. Teachers who participated in the study will participate in one on one interview and these teachers will be the one responsible for implementing the programme.

The benefits of this study are that learners' academic writing skills will improve and this may translate to better academic performance in Physical Sciences.

There are no potential risks in this study. There will be no reimbursement or any incentives for participation in the research. Feedback procedure will be through an information session that will be held after data has been analysed.

Yours sincerely

Alfred Sipho Hlabane (Mr)

UNISA Doctoral student

Appendix 4: A letter to the teachers

Title of the research: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Dear teacher

This letter is an invitation to consider participating in a study I, Mr. Alfred Sipho Hlabane am conducting as part of my research as a Doctoral student entitled "The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces" at the University of South Africa. Permission for the study has been given by Mpumalanga Department of Education and the Ethics Committee of the College of Education, UNISA. I have purposefully identified you as a possible participant because of your valuable experience and expertise related to my research topic.

I will provide you with more information about this project and what your involvement would entail if you should agree to take part. The importance of academic writing in science education is substantial and well documented. In this project, I would like you to get involve in implementing the intervention and later I would like to have your views and opinions on this topic. This information can be used to improve our teaching as Physical Science Teachers.

Your participation in this study is voluntary. It will involve an interview of approximately 20 minutes in length to take place in a mutually agreed upon location at a time convenient to you. You may decline to answer any of the interview questions if you so wish. Furthermore, you may decide to withdraw from this study at any time without any negative consequences. In addition to the interview, you will be asked to facilitate the writing-to-learn project in science education which involve the topic of intermolecular forces. During the teaching, I might sit in some of the presentations but not actively participate in the teaching.

With your kind permission, the interview will be audio-recorded to facilitate collection of accurate information and later transcribed for analysis. Shortly after the transcription has been completed, I will send you a copy of the transcript to give you an opportunity to confirm the accuracy of our conversation and to add or to clarify any points. All information you provide is considered completely confidential. Your name will not appear in any publication resulting from this study and any identifying information will be omitted from the report. However, with your permission, anonymous quotations may be used. Data collected during this study will be retained on a password protected computer for 5 years in a locked office.

The benefits of this study are that the learners that you teach will be able to write well which may also improve their academic performance and there are no known or anticipated risks to you as a participant in this study. You will not be reimbursed or receive any incentives for your participation in the research. If you would like to be informed of the final research findings, please contact Mr Alfred Sipho Hlabane on 011 717 1485or email hlabaneas@gmail.com.

If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please contact me telephonically or by email provided above.

I look forward to speaking to you and thank you in advance for your assistance in this project.

If you accept my invitation to participate, I will request you to sign the consent form.

Yours sincerely

__________________________ ________________________

Researcher's name (print) Researcher's signature:

UNISA college of education

Appendix 5: A letter requesting parental consent for minors

Title of the research: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Dear Parent

Your child is invited to participate in a study entitled "The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces". I am undertaking this study as part of my Doctoral research at the University of South Africa. The general aim and objective of this study is to critically analyse and investigate the significance of academic writing skills in the learning of Physical Sciences and to examine the extend at which Physical Sciences teachers engage learners to expository and argumentative writing. The possible benefits of the study are that your child's proficiency in academic writing will improve in the context of science as a discipline, which may lead to improved academic performance. I am asking permission to include your child in this study because they are currently in grade 11 and they are doing Physical Sciences as their subject choice. I expect to have an additional of 316 other learners participating in the study.

If you allow your child to participate, I shall request him/her to:

- Take part in focus group interviews.
- Complete a pre-test and a post-test.

Any information that is obtained in connection with this study and can be identified with your child will remain confidential and will only be disclosed with your permission. His/her responses will not be linked to his/her name or your name or the school's name in any written or verbal report based on this study. Such a report will be used for research purposes only.

There are no foreseeable risks to your child by participating in the study. Your child will receive no direct benefit from participating in the study; however, the possible benefits to education are writing skills and academic performance. Neither your child nor you will receive any type of payment for participating in this study.

Your child's participation in this study is voluntary. Your child may decline to participate or to withdraw from participation at any time. Withdrawal or refusal to participate will not affect him/her in any way. Similarly, you can agree to allow your child to be in the study now and change your mind later without any penalty.

The study will take place during school holidays and weekends with the prior approval of the school principal and your child's teacher.

In addition to your permission, should your child agree to participate in the study, you and your child will be asked to sign the assent form, which accompanies this letter. If your child does not wish to participate in the study, he or she will not be included and there will be no penalty. The information gathered from the study and your child's participation in the study will be stored securely on a password locked computer in my locked office for five years after the study. Thereafter, records will be erased.

If you have questions about this study please ask me or my study supervisor, Prof Nkopodi in Department of Science and technology Education, College of Education, University of South Africa. My contact number is 011 717 1485 and my email is hlabaneas@gmail.com.The e-mail of my supervisor is nkopon@unisa.ac.za . Permission to conduct the study has already been given by Mpumalanga Department of Education and the Ethics Committee of the College of Education, UNISA.

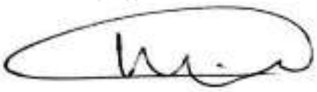
You are making a decision about allowing your child to participate in this study. Your signature below indicates that you have read the information provided above and have decided to allow him or her to participate in the study. You may keep a copy of this letter.

Name of child: ______________________________

Sincerely

______________________________ ________________________ ________________

Parent/guardian's name Parent/guardian's signature: Date:



Mr Alfred Sipho Hlabane

____

Researcher's name (print) Researcher's signature Date:

UNISA | college of education

APPENDIX 6: A letter to the learners

Title: The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces

Dear Respondent Date:

I am doing a study on the effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces as part of my doctoral studies at the University of South Africa. Your principal and the provincial Department of Education have given me permission to do this study in your school. I would like to invite you to be a very special part of my study. I am doing this study so that I can find ways that your teachers can have strategies to teach intermolecular forces in your classroom. This may help you and many other learners of your age in different schools.

This letter is to explain to you what I would like you to do. There may be some words you do not know in this letter. You may ask me or any other adult to explain any of the words that you do not know or understand. You may take a copy of this letter home to think about my invitation and talk to your parents about this before you decide if you want to be in this study.

I would like to ask you to participate in the writing-to-learn (WTL) programme that will take place during school holidays and weekends. The programme will focus on your ability to write in the topic intermolecular forces and during this session you will complete the pre-test and the post-test as well as the focus group interview.

I will write a report on the study but I will not use your name in the report or say anything that will let other people know who you are. Participation is voluntary and you do not have to be part of this study if you do not want to take part. If you choose to be in the study, you may stop taking part at any time without penalty. You may tell me if you do not wish to answer any of my questions. No one will blame or criticise you. When I am finished with my study, I shall return to your school to give a short talk about some of the helpful and interesting things I found out in my study. I shall invite you to come and listen to my talk.

The benefits of this study are that you will be able to write well in the language of instruction in the context of Physical Sciences which is a challenge that most of the learners are experiencing and this will translate to improvement in academic performance. Note that there are no potential risks to the study and you will not be reimbursed or receive any incentives for your participation in the research.

If you decide to be part of my study, you will be asked to sign the form on the next page. If you have any other questions about this study, you can talk to me or you can have your parent or another adult call me. Do not sign the form until you have all your questions answered and understand what I would like you to do.

Researcher: Mr Alfred Sipho Hlabane Phone number: 011 717 1485

Do not sign the written assent form if you have any questions. Ask your questions first and ensure that someone answers those questions.

APPENDIX 7: A letter from Mpumalanga Department of Education

education
MPUMALANGA PROVINCE
REPUBLIC OF SOUTH AFRICA

Building No. 5, Government Boulevard, Riverside Park, Mpumalanga Province
Private Bag X11341, Mbombela, 1200.
Tel. 013 766 5552/5115, Toll Free Line: 0800 203 116

Litiko le Temfundvo, Umnyango we Fundo | Departement van Onderwys | Ndzawulo ya Dyondzo

Mr Alfred Sipho Hlabane
Email:sipho.hlabane@wits.ac.za
011 717 1485
076 281079

RE: APPLICATION TO CONDUCT RESEARCH: MR ALFRED SIPHO HLABANE

Your application to conduct research study was received and is therefore acknowledged. The tittle of your research project reads:" **A microscopic view of physical sciences leaners' academic writing skills on the topic of Intermolecular forces".** I trust that the aims and the objectives of the study will benefit the whole department especially the beneficiaries. Your request is approved subject to you observing the provisions of the departmental research policy which is available in the department website. You are requested to adhere to your university's research ethics as spelt out in your research ethics.

In terms of the research policy, data or any research activity can be conducted after school hours as per appointment with affected participants. You are also requested to share your findings with the relevant sections of the department so that we may consider implementing your findings if that will be in the best interest of the department. To this effect, your final approved research report (both soft and hard copy) should be submitted to the department so that your recommendations could be implemented. You may be required to prepare a presentation and present at the departments' annual research dialogue.

For more information kindly liaise with the department's research unit @ 013 766 5476/5148 0r a.baloyi@education.mpu.gov.za

The department wishes you well in this important project and pledges to give you the necessary support you may need.

MRS MOC MHLABANE
HEAD: EDUCATION
08/5/18
DATE

MPUMALANGA

APPENDIX 8: Ethical clearance certificate from UNISA

UNISA university of south africa

UNISA COLLEGE OF EDUCATION ETHICS REVIEW COMMITTEE

Date: 2018/07/18

Ref: **2018/07/18/44589689/38/MC**
Name: Mr AS Hlabane
Student: 44589689

Dear Mr Hlabane

Decision: Ethics Approval from 2018/07/18 to 2023/07/18

Researcher(s): Name: Mr AS Hlabane
E-mail address: 44589689@mylife.unisa.ac.za
Telephone: +27 73 661 4570

Supervisor(s): Name: Prof N Nkopodi
E-mail address: nkopon@unisa.ac.za
Telephone: +27 12 429 4739

Title of research:

Comparative Effectiveness of Writing Intensive Teaching and Traditional Teaching pedagogies in enhancing academic performance in the topic of Intermolecular Forces

Qualification: D.Ed. in Science and Technology Education

Thank you for the application for research ethics clearance by the UNISA College of Education Ethics Review Committee for the above mentioned research. Ethics approval is granted for the period 2018/07/18 to 2023/07/18.

*The **medium risk** application was reviewed by the Ethics Review Committee on 2018/07/18 in compliance with the UNISA Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

UNISA College of Education Ethics Review Committee.

3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.
7. No field work activities may continue after the expiry date **2023/07/18**. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number **2018/07/18/44589689/38/MC** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Kind regards,

M Claassens

Dr M Claassens
CHAIRPERSON: CEDU RERC
mcdtc@netactive.co.za

PP: Sebate
Prof V McKay
EXECUTIVE DEAN
Mckayvi@unisa.ac.za

Appendix 9: Learner consent form

WRITTEN ASSENT

I have read the letter which asks me to be part of a study titled "the effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces" at my school. I have understood the information about the study and I know what I will be asked to do. I am willing to be in the study.

Learner's name (print):	Learner's signature	Date:
Parent's name (print):	Parent's signature	Date:
Researcher's name (print):	Researcher's signature	Date:

Appendix 10: Teacher consent form

CONSENT FORM

I have read the information presented in the information letter about the study entitled "The effectiveness of writing-to-learn pedagogies in enhancing learners' understanding in the topic of Intermolecular forces". I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and add any additional details I wanted. I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses. I am also aware that excerpts from the interview may be included in publications to come from this research, with the understanding that the quotations will be anonymous. I was informed that I may withdraw my consent at any time without penalty by advising the researcher. With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

Participant Name (Please print):______________________________

Participant Signature: _______________________________________

Researcher Name: (Please print) _______________________________

Researcher Signature: _______________________________________

Date: ____

Appendix 11: Teacher's interview guide

Introductions

I am very grateful to you all for committing your time to participate in this interview on the study of intermolecular forces and writing intensive teaching. My name is Mr Alfred Sipho Hlabane and I work for University of the Witwatersrand. I am a researcher in Physical Sciences education, and I am currently researching the study of teaching intermolecular forces in schools and the study is part of my doctoral study with the University of South Africa. You have just participated in the writing-to-learn (WTL) project for the study of intermolecular forces, and I would like to know how you feel about it. The reason for our discussion is to try to understand what you think about the study, so that we may find effective ways of teaching the topic.

Your views and feelings will be confidential amongst the research team, for the purpose of the research. Anything you say will remain anonymous, and will not be used against you in any way, including assessing or judging you. You are free to decline from participating at any time if you so wish, and there will be no consequences for you. The interview will take approximately 20 minutes, and it will be audio-recorded so that we may be able to listen to it at a later stage, to make sure that we capture your views correctly. The materials on the tape will not be reproduced or used anywhere else. Do you have any questions or comments, before we start?

1. How did you find teaching intermolecular forces to your learners? Did you find it easy or difficult? Tell me more.
2. How did you go about teaching intermolecular forces as it is a topic that contains concepts that are defined and require language facility?
3. Do you think that English language may be an issue to the learners learning such concepts?
4. Which aspects of language are problematic according to your views (reading, writing, comprehension).

5. Do you think that writing is a problem for them? Why is that so?
6. When you give learners essay type (extended written questions), how well do they do in such questions. How do you normally assess such questions? Do you require explanations or look for facts only? Do you look for understanding?
7. Do you think that learners benefitted from the writing-to-learn programme?
8. What are the strengths and weaknesses of the Writing-to-learn programme?
9. Do you think that other teachers will benefit from this programme if they have to go through the same programme?
10. If you were to teach the other teachers to teach the programme, will you be able to do it?
11. Do you think you will be able to incorporate the programme into other topics? If so, which other topics do you think will be suitable for the writing-to-learn programme?
12. What do think teachers need to be able to implement writing to learn effectively in their classroom?

Thank you very much for your participation and patience. Your contribution is highly appreciated.

APPENDIX 12: FOCUS GROUP INTERVIEW SCHEDULE

Introduction:

I am very grateful to you all for committing your time to participate in this discussion on the study of intermolecular forces. My name is Mr Alfred Sipho Hlabane and I work for University of the Witwatersrand. I am a researcher in Physical Sciences, and I am currently researching the study of teaching intermolecular forces in schools and the study is part of my doctoral study with the University of South Africa. You have just completed the study of intermolecular forces, and I would like to know how you feel about it. The reason for our discussion is to try to understand what you think about the study, so that we may find effective ways of teaching the topic.

Your views and feelings will be confidential amongst the research team, for the purpose of the research. Anything you say will remain anonymous, and will not be used against you in any way; including assessing or judging you. There are no wrong or right answers. Everyone's contribution is important, welcomed and encouraged. You are therefore requested to feel free to say what you really think and how you really feel. You are free to decline from participating at any time if you so wish, and there will be no consequences for you. The discussion will take approximately 20 minutes, and it will be audio-recorded so that we may be able to listen to it at a later stage, to make sure that we capture your views correctly. The materials on the tape will not be reproduced or used anywhere else. Do you have any questions or comments, before we start?

Questions:

1. Let us talk about your experience in the implementation of writing-to-learn in the topic of intermolecular forces. What do you think about it? What are your thoughts? Tell me more. If you liked it, what is it that you liked about it? What is it that you did not like about it?
2. Is it different from the way you have been taught before or is it similar? Did you find it easy or difficult?
3. After studying intermolecular forces and writing intensive teaching, you wrote a test to assess your understanding of the topic. Tell me what you think of your performance in the test?
4. What do you think is the best strategy to improve the language in science?
5. Is there anything else regarding the study of intermolecular forces using writing intensive teaching that you would like to share with us?

Thank you very much for your participation and patience. Your contribution is highly appreciated.

APPENDIX 13: Pre-test-post-test

PHYSICAL SCIENCES

PRETEST/POSTTEST

GRADE 11

Intermolecular Forces

ASSESSOR: MR AS HLABANE

TIME: 1.5 Hours MARKS: 44

Instructions:

1. ANSWER all questions.

2. Give examples in your explanations to show understanding.

3. Do not regurgitate definitions and explanations; use your own words in explanations

4. Write neatly and legibly.

QUESTION 1 **[8]**

Answer the following multiple choice questions by circling the correct answer:

1. Of the following substances, only __________ has induced-dipole (London dispersion) forces as its only intermolecular force.

A CH_3OH

B NH_3

C H_2S

D CH_4

E HCl

2. Which of the following has hydrogen bonding as its only intermolecular force?

A HF

B H_2O

C $C_2H_{13}NH_2$

D $C_5H_{11}OH$

E None, all exhibit dispersion/induced dipole forces.

3. What is the major intermolecular force in CBr_4?

A induced-dipole (London-dispersion) forces

B ion-dipole forces

C ionic bonding

D dipole-dipole attraction

E hydrogen-bonding

4. Of the following substances, __________ has the highest boiling point.

A H_2O

B CO_2

C CH_4

D Kr

E NH_3

QUESTION 2
[16]

Intermolecular forces are electrostatic forces that you find between molecules. In your Physical Sciences class you discussed types of intermolecular forces. Answer the following questions about intermolecular forces and give example and elaborate more where necessary

2.1 Explain the differences between intermolecular forces and intramolecular forces. Use examples where necessary. (4)

2.2 Explain the following concepts using own words and give examples where necessary.

2.2.1 Dipole-dipole forces (4)

2.2.2 Induced-dipole forces (London forces) (4)

2.2.3 Hydrogen bonds
(4)

QUESTION 3
[10]

Learners conduct an investigation to determine which of the following compound have the weakest intermolecular forces. In one of the investigations, they determine the boiling points of the substances. The results are shown on the table below.

COMPOUND		**Boiling Point (20°C)**
A	water	100
B	Nail polish remover remover	56
C	Ethanol	90
D	Methylated spirit	78

3.1 Write down the investigative question for this investigation.
(2)

3.2 Explain in terms of intermolecular forces why compound A and C have high boiling points as compared to compound B. Indicate which of the compounds have the weakest intermolecular forces.
(5)

3.3 Write down your conclusion for this investigation. (3)

QUESTION 4
[10]

Learners use compounds A to C, shown in the table below, to investigate factors that influence the boiling point of organic compounds.

A	$CH_3CH_2CH_2CH_3$
B	$CH_3CH_2CH_2CH_2CH_3$
C	$CH_3CH_2CH_2CH_2CH_2CH_3$

4.1 Which of the compounds (A, B or C) has the highest boiling point looking at the molecular masses of the substances? Explain. (4)

4.2 Write down the hypothesis for this investigation. (2)

The learners now compare the boiling points of compounds **D** and **E**, shown in the table below.

D	HCl
E	CO_2

4.3 How does the boiling point of compound **D** compare to that of compound **E**? Write down HIGHERTHAN, LOWERTHAN or EQUAL TO .Fully explain your answer. (4)

TOTAL: [44]

APPENDIX 14: Transcriptions for the focus group interview

Questions:

1. Let us talk about your experience in the implementation of WIT in the topic of intermolecular forces. What do you think about it? What are your thoughts? Tell me more. If you liked it, what is it that you liked about it? What is it that you did not like about it?

Group 1

Learner 1: ya le material isicedile because lamatest lawa osi nikeze wona esiwabhale macala, amange questions esiwabhale lapha ematesten wamange esiwatholile kuexam yethu, so isicede kakhulu ngoba like zange skhathesningi sibhalile le test, sithe masibali exam sakhumbula lamaquestion la afamiliar kunala siwabone khona, so like I study guide siscedile ngoba like sisenze kuthi masibhali exam kuba into siyibona leya, kubeyinto esine clue ngayo like isicedile lapho so immaterial ibe valid

Leaner 2: ngiyavumelana no (learner A) i material iscede kakhulu amaintermolecular forces ngiwa understanda better kunokucale

Learner 3: Imaterial isicedile because Eh eh amalokhanje amagama ala kuscience la asiniki challenge, ngoba amaga akhona amange a difficult so kukose kuthi sithole some research kuthi ikhonikuwaziswisa ngoba a xazi kuthithini, ngoba amanye amagama akatholakali kudictionary nanoma siwazuma akekho. Mara kumaterial bewakhona axazeka kahle.

Group 2

Leaner 4: le material and the way u maneer beka fundisa nga khona kube lula ukuthi siunderstande amaintermolecular forces ngoba agcwele ngama definition angazisiseki. Mara istudy guidenama assignments asiprepare kahle fo le topic.

Learner 5: Mina I enjoyed doing the assignments ngoba most of the concepts I was able to find from the study guide. Nyikgone ukuthole more information about intermolecular forces juinternet especially amaaplication wamaintermolecular forces

Group 3:

Learner 6: The material was valid and I ngienjoye umaumeneer asiyenziza kumawriting cards. First bengingaundertande ukuthi why siyenza lama writing cards mara after that ngabona kuthi abalulekile ngoba bekangiforster ukuthi ngicabange. It was easy ngoba besengiyenze amassignments wakhona. Ungathi abanye bo meneer banga yenza so besizozwisiza kancono

Learner 7: Benginga undertande ukuthi why sifanele sibhale amassignments if akekho ku CAS mara mangiceda kuwabhala I was happy because I did understand intermolecular forces better.

Group 4:

Learner 8: Sicede isikhathi esiningi eclassinini sibhala. Bengicabanga ukuthi Ms akafuni ukusifundisa uyavilapha, mara after that ngabona ukuthi mangibheka istudy guide sicaza kancono nokuthi uMs Uyasiceda ngoba mawubhala understanda better.

Leaner 17: Ngithande ilearner guide ngoba beyicaza kancono ane isiforter ukuthi sianswere amactivities. Amaassignments angiprepere ncono, uMs amkafundisa besengineknowldge ngama intermolecular forces

2. Is it different from the way you have been taught before or is it similar? Did you find it easy or difficult?

Group 2:
Leaner 18: ya Sihlukile immaterial leya beyina mahard question compared to amatax book so that masifika kuexamination amaquestion abawavesa lapha sikgone ukuwanswera rather than lawa bavesa kutext book because bona bawenza ukuthi abe simpler but immaterial iwanzesa ukuthi abe difficult ukuthi sikgone ukuwaziswa ncono

Learner 19: It was different ngoba besibhala kakhulu ene beyisenza ukuthi sicabange ene besingazwisisi ukuthi why mara nje siyabona ukuthi kubalulekile

Group 2

Learner 20: Mina ngibone kudifferent espeacially ngoba sicale ngama assignments, kuphysics bathanda mapractical abathande ukusipha maassignments. Ngikgone ukuunderstanda amaintermolecular forces better ngamaassignments.

Group 3:

Learner 21: Khona bekudifferent bekungafani nangendlela umeneer ahlala asifundisa ngakhona. Mara idinga iskhathi esinenge ukuthi isebenze kahle. Mara yona iyasebenza ngoba thina sometimes siyavhilapha ukucabanga

Group 4

Learner 22: Mina bengicabanga ukuthi uMs uyasidlalisa ngala macards mara ngathola ukuthi asicabangisa kakhulu ngoba kuphysics sibhala kakhulu masenza macalculations hay amaexplanations

Learner 23: Yoh bengicabanga ukuthi amaasignments lawa anzima mara istudy guide sawayenza abalula. Angifoste ukuthi ngi funde istudy guide before uMs asifundisa. UMs makafundisa bewungathi ngingafundisa mina ngoba besengazi kakhulu. Kuyasiza ukufunda itopic in advance. Nje ngenza njalo kumasujects afana ne maths and biology. Siyangisebenzela le strategy.

3. After studying intermolecular forces and writing intensive teaching, you wrote a test to assess your understanding of the topic. Tell me what you think of your

performance in the test? Do you think that WIT could have helped to improve your performance in the topic?

Group 1
Learner 24: yona beyingasi difficult kangaka because besesifundile ngama intermolecular forces befor.

Learner 3: angisho sixale ngokubhala ipre-test, iprestest beku diffiscult kuthi ukubhala maquestion lawa couse besingangeni kuma intermolecular forces then is stdy guide, uman wasipha mastudy guide, then masesifunda nge study guide sawa understand better ama intermolecular forces, then masesiyobhala I post-test besesiunderstanda ncono.

Group 2

Learner 25: Ipre-test was difficult mara after senza amaassignments and sifuna nge study guide ipost-test yabaula

Learner 5: Mina ngicabanga ukuthi I did perform well ku post-test.

Group 3:

Learner 13: Yah, name ngi bone ipost-test ilula ngobana masifunda ngamacards and from study guide bengizwisa ka ncono

Group D:

Learner 14: Ngiyithole ilula ipost-test mara ipre-test was difficult. Ama assignments angiprepare kancono for ipost-test.

4. What do you think is the best strategy to improve the language in science

Group 1

Learner 15: Mina ngixabanga ukuthi istudy guide lesa mangungaba nama keywords, amakeywords is caza ukuthi igama elinje licaza lokku. Licaza so lizosiza ukuthi sikgonu kuunderstanda better.

Learner 16: Ukungena ku internet kufuna imali kuthi sisongena kuinternet uthola ukuthi awunamali you kuthenga madata

Learner 17: ilanguage ku science aisi bad ngaleyondlela because most amatextbook esiwasebenzisayo like after I chapter kune summary so bayasenzela but isummary leya bayicuta in short buyictta msinyana, like manga increase istandard sa le summary, bayenze siundertande of that isummary nese anyway lamanye bayabhala ku glossary , siyathola amanye madefinition like baincrease istandardt so like mabanga increase instard seglossary ne summary kuzoba right.

Group 2
Ilanguange yescience is difficult mara masingapractice ukufunda nokubhala eclassini kuzobalula

Group 3

Learner A:Amateachere afundisa ienglish abayazi iscience masingaba naboteachere abaunerstanda iscience kuenglish kungasiceda khulu

Group 4:

Learner A: Ku science sifocusa kakhulu kumacalculations kuzoxeda kakhulu masingafunda amadefinitions ukuthi sikgone ukuzwisisa

Learner B: Amascientist athanda macalculations ne mapractical khulu mara siyakhohlwa ukuthi sifanele siundertande amanye amagama ku science.

Is there anything else regarding the study of intermolecular forces using writing intensive teaching that you would like to share with us?

Thank you very much for your participation and patience. Your contribution is highly appreciated.

APPENDIX 15: Transcriptions of interview for Teachers

1. How did you find teaching intermolecular forces to your learners? Did you find it easy or difficult? Tell me more.

Teacher A: No sometimes , it depends on the learners because the must, some of them when the come to the grade they do not have the foundation so they find intermolecular forces in grade 11, so of them they find it difficult and some of them is easy but when you do those practicals of intermolecular forces like water, and then eh spirit, gasoline, when you show them through practicals, the become, they, they understand it more.

Teacher B: intermolecular forces inzima to the students, ngoba it requires students to do the explanations, ayifani with other computational topics like stoichiometry. I don't like teaching this topic ngoba it requires that I explain a lot to students and thina amascientist we are not good at that. The sad part is that the topic continues in garde 12 when they do organic chemistry and they still struggle especially with the physical properties of organic compound. Abantwana bethu are not good in writing explanations, they are good in calculating and this creates a problem for us as we are not prepared for this like they do in the social studies and other subjects.

Teacher C. You know I am struggling to teach this topic. The topic has a lot of concepts to explain. Even though they understand amaconcepts when you start to relate them to physical properties bayabalwa. I wish can have a good strategy to teach this topic, but hey kunzima ngoba uzathi bayaunderstander mara ma ba bhala kula ubona kuthi abazwi nex. I intermolecular forces beyingekho e teacher college, for that reason we were not well prepared to teach it. So sometimes ngibiza laba abasha so that they can teach it for me. Hey ziya buya.

Teacher D. intermolecular forces is difficult to students. I like teaching the topic and I enjoy it but my learners still struggle in the exam as they have to explain concepts. Especially if you are a foreigner, it becomes difficult to code switch and speak isiNdebele to make them understand. But all in all it is an interesting topic as it is related to real life and has a lot of applications in industry. I wish I can have a good strategy to make learners understand it better, especially in examination because they have to explain and they still eh struggle, and they struggle indeed.

Teacher E: hey baba kunzima ngempela. For teachers we find it easy,but for ama2000 they are not good in learning this topic. What make it worse ukuthi le topic ifuna ba explane ama concepts inrelation to physical properties, ene aba boni lutho. Especially ngoba they are not good inreading and therefore it makes matters worse. I always tell them that it is important for them to understand scientific concepts but only few of them bayanglale ene bayenze what I tell them to do. The department does not prepare us to teach topics that ezifana nalezi, bona they are only interested ukuthi abantwana ba phase but they don't prepare us. Science as a subject want students who are committed all the time and who are good readers. But lama2000 aworse, bafuna amaresults mara abafuni ku sebenza. Thina evarsity we did amamodule afana nabo academic literacy and English for specific purpose. E high school asinazo, angazi ukuthi bayenzani ku English. Ngoba aba aba prepari enough for amasubject wethu. Manje thina we are not English teachers. Manje thina we will just drill them to pass, mara iintermolecular forces bayayifailer ngoba ifuna iunderstanding.

2. How did you go about teaching intermolecular forces as it is a topic that contains concepts that are defined and require language facility?

Teacher A: As I have indicated, when do practical they understand better, but when write in exam they fail because they have to explain concepts. Other teachers in the lower grade they use local language and eh this become a problem to us when the come to grade 11 because they have to learn for understading especially in exam and they suffer because of that. Intermolecular forces for them is difficult because they content need explanation and and that is not easy for the learners.

Teacher B. Ababoni lutho ngoba they have to explain and do description. The topic is not difficult but because abakwazi uku explainer bayahlupheka. Maybe when they learn in their mother toungue they will understand. But laba bona ba worse because they courriculum does not encouaage them to read. ene iCAPS is results oriented and it does not ecourage the skills like reading and writing ene that's why this topic challenge them.

Teacher C: Mina nje ngomdebele, I will recommend ukuthi bafunde letopic in their mother tongue because explaining the concepts like intermolecular and intramolecular forces is not easy for second language learners that we are teaching. The concepts are very difficult because they cannot see them in real life. How do you explain that there are forces between molecules when they cannot even see the molecules. Some of them they do not even believe when you say

matter has got particles that are always in constant motion, manje we have to convince them and sometimes because of their traditional and religious believe abaccepti. Babelivela kubozimu manje if you say to them matter is made up of small particles, bazothi why because yonke into is created by God and the Gods.

Teacher D: Intermolecular forces is a topic for intelligent student who are good readers. To explain these abstract concepts, learners find it difficult, especially because they are not good in English, it makes it difficult to explain although as a teacher is easy, but for the topic to penetrate their minds it always difficult. I always spend a lot of time trying to make them understand but if they can't read after class it become a useless exercise to explain too much.

Teacher E: Yah eish ziyabuya broer. Angazi niyenza kanjani e wits. Phela it is like forcing a donkey to drink water and yona mayingafuni ayifuni. Usually I make them write a notes on the topic and after that I give them a classwork based on the notes. Bit still uzobona ukuthi I language is till a problem. Maybe we should go back to primary school and make them recite concepts by singing. But they find letopic difficult.

3. Do you think that English language may be an issue to the learners learning such concepts?

Teacher A:

Yes, because is problem to them because when they start from other grade they don't they don't start with the english they start with on when start teaching them the those language when they come to us we speak English, then become problem to them, but as times goes on when we start teaching them small small they get used to the language , especially the the scientific terms.

Teacher B: English is not our mother toungue. Yebo, english is a contributing factor. Nge intermolecular forces is even worse ngoba they have to explain concepts like hydrogen bonds, dipole-dipole forces which are Greek to them.
Teacher C: mfoo ziyajika lana. English iyinkinga. Abanye the reason of not participating in class is because of lesislungu sabo esibuya eBritain. Ku matopic afana ne intermolecular forces siyahlupheka ngoba they need to understand english. Masenza macalculations in other topics kuba bette.

Teacher D: English is big problem in South Africa. In my country is not a problem because they start with English from foundation phase. This thing of mother tongue does not apply in my country. That's we don't have a language problem, in South Africa even the teachers are struggling because they did not have a good foundation. For the topic of intermolecular forces, they are expected to explain, how will they do it if they don't understand the English,

Teacher E: Islungu sinzima. Even for us teachers but because we used to the language of the subject we are able to cope. In the lower grades ababapreperi kahle ukuthi bakhone ku explaina and to speak I cant even mention reading which is also the most contributing factor. They are not even aware that they need to read previous notes before they come to class. Mawubabuza about what we did yesterday bakuhlahlela mehlo as if they were not in class yesterday. Hybo, that's what we have to deal with every day. But siyasurviva against all odds.

4. Which aspects of language are problematic according to your views (reading, writing, comprehension).

Teacher A: They find it difficult when it comes to reading and writing, yah those two

Teacher B: Reading is my number one problem with this learners, because I expect them to do some look at previous work before they come to class, mara when you come to class kubamnyama tshuu. I cannot even mention writing because how will they write if they cant even read, hey
Teacher C: Ngixabanga ukuthi ireading and writing. Ubabona kahle mabaza eclassini ukuthi they did not read enough. Mababala bayashaya I cram and pass. When you bring the problem in another situation they cannot even remember that it is the similar problem we tackled yesterday. Mara they expect us to teach these leaners science which need them to have I understanding edeep.

Teacher D: Reading is a problem in South Africa. I am wondering what were they doing in Primary school if they are not well prepared for the language. That is why they have the poorest education system in the world, they are not well prepared when they come to us. Reading and writing must be the basic skills.

Teacher E: For me iwriting is a problem. When I mark their scripts, they cant even explain basic concepts. Ba good ngama calculations but interpret those

calculations bayahluleka. If you ask them how did you get to this answer, they cant even expalain. For itopic efana ne intermolecular forces what do you expect, bazothola bo zero.

5. Do you think that writing is a problem for them? Why is that so?

Teacher A: Writing is a big problem. because eh, one when they normaly other teachers teach them, they use the local language to explain when they teach the other subject they use the local the local language to explain to them but when they come to the scientific to us, we don't use the local language, we speak english and it become difficult for them

Teacher B: It is a big problem. Jo if you see what they are writing in their script uzohleka noma kungahlekisi. Especially where bafanele ba explaine, joo uzobonumhlolo.

Teacher C: I think writing is a major problem because they always fail examination as they are expected to write in exams. But amapractical bayawapha ngoba bayakopa kuphela.
Teacher D: Writing is a big problem especially with our subject which is difficult in terms of the new concepts they have to understand
Teacher E: Iwriting iyabashaya. Angazi ukuthi bayenzani ku english. When it comes to writing ku science, kula ubona khona ukuthi they lack amafoundations.

6. When you give students essay type (extended written questions), how well do they do in such questions. How do you normally assess such questions? Do you require explanations or look for facts only? Do you look for understanding?

Teacher A : Yah before you write those question we explain to them first we tell them you going to answer this question, this question. During our teaching we tell when you answer question, you must go answer like this so through that then when you give them a question they can be able to answer it.

Teacher B: They struggle they are only good with simple calculations. They jump those questions in exams.
Teacher C: Most of them they don't even attempt them in exams mara it is because we do not prepare them to answer them.

Teacher D: I do marking every year. They do not attempt them. The will only answer agree, disagree that's all.

Teacher E: Asking science learners to explain is just not worth trying. They are not like History learners who write a lot of essay. Laba they like calculation, even though they even struggle but its better than asking them to write those explanations.

7. Do you think that learners benefitted from the writing intensive programme?

   Teacher A: yes yah they can benefit from it

   Teacher B: Ingasiza kakhulu only if we can find time to squizz it into the curriculum. Because even now we teach morning and afternoon class to cover the content. Physical science teachers are the busiest here. Uphumula ngo December kphela.

   Teacher C: They can benefit. I implemented the programme in my class you know, they marks improved as compared to my previous years classes. It is just that more time is needed to implement the programme well. But I used my extra classes to incorporate it well. Those assignments I gave them before we amazing. Learners came to class knowing the topic. Ey bangthusile ngempela.

   Teacher D: The programme is good but need aleast two more periods to cover everything. I especially like the idea of giving them assignments before we start with the topic. That prepared them well for the topic. I want to implement it on the topic of mining as I always struggle to teach this topic as it is all about concepts and history.

   Teacher E: I enjoyed the programme and my learners benefitted and I am planning to do that in grade 12 to prepare them in advance. Those marks were they are required to fully explain, bazozishaya next year.

8. What are the strengths and weaknesses of the Writing intensive programme?

Teacher A: YAH the, what could be the strength is that the teacher must always show them how to answer those questions, how to write it wit. If the teacher fail to teach them they cannot answer them, the teacher must always teaching them how write those questions, those eh answers yah if he continue to do that, they become used to but he fails, then those learners cannot answer those questions

Teacher B: The problem is time, if enough time is given, they will benefit. The strength is that it prepares them to deal with the explanation questions in exams and tests
Teacher C: The programme igood. Bazoba good in writing science concepts but what I noticed is that it needs committed teachers who will go an extra mile by investing more time in the topic.
Teacher D: My learners were well prepared as they wrote assignments before I teach the topic. But it will not work if learners are not committed to complete the assignments. For teachers more time is needed to plan those assignments.
Teacher E: I enjoyed the writing programme because the material was prepared in advance. The study guide given to learners was easy to read and those writing activities prepared the learners well. But ngizodinga extra time to prepare a study guide like that for other topics which I don't have because most of the time I have to be in class teaching. I do not have enough time to prepare. The science department is overloaded and on the other hand I am the HOD and I have many responsibilities and I am the only Physical science teacher in my school. If we are two teaching science, I can do it.

9. Do you think that other teachers will benefit from this programme if they have to go through the same programme?

Teacher A: Yah they can benefit from this
Teacher B: they can benefit if they are trained. The curriculum implementers just tell us what we must do but they do not give us workshops that teachers exactly what we must do. It is a total waste of time to have curriculum implementers who don't know what they are doing.
Teacher C: I believe it's a good programme, I will share this with my cluster leader
Teacher D: very good. It can help them
Teacher E: yah banga benefita. Only if they can get time to come for training.

10. If you were to teach the other teachers to teach the programme, will you be able to do it?
    Teacher A: Yes only if I get more training and it is implemented in other topics. This can be good for grade 12 topics like chemical equilibrium. Also in Physics, my learners bayahlupheka in explaining concepts such as momentum, Newtons laws and Ohm's law.
11. Do you think you will be able to incorporate the programme into other topics? If so, which other topics do you think will be suitable for the wiring intensive programme?

Teacher A: Mining in grade 11 it is difficult to teach and its only taught at the end of the year
Teacher B: Yes, it should apply in all Physical Sciences topic, izo baceda ukuunderstanda ama concepts.
Teacher C: I am struggling to teach Le chatelier's principles, I can give them writing assignments on this topic
Teacher D: My learners struggle with the topic of electromagnetism, if they do research in advance by submitting an assignment it can help.
Teacher E: yes ngiyayibona ku grade 10 learners in all the topics, they will come prepred for grade 11 because it seems like they like to cram, the assignments will prepare them in advance

12. What do think teachers need to be able to implement writing intensive effectively in their classroom?
    Teacher A: Training is important and good salary
    Teacher B: commitment to go an extra mile
    Teacher C: Enough time to do the planning
    Teacher D: Less workload so that they can have iskhathi sokuplanna
    Teacher E: Support from all stakeholders and a lot of commitment and motivation. Most teachers are demotivated by the system and there are no incentives that comes with innovation and going an extra mile. We just work to uplift our community

Thank you very much for your participation and patience. Your contribution is highly appreciated.

Appendix 16: Raw marks for the pre-test/post-test

Key:

Group 1: Control group

Group 2: Experimental group

Learner ID	Group	Posttest (44)	Pretest (44)	Gender	Schools
2	1	24	2	F	A
4	1	34	5	F	A
5	1	30	3	F	A
9	1	28	3	M	A
10	1	22	0	M	A
11	1	35	6	M	A
16	1	28	7	F	A
17	1	38	2	F	A
18	1	36	1	F	A
22	1	36	5	M	A
23	1	22	3	M	A
24	1	39	2	M	A
31	1	4	5	F	A
32	1	12	1	M	A
33	1	8	2	F	A
34	1	2	4	M	A
35	1	8	9	M	A
39	1	8	5	M	A
40	1	6	3	M	A
41	1	4	2	F	A
43	1	2	6	M	A
44	1	4	4	M	A
46	1	4	3	F	A
49	1	4	2	F	A
50	1	4	3	F	A
52	1	2	7	F	A
56	1	0	5	M	A
57	1	15	9	F	A
58	1	18	4	F	A
62	1	6	7	F	A
63	1	18	2	M	A
64	1	6	3	F	A
68	1	8	8	M	A
69	1	16	6	M	A
71	1	4	5	M	A
74	1	6	3	M	A

75	1	16	4	F	A
76	1	2	4	F	A
80	1	6	6	M	A
81	1	2	4	F	A
82	1	17	3	F	A
84	1	15	2	F	A
88	1	10	2	M	A
89	1	8	5	F	A
90	1	10	5	F	A
92	1	6	5	F	A
95	1	0	3	M	A
96	1	0	7	F	A
97	1	0	4	F	A
104	1	16	4	F	A
105	1	8	3	M	A
106	1	8	3	F	A
110	1	4	3	F	A
111	1	6	7	F	A
113	1	12	7	M	A
116	1	4	4	F	A
117	1	2	3	F	A
118	1	12	3	F	A
125	1	22	5	F	A
127	1	14	6	F	A
128	1	20	6	F	A
129	1	8	5	M	A
131	1	10	4	F	A
135	1	6	2	M	A
136	1	14	4	F	A
137	1	16	6	F	A
142	1	29	4	M	A
143	1	28	11	M	A
144	1	20	3	F	A
145	1	18	2	F	A
147	1	20	7	M	A
304	1	37	10	M	A
305	1	39	2	M	A
3	1	42	2	F	A
6	1	33	1	M	B
7	1	31	4	F	B
12	1	31	2	F	B
13	1	37	3	M	B
19	1	39	5	F	B
20	1	33	3	F	B
26	1	35	2	F	B
27	1	33	1	F	B

29	1	33	6	F	B
30	1	35	1	F	B
36	1	4	5	M	B
37	1	9	2	M	B
42	1	12	6	F	B
47	1	4	8	F	B
48	1	8	4	F	B
53	1	4	8	F	B
54	1	0	3	F	B
59	1	2	3	F	B
61	1	14	3	F	B
66	1	8	9	F	B
67	1	6	9	M	B
72	1	10	4	M	B
77	1	15	6	M	B
78	1	2	3	F	B
85	1	12	5	F	B
86	1	13	2	F	B
93	1	18	4	F	B
94	1	8	6	M	B
98	1	9	7	F	B
99	1	0	2	F	B
102	1	5	2	F	B
103	1	4	1	F	B
108	1	20	9	M	B
109	1	6	3	F	B
112	1	2	4	F	B
114	1	2	2	F	B
119	1	13	2	F	B
120	1	6	4	M	B
122	1	4	6	M	B
124	1	8	9	F	B
126	1	24	6	F	B
132	1	12	7	F	B
133	1	12	7	F	B
139	1	9	2	F	B
140	1	28	1	F	B
141	1	20	3	F	B
148	1	24	5	F	B
304	1	36	7	F	B
1	1	34	4	F	C
8	1	29	2	M	C
14	1	29	6	F	C
15	1	37	4	M	C
21	1	37	5	M	C
25	1	42	5	M	C

28	1	12	3	F	C
38	1	0	7	M	C
45	1	4	5	M	C
51	1	4	5	M	C
55	1	4	9	F	C
60	1	0	11	F	C
65	1	14	6	F	C
70	1	32	2	M	C
73	1	8	3	F	C
79	1	2	9	M	C
83	1	6	3	M	C
87	1	13	5	F	C
91	1	12	6	M	C
100	1	4	7	F	C
101	1	2	0	F	C
107	1	2	6	M	C
115	1	4	8	F	C
121	1	8	0	M	C
130	1	2	3	M	C
134	1	18	2	F	C
138	1	5	9	F	C
146	1	16	7	F	C
303	1	35	3	F	C
123	1	8	2	F	C
153	1	7	4	M	C
154	1	15	7	M	C
151	2	30	3	F	A
156	2	29	4	F	A
157	2	34	2	M	A
158	2	38	2	M	A
162	2	24	3	M	A
163	2	35	7	M	A
164	2	34	6	F	A
170	2	4	8	M	A
171	2	21	3	M	A
172	2	2	2	M	A
175	2	4	3	M	A
176	2	8	5	M	A
177	2	2	8	M	A
181	2	8	9	F	A
182	2	2	8	M	A
187	2	12	5	M	A
188	2	4	4	F	A
192	2	8	4	M	A
193	2	6	3	M	A
194	2	6	6	M	A

200	2	22	9	F	A
201	2	24	2	M	A
202	2	22	5	M	A
204	2	14	12	F	A
207	2	44	6	F	A
208	2	25	0	F	A
212	2	40	0	F	A
213	2	32	7	M	A
214	2	33	1	M	A
221	2	26	4	F	A
223	2	28	6	F	A
224	2	23	8	F	A
225	2	12	1	F	A
229	2	25	3	M	A
230	2	25	8	F	A
231	2	24	6	F	A
236	2	28	4	F	A
241	2	23	2	F	A
242	2	24	4	M	A
243	2	26	6	M	A
245	2	30	8	F	A
246	2	31	9	F	A
247	2	24	3	F	A
251	2	29	2	F	A
252	2	22	1	F	A
253	2	26	8	F	A
256	2	29	0	F	A
257	2	34	3	F	A
258	2	30	5	F	A
262	2	34	2	M	A
263	2	16	2	F	A
265	2	30	6	F	A
269	2	27	4	F	A
270	2	26	4	F	A
271	2	24	4	F	A
276	2	30	2	M	A
277	2	36	5	M	A
278	2	28	4	F	A
280	2	30	3	F	A
281	2	26	2	M	A
282	2	22	4	M	A
288	2	35	2	M	A
289	2	31	5	F	A
290	2	27	3	F	A
292	2	14	2	F	A
293	2	31	5	F	A

294	2	32	7	F	A
298	2	2	4	F	A
299	2	4	1	M	A
149	2	38	4	F	A
301	2	40	5	F	A
302	2	28	7	F	A
308	2	42	9	M	A
309	2	37	9	F	A
310	2	40	4	F	A
153	2	26	5	F	B
154	2	37	6	F	B
159	2	40	3	M	B
160	2	38	7	F	B
165	2	20	2	M	B
166	2	13	5	M	B
168	2	0	5	M	B
169	2	4	7	M	B
178	2	4	4	F	B
179	2	4	4	M	B
184	2	4	4	F	B
185	2	24	7	F	B
186	2	4	7	F	B
190	2	4	7	F	B
191	2	8	4	F	B
197	2	42	5	F	B
198	2	23	5	M	B
199	2	22	5	F	B
205	2	26	3	F	B
209	2	38	5	M	B
210	2	31	6	M	B
215	2	40	5	F	B
217	2	33	4	F	B
218	2	29	3	F	B
219	2	33	2	M	B
222	2	33	3	M	B
227	2	26	7	M	B
228	2	25	5	M	B
233	2	40	3	F	B
234	2	42	7	F	B
238	2	28	2	F	B
239	2	28	8	F	B
240	2	24	2	F	B
248	2	22	4	F	B
249	2	29	6	F	B
250	2	32	1	F	B
259	2	30	8	F	B

260	2	30	3	M	B
261	2	36	4	M	B
267	2	22	6	F	B
268	2	34	4	F	B
273	2	27	6	F	B
274	2	20	2	M	B
284	2	29	7	F	B
285	2	27	2	F	B
287	2	26	8	M	B
296	2	8	2	F	B
297	2	6	5	F	B
150	2	44	2	M	B
312	2	41	5	F	B
152	2	35	3	F	C
155	2	37	7	F	C
161	2	24	7	F	C
167	2	0	9	M	C
173	2	9	8	M	C
174	2	6	8	M	C
180	2	10	8	M	C
183	2	12	6	F	C
189	2	6	4	F	C
195	2	29	5	F	C
196	2	27	7	M	C
203	2	36	3	M	C
206	2	42	6	F	C
211	2	38	9	M	C
216	2	33	0	M	C
220	2	31	1	M	C
226	2	24	0	M	C
232	2	22	3	F	C
235	2	32	7	F	C
237	2	30	2	F	C
244	2	29	3	F	C
254	2	28	7	F	C
255	2	29	5	F	C
264	2	38	4	F	C
266	2	33	2	M	C
272	2	29	6	M	C
275	2	22	3	M	C
279	2	27	5	F	C
283	2	17	6	M	C
286	2	20	0	M	C
291	2	42	4	F	C
295	2	26	3	F	C
300	2	6	3	F	C

306	2	30	2	F	C
307	2	36	5	M	C
311	2	36	3	M	C
312	2	32	6	F	C
313	2	33	8	F	C

Appendix 17: IMF study guide

PHYSICAL SCIENCES
INTERMOLECULAR FORCES MANUAL

GRADE 11

Compiled by: Hlabane AS

Food of thought

“Have you ever wondered how soap works while washing your hands? What is going on chemically when it removes all that dirt, grease, and blood? Whoopsiedoodle, did I just say blood? Shhh… The germs which have accumulated on our hands are usually found in dirt or grease, which are held together by oils. As you may know, oil and water don’t mix. Have you ever seen the different layers it creates when you try to mix them? Water can dissolve most substances, but because oil molecules are attracted to each other more than water molecules, and the water molecules are much smaller, it takes a stronger intermolecular force to break their hydrogen bonds to accommodate the oil molecules. Soap acts as a middleman, attaching to both the water and oils.
When we mix soap with water, the sodium atom dissociates (or separates) completely from the soap molecule, leaving its one available electron with the oxygen atom, which becomes negatively charged. The positively charged sodium ion is attracted to the slightly negatively charged oxygen portion of the water molecule. This attraction is called an ion-dipole interaction because the sodium ion is attached to one of the poles (opposites) of the water molecule. As the soap dissolves, hydrogen bonds form due to the attraction between the slightly positively charged hydrogen atoms in the water molecules and the negatively charged oxygen (Stengler, A.E., n.d.).

When the soap attaches a molecule of grease to a water molecule through weak London dispersion forces, a micelle – or ball-like structure of the non-polar tails of the molecules clumped in the center – is formed for every particle of grease carried away by the rinse water. The negatively charged oxygen ion of the micelle’s soap molecules attach to the positively charged hydrogen atoms of the water molecules using hydrogen bonds. The surface tension of the water is reduced, and the micelle containing the grease (which is now attached to the water) goes down the drain (Stengler, A. E., n.d.).
You may now be wondering what intermolecular forces are. You know that they are involved in the attraction of molecules in soap, dirt, and water, and in simple

mundane tasks such as washing our hands. But did you know that they are at play all around us in our everyday lives?” (Rewriting chemistry, 2016).

1. Orientation

Dear learner

Welcome to the Writing to learn project on the topic of Intermolecular forces!

Thank you for agreeing to participate in this study. I wish you a happy and fulfilling learning experience!

Please, do not hesitate to contact the project leader should you have trouble with regard to this project.

Much of what you will do as learners is self-study, using the Study Guide. The role of the teacher will be to guide/mediate you as a learner through the topic of intermolecular. Three main intermolecular forces will be covered in this study guide. These include dipole-dipole forces; hydrogen bonds and induced dipole forces (London-dispersion forces). The facilitator will not facilitate this learning directly, but he/she will facilitate activities and link the learning that happens through self-study to the learning and teaching during this session. The facilitator will explain the concept and discuss its implications of the concept. However, as learners, you need to be involved in this. You will have to give examples from your everyday experience while the facilitator is explaining what the theories and concepts entail. The sessions will be writing intensive meaning that most of the learning will happen through writing. Please make sure that you bring enough writing material although the manual will provide enough space for that, sometimes there might be a need.

2. Work schedule and learning

UNIT	Duration	Action	Remarks
1		Orientation Induced-dipole forces	
3		Dipole-dipole forces	
4		Hydrogen bonds	
5		Physical properties and intermolecular forces	
Final comments by the learner:			

Unit 1: Induced-Dipole forces

Outcomes

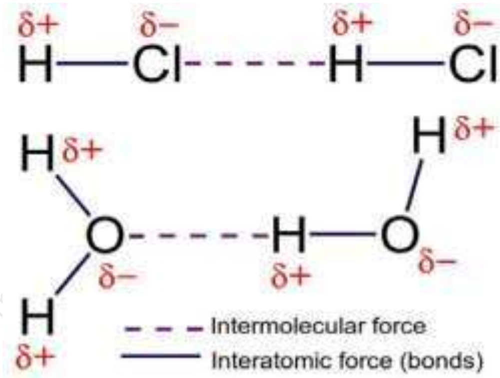
At the end of this unit you will be able to

Explain what induced-dipole forces entail and

Apply the knowledge of induced-dipole forces in different contexts.

1.1 Introduction

All around us, we see matter in different phases. The air we breathe is a gas, while the water you drink is a liquid and the chair you are sitting on is solid. In this session, we are going to look at one of the reasons that matter exists as solids and liquids.



In the previous topics that you did with your teachers, you discussed the different forces that exist between atoms(inter-atomic forces or intramolecular forces). When atoms are joined to one another they form molecules, and these molecules in turn have forces that bind them together. These forces are known as intermolecular forces.

Intermolecular forces allow us to determine which substances are likely to dissolve in which other substances and what the melting and boiling points of substances are. Without intermolecular forces holding molecules together, we would not exist. Note that we will use the term molecule throughout these sessions as the compounds we are looking at are all covalently bonded and do not exist as giant networks (recall from grade 10 that there are three types of bonding: metallic, ionic and covalent). Sometimes you will see the term simple molecule. This is a covalent molecular structure.

- **Intermolecular:** A type of interaction between two different molecules.

The difference between interatomic forces and intermolecular forces

It is important to realise that there is a difference between the types of interactions that occur in molecules and the types that occur between molecules. In the previous sections with your educator, you focused on the interactions between atoms. These are known as interatomic forces or chemical bonds. Intermolecular forces occur between molecules and do not involve individual atoms. Interatomic forces are the forces that hold the atoms in molecules together. The table below gives us an illustration of the differences between intramolecular/interatomic forces and intermolecular forces.

	Interatomic/intramolecular forces	**Intermolecular forces**
Atoms or molecules	Forces between atoms	Forces between molecules
Strength	Strong forces	Relatively week forces
Distances between atoms or molecules	Very short distances	Large distances than bonds

1.2 Exploring Induced dipole forces

We know that while carbon dioxide is a non-polar molecule, we can still freeze it (and we can also freeze all other non-polar substances). This tells us that there must be some kind of attractive force in these kinds of molecules (molecules can only be solids or liquids if there are attractive forces pulling them together). This force is known as an induced dipole force (London dispersion forces).

Key Terms

- **London dispersion forces**: A weak intermolecular interaction arising from induced instantaneous dipoles in molecules; part of the Van der Waals forces.
- **Dipole:** Any molecule that has both slight positive and negative charges on either end.
- **Van der Waals forces**: The sum of the attractive or repulsive forces between molecules (or between parts of the same molecule) other than those due to covalent bonds, or the electrostatic interaction of ions with one another, with neutral molecules, or with charged molecules.

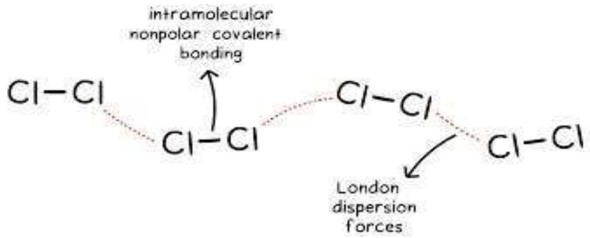
Key Points

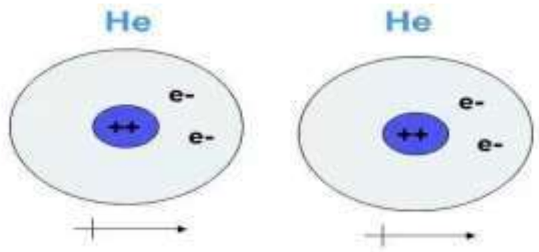
- London dispersion/induced-dipole forces are weak intermolecular forces and are considered van der Waals forces.
- Temporary dipoles can occur in non-polar molecules when the electrons that constantly orbit the nucleus occupy a similar location by chance.
- Temporary dipoles can induce a dipole in neighbouring molecules, initiating an attraction called a London dispersion/induced dipole force.

Induced dipole in detail

Although charges are usually distributed evenly between atoms in non-polar molecules, spontaneous dipoles can still occur. When this occurs, non-polar molecules form weak attractions with other non-polar molecules. These London dispersion forces are often found in the halogens (e.g., F_2 and I_2), the noble gases (e.g., Ne and Ar), and in other non-polar molecules, such as carbon dioxide and methane. London dispersion forces are part of the van der Waals forces or weak intermolecular attractions.

In non -polar molecules , the electronic charge is





usually evenly distributed but it is possible that at a particular moment in time, the electrons might not be evenly distributed (remember that the electrons are always moving in their orbitals). The molecule will have a temporary dipole. In other words, each end of the molecules has a slight charge, either positive or negative. When this happens, molecules that are next to each other attract each other very weakly.

Liquid nitrogen: Without London dispersion forces, diatomic nitrogen would not remain liquid.

Van der Waals forces help explain how nitrogen can be liquefied. Nitrogen gas (N_2) is diatomic and non-polar because both nitrogen atoms have the same degree of electronegativity. If there are no dipoles, what would make the nitrogen atoms stick together to form a liquid? London dispersion forces allow otherwise non-polar molecules to have attractive forces. However, they are by far the weakest forces that hold molecules together.

Activity 1: Freewriting and Scientific inquiry activities

Work alone

You should use about 5-10 minutes for this activity.

1. Briefly describe what you understand about the following concepts. This is a free writing activity, just write everything that comes to your mind about your understanding of each concept.

1.1 Intermolecular forces
1.2 Intramolecular/interatomic forces
1.3 Polar molecule
1.4 None polar molecule
1.5 Induced-dipole forces

2. A chloride (Cl_2) is an example of a non-polar molecule. When electrons in the chloride molecules are unevenly distributed, a temporary dipole is created. Meaning that the molecule will have a positive end and a negative end. The positive end will be attracted to the negative end. This results in the formation of induced dipole forces. Now explain in simple language the interactions of the intermolecular forces between CO_2 and I_2 molecules.

Activity 2: Summary/journal entry activity

Work alone

You should use about 5-10 minutes for this activity.

1. Provide a summary of what you have learned about intermolecular forces and induced-dipole forces in Unit 1. Do you think there is something that you have not understood in Unit 1? If so, write them down and ask your teacher about that the following day.

Unit 2: Dipole-dipole forces

Outcomes

At the end of this unit, you will be able to

Explain what dipole-dipole forces entail and

Apply the knowledge of dipole-dipole forces in different contexts.

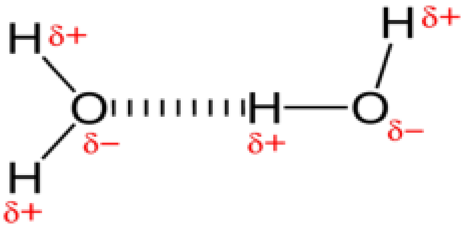
2.1 Dipole-dipole forces

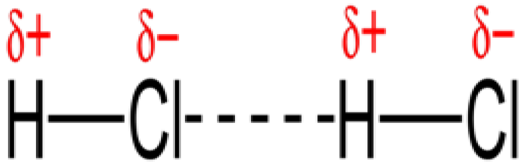
Key terms

- **dipole:** In chemistry, a permanent dipole describes the partial charge separation that can occur within a molecule along with the bond that forms between two different atoms. Dipoles generally occur between two nonmetals that share electrons as part of their bond. Since each atom has a different affinity for electrons, the ‘push and pull’ of their shared electrons results in one atom maintaining most of the electron density and a partial negative charge, leaving the other atom with a partial positive charge.
- **Polar:** In chemistry, a polar molecule is one that has uneven charge distribution. **Polar molecules** align so that the positive end of one molecule interacts with the negative end of another molecule. Unlike covalent bonds between atoms within a molecule (intramolecular bonding), dipole-dipole interactions create attractions between molecules of a substance (intermolecular attractions).
- **Partial charges-** Partial charges are created due to the uneven distribution of electrons in chemical bonds. For example, in a polar covalent bond like HCl, the shared electron oscillates between the bonded atoms.

Dipole-dipole interactions occur when the partial charges formed within one molecule are attracted to an opposite partial charge in a nearby molecule. Dipole-dipole interactions are electrostatic interactions between the permanent dipoles of different molecules. These interactions align the molecules to increase the attraction.

An electric **monopole** is a single charge, while a dipole is two opposite charges closely spaced to each other. Molecules that contain dipoles are called polar molecules and are very abundant in nature. For example, a water molecule (H2O) has a large permanent electric dipole moment. Its positive and negative charges are not centred at the same point; it behaves like a few equal and opposite charges separated by a small distance. These dipole-dipole attractions give water many of its properties, including its high surface tension.





When one dipole molecule comes into contact with another dipole molecule, the positive pole of the one molecule will be attracted to the negative pole of the other, and the molecules will be held together in this way (see the Figures above). Examples of materials/substances that are held together by dipole-dipole forces are HCl, SO2 and CH3Cl.

Activity 1: Free writing activity and Scientific inquiry activities

You should use about 5-10 minutes for this activity.

1. Briefly describe what you understand about the following concepts. This is a free writing activity, just write everything that comes to your mind about your understanding of each concept.
   1.1 Di-pole
   1.2 Mono-pole
   1.3 Dipole-dipole forces

2. The water molecule above is polar. Meaning that it has a positive pole and a negative pole. When two water molecules come to contact with each other, the negative end of the water molecule will be attracted to the positive end of the water molecules. This results in the formation of dipole-dipole forces. Now explain the dipole-dipole interaction between the following molecules

2.1 HCl,

2.2 HBr

2.3 SO_2 molecules.

Activity 2: Summary/journal entry activity

Work alone

You should use about 5-10 minutes for this activity.

1. Provide a summary of what you have learned about intermolecular forces and Dipole-dipole forces in Unit 2. Do you think there is something that you have not understood in Unit 2? If so, write them down and ask your teacher about them the following day.

Unit 3: Hydrogen bonds

Outcomes

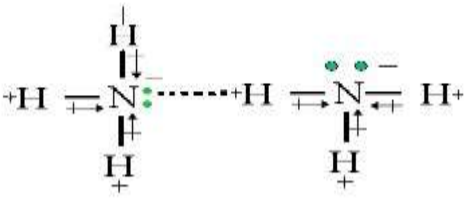
At the end of this unit, you will be able to

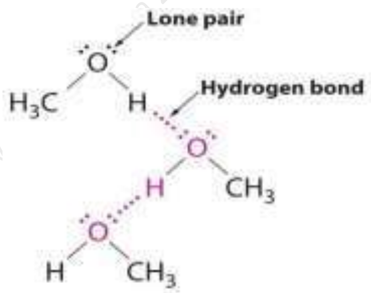
Explain what hydrogen bonds entail and

Apply the knowledge of hydrogen bonds in different contexts.

3.1 Introduction

As the name implies, this type of intermolecular force involves a hydrogen atom. When a molecule contains a hydrogen atom covalently bonded to a highly electronegative atom (O, N or F) this type of intermolecular force can occur. The highly electronegative atom on one molecule attracts the hydrogen atom on a nearby molecule. Water molecules, for example, are held together by hydrogen bonds between the hydrogen atom of one molecule and the oxygen atom of another. The same applies to ammonia.





Hydrogen bonding in methanol

Hydrogen bonds are a relatively strong intermolecular force and are stronger than other dipole-dipole forces. It is important to note, however, that hydrogen bonds are weaker than the covalent and ionic bonds that exist between atoms

Key Terms

- **Electronegativity:** The tendency of an atom or molecule to draw electrons towards itself
- **Hydrogen bond**: The attraction between a partially positively charged hydrogen atom attached to a highly electronegative atom (such as nitrogen, oxygen, or fluorine) and another nearby electronegative atom.
- **Intermolecular:** A type of interaction between two different molecules

3.2 Hydrogen bonds in details

Hydrogen bonds are strong intermolecular forces created by the relative positivity of hydrogen atoms. A hydrogen bond is an electromagnetic attraction created between a partially positively charged hydrogen atom attached to a highly electronegative atom and another nearby electronegative atom. A hydrogen bond is a type of dipole-dipole interaction; it is **not a true**

chemical bond. These attractions can occur between molecules (intermolecularly) or within different parts of a single molecule (intramolecularly).

Hydrogen bonds occur in inorganic molecules, such as water, and organic molecules, such as DNA and proteins. The two complementary strands of DNA are held together by hydrogen bonds between complementary nucleotides (A&T, C&G). Hydrogen bonding in water contributes to its unique properties, including its high boiling point (100 °C) and surface tension.

Water droplets on a leaf: The hydrogen bonds formed between water molecules in water droplets are stronger than the other intermolecular forces between the water molecules and the leaf, contributing to high surface tension and distinct water droplets.

In biology, hydrogen bonding is partly responsible for the secondary, tertiary, and quaternary structures of proteins and nucleic acids. The hydrogen bonds help the proteins and nucleic acids form and maintain specific shapes.

Activity 1: Freewriting and scientific inquiry activities

Work alone

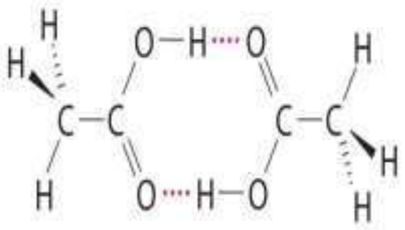
You should use about 5-10 minutes for this activity.

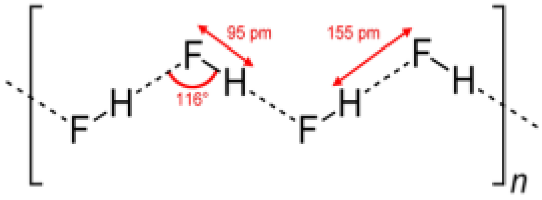
1. Briefly describe what you understand about the following concepts. This is a free writing activity, just write everything that comes to your mind about your understanding of each concept.

1.1 Electronegativity

1.2 Hydrogen bond

2. Ammonium molecules contain a hydrogen molecule and a highly electronegative nitrogen atom. When two molecules of ammonia come to contact with each other, the positive hydrogen will be attracted to the negative nitrogen. Then the hydrogen bond will be formed. Now explain the interactions of the intermolecular forces between **HF molecules a**nd acetic acid. Use diagrams where necessary.

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Activity 2: Summary/journal entry activity

Work alone

You should use about 5-10 minutes for this activity.

1. Provide a summary of what you have learned about intermolecular forces and Hydrogen bonds in Unit 3. Do you think there is something that you have not understood in Unit 3? If so, write them down and ask your teacher about that the following day.

Unit 4: Physical properties and Intermolecular forces

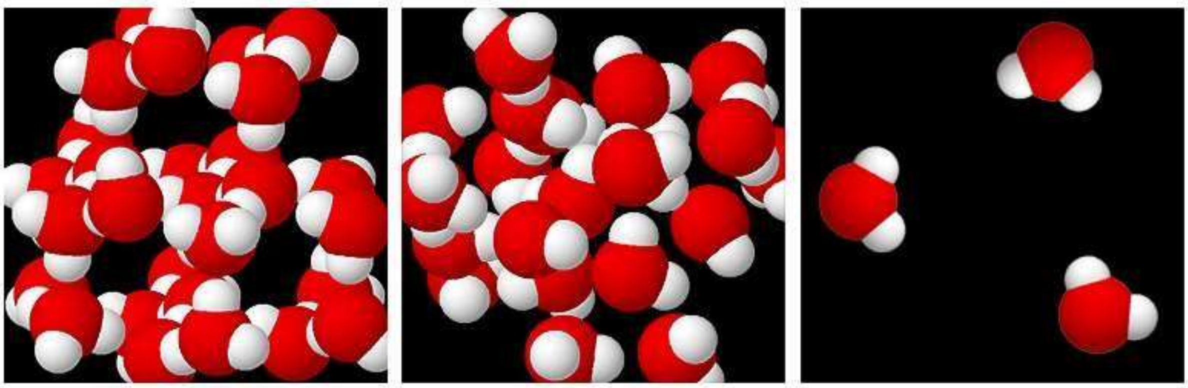
Outcomes

At the end of this unit, you will be able to

- Explain how intermolecular forces affect the physical properties of the material; and
- Apply the knowledge of IMF in different contexts.

4.1 Introduction

The types of intermolecular forces that occur in a substance will affect its properties, such as its phase, melting point and boiling point. You should remember from the kinetic theory of matter (see grade 10), that the phase of a substance is determined by how strong the forces are between its particles.



The weaker the forces, the more likely the substance is to exist as a gas. This is because the particles can move far apart since they are not held together very strongly. If the forces are very strong, the particles are held closely together in a solid structure. Remember also that the temperature of a material affects the energy of its particles. The more energy the particles have, the more likely they are to be able to overcome the forces that are holding them together. This can cause a phase change.

4.2 Melting point and boiling point

Intermolecular forces affect the boiling and melting points of substances. Substances with weak intermolecular forces will have low melting and boiling points while those with strong intermolecular forces will have high melting and boiling points. In the experiment on intermolecular forces, you investigated the boiling points of several substances and should have seen that molecules with weaker intermolecular forces have a lower boiling point than molecules with stronger intermolecular forces.

One further point to note is that covalent network structures (recall from grade 10 that these are covalent compounds that form large networks and an example is a diamond) will have high melting and boiling points because some bonds (i.e. the strong forces between atoms) have to break before the substance can melt. Covalent molecular substances (e.g. water, sugar) often have lower melting and boiling points, because of the presence of the weaker intermolecular forces holding these molecules together.

4.3 Molecular size or chain length

The alkanes are a group of organic compounds that contain carbon and hydrogen bonded together. The carbon atoms link together to form chains of varying lengths. The boiling point and melting point of these molecules is determined by their molecular structure and their surface area. The more carbon atoms there are in an alkane, the greater the surface area and therefore the higher the boiling point. The melting point also increases as the number of carbon atoms in the molecule increases. This can be seen in the table below.

Formula	**CH_4**	**C_2H_6**	**C_5H_{12}**	**C_6H_{14}**	**$C_{20}H_{42}$**
Name	**Methane**	**Ethane**	**Pentane**	**Hexane**	**Icosane**
Molecular mass ($g \cdot mol^{-1}$)	16	30	72	86	282
Melting point (^oC)	-183	-183	-130	-95	37
Boiling point (^oC)	-164	-89	36	69	343
Phase at room temperature	Gas	Gas	Liquid	Liquid	solid

You will also notice that, when the molecular mass of the alkanes is low (i.e. there are few carbon atoms), the organic compounds are gases because the intermolecular forces are weak. As the number of carbon atoms and the molecular mass increases, the compounds are more likely to be liquids or solids because the intermolecular forces are stronger. You should see that the larger a molecule is the stronger the intermolecular forces are between its molecules. This is one of the reasons why methane (CH_4) is a gas at room temperature while pentane (C_5H_{12}) is a liquid and icosane ($C_{20}H_{42}$) is solid.

Activity 1: Freewriting activity

Work alone

You should use about 5-10 minutes for this activity.

1. Briefly describe what you understand about the following concepts. This is a free writing activity, just write everything that comes to your mind about your understanding of each concept.

1.1 Physical properties

1.2 Boiling point

1.3 Melting point

1.4 Molecular size

1.5 Chain length

Activity 2: Physical properties

Homework

You should use about 10-15 minutes for this activity.

Given the following molecules and solutions:

1. Complete the table below by placing each molecule next to the correct type of intermolecular forces.

Molecule	Type of IMF and explanation
HCl,	
CO2,	

I2,	
H2O	
KI(aq),	
NH3	
NaCl(aq),	
HF	
MgCl2 in CCl4	
, NO,	
Ar,	
SiO2	

2. In which one of the substances listed above are the intermolecular forces:

a) Strongest. Fully explain your answer

____

____

____

____

____

b) Weakest. Fully explain your answer.

3. Use your knowledge of different types of intermolecular forces to explain the following statements:

a) The boiling point of F_2 is much lower than the boiling point of NH_3

b) Water evaporates slower than carbon tetrachloride (CCl_4).

c) Sodium chloride is likely to dissolve in methanol (CH_3OH)

Activity 3: Physical properties and applications

Work alone

You should use about 45 minutes for this activity.

1. The respective boiling points for four chemical substances are given below:

Substance	Boiling point (°C)
Hydrogen sulphide	-60
Ammonia	-33
Hydrogen fluoride	20
Water	100

a) Which one of the substances exhibits the strongest forces of attraction between its molecules in the liquid state?

b) Give the name of the force responsible for the relatively high boiling points of hydrogen fluoride and water and explain how this force originates.

c) The shapes of the molecules of hydrogen sulfide and water are similar, yet their boiling points differ. Explain.

2. Learners investigate factors that influence the boiling points of alkanes. In one of the investigations, they determine the boiling points of the first five alkanes. Learners drew the following table and recorded their results.

Name of substance	**Formula**	**Boiling point (°C)**
Methane	CH_4	-164
Ethane	CH^1CH_3	-89
Propane	$CH_3CH_2CH_3$	-20
Butane	$CH_3CH_2CH_2\ CH_3$	5
Pentane	$CH_3\ CH_2\ CH_2\ CH_2\ CH_3$	36

3. Jason and Bongani are arguing about which molecules have which intermolecular forces. They have drawn up the following table:

Compound	Type of force
Potassium iodide in water (KI(aq))	dipole-induced dipole forces
Hydrogen sulfide (H2S)	induced dipole forces
Helium (He)	ion-induced dipole forces
Methane (CH4)	Methane (CH4)

a) Write down the investigative question for this investigation.

b) Fully explain why the boiling point increases from methane to pentane.

a) Jason says that hydrogen sulfide (H2S) is non-polar and so has induced dipole forces. Bongani says hydrogen sulfide is polar and has dipole-dipole forces. Who is correct and why?

b) Bongani says that helium (He) is an ion and so has ion-induced dipole forces. Jason says helium is non-polar and has induced dipole forces. Who is correct and why?

c) They both agree on the rest of the table. However, they have not got the correct force for potassium iodide in water (KI(aq)). What type of force actually exists in this compound?

Activity 4: Summary/journal entry activity

Work alone

You should use about 5-10 minutes for this activity.

1. Provide a summary of what you have learned about physical properties and intermolecular forces in Unit 4. Do you think there is something that you have not understood in Unit 4? If so, write them down and ask your teacher about that the following day.

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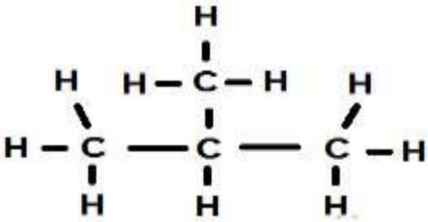
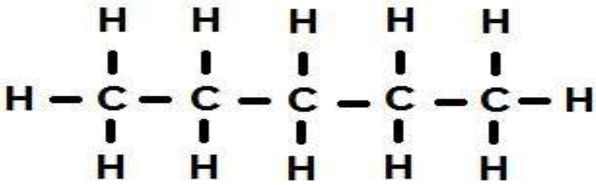
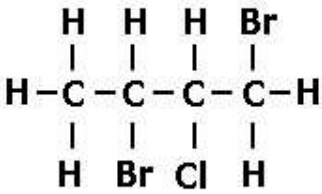
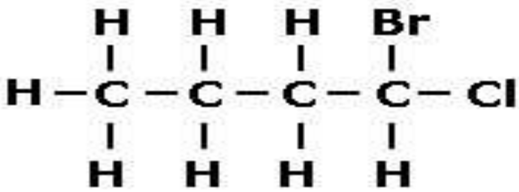
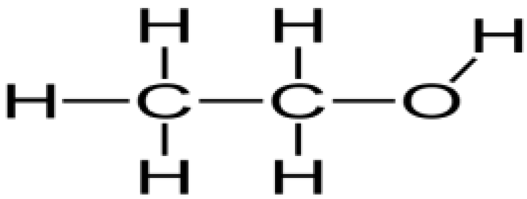
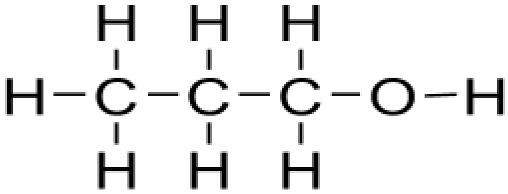
List of polar, non-polar and ionic molecules

Polar molecules	Non-polar molecules	Ionic molecules
HF	CCL4	NaCl, sodium chloride KI, potassium iodide
NH3	CO2	NaF, sodium fluoride NaHCO3, sodium bicarbonate
HCl	BF3	
HBr	SF6	Na2CO3, sodium carbonate
HI	H2	NaOCl, sodium hypochlorite
OF2	O2	CaCO3 calcium carbonate Mg(OH)2, magnesium hydroxide
SeCl2	N2	
SCl2	I2(s) SF6	Al(OH)3, aluminium hydroxide
PCl3	SO4 (2-)	NaOH, sodium hydroxide K3PO4, potassium phosphate
SO2 Ch3Cl	BeCl2	MgSO4, magnesium sulfate
CH3Br	CH4CO2	Na2HPO4, sodium hydrogen phosphate
SeCl	Methane (CH4) and Ethylene (C2H4) molecules	Na2SO3, sodium sulphite
CHCl3	SiH4	
CO(CH3)2	GeH4	
H2S	SnH4	
CH3Cl	C30H62 (paraffin wax)	
KBr & H20(ion-dipole forces)	C6H14 (hexane)	
H2O2	CS2(76)	
CH3OH(methanol)	C2H4	
CH3COOH(acetic acid)	C2H2	
CH3NH2 methyl amine		
C2H5OH ethyl alcohol		
(C6H12O6 glucose)		

Intermolecular forces in organic molecules

Name of substance	Structures	Type of intermolecular forces
Hydrocarbons	 	Induced-dipole forces
Haloalkanes	 	Dipole-dipole forces

Alcohols	 	Hydrogen bond