THE USE OF COMPUTER SIMULATIONS AS AN INTERVENTION TO ADDRESS MISCONCEPTIONS OF GRADE 11 PHYSICAL SCIENCES LEARNERS IN TOWNSHIP SCHOOLS

by

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ABSTRACT

This study examined the affordances of the use of computer simulations as an intervention to address acid-base misconceptions of grade 11 Physical Sciences learners in South African township schools. Technological Pedagogical Content Knowledge (TPACK) framework was invoked to provide valuable insights into the efficacy of computer simulations as an innovative intervention to address misconceptions associated with acids and bases. The study adopted a mixed-method approach located within a case study design and involved purposively selected grade 11 Physical Sciences learners from two South African township schools. Quantitative data was collected by administering *Acids-Bases Chemistry Achievement Test* developed by Damanhuri, Treagust, Won and Chandrasegaran (2016) as part of a control group-experimental group design. Qualitative data was collected through semi-structured interviews with the participants. Findings revealed significant differences between pre-test and post-test scores as a result of the implementation of virtual laboratory simulations as a remedial intervention. The results showed that the post-test mean score was higher than the pre-test mean score for the experimental group. There was no significant difference between the post-test mean score and the pre-test mean score for the control group. Elicited responses indicated that learners perceived the use of virtual laboratory simulations as a useful alternative means to demystify abstract scientific concepts associated with acids and bases as a Physical Sciences key knowledge area. In addition, the learners demonstrated fundamental appreciation of the affordances of virtual laboratory simulations as an innovative intervention to address misconceptions. The use of virtual laboratory simulations was largely perceived to provide meaningful opportunities for self-directed learning. However, the learners indicated that virtual laboratory simulations cannot supersede the experiences provided by traditional science laboratories in view of their critical role in the development of science process skills. Theoretical implications for meaningful development of technology-enhanced learning are discussed.

Keywords: Misconceptions, virtual laboratory simulations, technology-enhanced learning

DECLARATION

I declare that this minor dissertation, titled

The use of computer simulations as an intervention to address misconceptions of grade 11 Physical Sciences learners in township schools

is my own work and that all resources that I have used or quoted have been indicated and acknowledged by means of complete references. It is being submitted for the degree of Master of Education at the University of Johannesburg. It has not been submitted before for any degree or examination at any other university.

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Kgoboki James Mphafudi

2020

DEDICATION

I dedicate this study to my Mother, Sister Bertha, Brother Pitso, Grandmother Nkotsane Stamp Mphafudi, my Uncles Thomas Mphafudi, Johannes Mphafudi, Vincent Mphafudi, Tloubatla Mokgaha, Simon Boloka, my friends Lumkile Msebi, Joseph Chikosi, Jokonoko Zivai and Pastor Livingstone.

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TABLE OF CONTENTS

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

CHAPTER 4: RESULTS

CHAPTER 5: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

OBE	Outcomes-Based Education
C2005	Curriculum 2005
DOE	Department of Education
DBE	Department of Basic Education
GDE	Gauteng Department of Education
NCS	National Curriculum Statement
CAPS	Curriculum and Assessment Policy Statement
PCK	Pedagogical Content Knowledge
TIMMS	Trends in International Mathematics and Science Study
PhET	Physics Education Technology
TPACK	Technological pedagogical content knowledge
ICT	Information and Communication Technology

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION AND ORIENTATION

1.1 Introduction

This chapter reflects on the purpose of the study and the concomitant background with a view to provide a rational basis for an empirical investigation into acid-base misconceptions of South African grade 11 Physical Sciences learners in township schools. The study specifically investigated the extent to which computer simulations can be used as an intervention to address acid-base misconceptions of South African grade 11 Physical Sciences learners in township schools. Inadequate performance of learners in Physical Sciences can partly be attributed to prevailing misconceptions associated with various content knowledge areas (Reddy, 2006). In particular, research has demonstrated that high school learners hold several misconceptions about acids and bases (Artdej, Ratanaroutai, Coll & Thongpanchang, 2010). Lack of essential resources at township schools in South Africa renders meaningful enactment of contemporary pedagogic approaches such as inquiry-based learning a daunting task for teachers. The use of computer simulations can be a viable alternative mechanism for adequately addressing misconceptions associated with various Physical Sciences content knowledge areas. Hence, there is a critical need to explore the efficacy of computer simulations as an intervention to address misconceptions associated with acids and bases with a view to enhance meaningful conceptual understanding.

1.2 Background to the study

The democratic breakthrough in South Africa was characterised by a series of science education curriculum reforms. These curriculum reforms provided the opportunity for critical reflection on the educational progress achieved within the basic education sector with a view to identify pervasive fundamental challenges afflicting the provision of quality education. The overall quality of mathematics and science education remained a key area of concern within the broader South African educational context. The erosion of quality in mathematics and science education can be attributed to a myriad of factors. De Beer and Van Rooyen (2007) assert that educational reforms are often influenced by social or political priorities. Many countries undertook science education curriculum reforms to foster sustainable levels of economic growth and to prepare learners for future challenges in life. There have been concerted efforts across the globe to reform curricula in science, mathematics, and technology in order to grow the economy, improve quality of life and preserve the environment for future generations (De Beer & Van Rooyen, 2007). Consolidated efforts in this regard were essentially geared towards the achievement of social justice through provision of accessible quality education that is responsive to the critical needs of all learners.

The adoption and subsequent implementation of outcomes-based education (OBE) remained an extremely difficult and complex undertaking (Conley *et al*., 2010). Outcomes-based education was not geared towards the promotion and inculcation of higher-order critical thinking skills for the benefit of learners. De Beer and Van Rooyen (2007) define outcomes-based education as an approach to education in which outcomes are specified. These outcomes provide targets that teachers are expected to embrace to help learners to achieve. By its very nature, outcomes-based education was not responsive to the critical needs of learners and its implementation remained a daunting task for teachers. In addition, it was largely focused on capability grounded education (Conley *et al*., 2010). At another pragmatic level, outcomes-based education does not give due consideration to the pivotal role played by parents in the learning process. Landsberg (2011) argues that parents, as community members, should be acknowledged as assets to the education of their children. This implies that the curriculum should be guided by a set of clearly defined norms and standards.

Frustrations experienced with the implementation of the outcomes-based education prompted a curriculum review process which culminated in the adoption of Curriculum 2005 predicated on the aims of outcomes-based education. The implementation of Curriculum 2005 represented a radical shift from teacher-centred approaches to learner-centred learning (Department of Education, 2002). Curriculum 2005 sought to redress historical injustices and imbalances bequeathed by the previous educational dispensation. The implementation of Curriculum 2005 was partly made difficult by teachers' lack of pedagogical content knowledge (PCK) required for meaningful implementation of the curriculum itself (Department of Education, 2005). In addition, Curriculum 2005 was assessment-driven and did not make provision for the incorporation of indigenous knowledge. A review of Curriculum 2005 led to the promulgation of the National Curriculum Statement (NCS) (Department of Education, 2002). Pervasive fundamental problems associated with the structural rigidity of the National Curriculum Statement were largely viewed as impediments to the achievement of social justice in its broadest sense. Donald, Lazarus and Lolwana (2002) allude to the significance of a flexible and inclusive curriculum that is responsive to the critical needs of all learners. In other words, the curriculum should be relevant to the learners and the situations that they experience in life. The Department of Education White Paper 6 (2001) emphasises that inclusive education and training should be about enabling education structures, systems and learning methodologies to meet the needs of all learners.

The Curriculum and Assessment Policy Statement (CAPS) was promulgated by the Department of Basic Education in 2011 in response to structural deficiencies associated with the National Curriculum Statement (Department of Basic Education, 2011). The Curriculum and Assessment Policy Statement took the form of a single, comprehensive, and concise policy document putting particular emphasis on the incorporation of indigenous knowledge and the role of prior knowledge in learning. In support of this development, Magagula and Mazibuko (2004) maintain that indigenous knowledge should be incorporated into the formal curriculum. Despite curriculum reform initiatives that engulfed the South African basic education sector, learner performance in Physical Sciences remained inadequate. Meaningful enhancement of learners' grasp of Physical Sciences content knowledge requires innovative strategies. It is for this reason that this research study investigated the extent to which computer simulations can be used as an innovative intervention to address misconceptions of grade 11 Physical Sciences learners in South African township schools. The study contributes to the development of a repertoire of innovative instructional strategies geared towards meaningful development of scientific literacy by demystifying the nature of scientific knowledge.

1.3 Problem statement

Research has demonstrated that the topic on acids and bases is difficult for high school students (Burns, 1982). In addition, high school students hold several misconceptions about acids and bases (Artdej, Ratanaroutai, Coll & Thongpanchang, 2010). Several studies have alluded to misconceptions about acids and bases that are held by students and teachers alike (e.g. Kala, Yaman & Ayas, 2013; Sheppard, 2006; Drechsler & Van Driel, 2009). According to Chandrasegaran, Treagust and Mocerino (2008), students develop their views about scientific concepts and phenomena based on their sensory experiences, cultural backgrounds, peers, mass media as well as classroom instruction. They further argue that there is a tendency for students to be satisfied with their own conceptions because they are often deeply rooted and supported in their daily life experiences. The need to adequately address learners' misconceptions in order to engender meaningful learning is paramount. This notion is informed by the fact that it is beneficial to identify students' understandings about various science concepts so that appropriate instructional strategies may be formulated to challenge and facilitate learners' understandings of science concepts (Chandrasegaran, Treagust & Mocerino, 2008).

The South African basic education system has been plagued by poor learner performance in Physical Sciences over the years. Hence, the performance of South African learners in the international benchmark tests such as the Trends in International Mathematics and Science Study has been inadequate (TIMMS, 2003) and this grim reality provides the basis for undertaking this research study. Inadequate learner performance can be attributed to a myriad of factors such as lack of curricular understanding, ineffective traditional teaching methods and models of teaching which do not stimulate learners' interest to learn and become innovative. Notably, many South African learners are performing poorly in science as a direct result of misconceptions (Reddy, 2006). Griffiths and Preston (1992) defined a misconception as any conceptual idea whose meaning deviates from the one commonly accepted by scientific consensus.

It is a known fact that learners come to the classroom with different beliefs, customs and cultural knowledge. Thus, they do not come to a science classroom as empty vessels. Sheets (2009) states that children bring culturally mediated, historically developing cultural knowledge, practices, values, and skills to school. This knowledge includes misconceptions in science. Pfundt and Duit (2006) argue that these prior conceptions are affecting learning when they are incorporated into cognitive structures of the students. Acquiring new knowledge requires a connection between the learner's prior cultural knowledge and the new knowledge being taught and learned (Sheets, 2009). Therefore, effective learning and conceptual understanding are extremely necessary for the learners' misconceptions to be identified and linked to the new knowledge of acids and bases in particular as the primary focus of this research study. More importantly, models of teaching which have tasks promoting effective learning can be used as a means to identify acid-base misconceptions held by grade 11 Physical Sciences learners. In addition, these models may be helpful in overcoming various causes of poor performance in science. Researchers such as Posner, Striker, Hewson and Gertzog (1982) and Stepans (2008) argue that only instructional models of instruction which utilize tasks that bring about a theoretical change can engender meaningful conceptual understanding. The key hypothesis in this study is: *The use of computer simulations can alleviate Physical Sciences learners' misconceptions in township schools*.

1.4 Rationale

This research study investigated the extent to which computer simulations can be used as an intervention to address acid-base misconceptions of South African grade 11 Physical Sciences learners in township schools. The main aim of using technologies in schools is to make teaching and learning more effective thereby improving the academic performance of the learners. One of the 21st century learning skills is the use of Information and Communication Technologies such as computer simulations for teaching and learning. In addition, to be effective in the 21st century, citizens and workers must be able to create, evaluate, and effectively utilize information, media and technology.

Inadequate learner performance and misconceptions are challenging issues that plague the teaching of Physical Sciences in South Africa. This research study is significant in the sense that it seeks to unearth and address acid-base misconceptions of South African grade 11 Physical Sciences learners by using computer simulations as a strategic and innovative intervention. The performance of South African learners in the international benchmark tests such as the Trends in International Mathematics and Science Study (TIMSS) has largely been inadequate (TIMMS, 2003). In the light of this grim reality, this research study proposes a pedagogic approach based on the use of computer simulations that may be adopted and implemented for identifying and eradicating misconceptions with a view to improve learner performance in Physical Sciences within the broader South African context. This pedagogic approach may also be used as a vital recommended tool by the South African Department of Basic Education.

Moreover, the study provides a critical reflection on the usefulness and significance of implementing computer simulations in science teaching and learning by recommending a technological strategy, i.e. computer simulations, as a viable strategy that can be used in the pedagogical process in order to overcome poor performance in general and acid-base misconceptions in particular. It also aims to improve scientific literacy in schools through innovative use of computer simulations in science classrooms. The use of 'chalk-and-talk' teaching is prevalent in schools in South Africa and this instructional approach has proved to be ineffective in addressing misconceptions. Several studies have established that virtual laboratory learning (immersive or non-immersive virtual reality and augmented reality) has positive impact on learners' attitudes and motivation towards science learning in general (e.g. Chua & Karpudewan, 2017; Hsu, Lin, & Yang, 2017). In support of this notion, Arvind and

Heard (2010) assert that the use of virtual laboratory simulations serves to simplify complex physics concepts and changes students' negative perceptions of the physics course. According to Tüysüz (2010), students who are comfortable with the use of virtual laboratory simulations often show a more positive attitude towards learning chemistry concepts. However, a study conducted by Faour and Ayoubi (2018) on the assessment of grade 10 students' attitudes towards physics following a virtual laboratory intervention found no significant attitude differences.

This research study aims to explore coherent infusion of computer simulations as a means to complement traditional teaching methods. In order to embrace advances in technology, the education discourse ought to focus on the necessity to utilise constantly developing technology in teaching and learning. The computer simulations adopted for utilisation in this study were sourced from the Physics Education Technology (PhET) research project of the University of Colorado in the United States of America. By their very nature, the computer simulations are useful and offer animated feedback to the user. In order to provide insightful elucidation into the nature of key research findings, this study is underpinned by a multi-theoretical framework which combines the principles of constructivism (learning by active participation and experimentation), technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009) and the cognitive theory of multimedia learning (Mayer, 2011). In essence, this research study was underpinned by a TPACK framework which was adopted as a conceptual lens for unearthing acid-base misconceptions of grade 11 Physical Sciences learners by using computer simulations as an innovative intervention. Accordingly, the following research question was formulated:

- To what extent can computer simulations be used as an intervention to address acid-base misconceptions of Physical Sciences learners in South African township schools?

1.5 Aim and objectives of the study

The aim of the study was to investigate the extent to which computer simulations can be used as an intervention to address acid-base misconceptions of South African grade 11 Physical Sciences learners in township schools. The study was underpinned by the following concomitant objectives:

- To identify acid-base misconceptions held by grade 11 Physical Sciences learners in township schools.
- To explore the effect of computer simulations as an intervention to address acid-base misconceptions of grade 11 Physical Sciences learners in township schools.

1.6 Research design and methodology

This study adopted a mixed-method approach as part of a case study involving purposively selected grade 11 Physical Sciences learners from two South African township schools. Quantitative data was collected by administering a questionnaire as a pre-test and post-test. Qualitative data was collected through semi-structured interviews and lesson observations. A broad reflection on the research design and methodology is provided in Chapter 3.

1.7 Significance of the study

Technology integration in Physical Sciences teaching and learning provides meaningful opportunities for pedagogic innovation. This study contributes to meaningful curriculum reform through provision of insightful elucidation into the development of technology-enhanced teaching and learning within the context of changing fortunes associated with the advent of the Fourth Industrial Revolution. The key findings of the study would pave the way for meaningful integration of technology in Physical Sciences teaching and learning as a facilitative and sustainable means through which digital transformation in its broadest sense can be realised. Contextually appropriate recommendations that can be adopted and implemented to bring about transformative change in relation to sustainable technology integration in Physical Sciences teaching and learning are provided in order to guide meaningful curriculum reform.

1.8 Structure of the minor dissertation

Consistent with the epistemological framework that underpins this research study, the breakdown in terms of the structure of the minor dissertation is provided below.

Chapter 2 provides a review of relevant literature related to the study.

Chapter 3 reflects on the research design and the justification of the research methods employed in this study.

Chapter 4 provides the results emanating from the research study.

Chapter 5 reflects on key findings, conclusion and recommendations arising from the study.

1.9 Chapter summary

This chapter provides an orientation to the study. The purpose and the significance of the study are highlighted. The roadmap essential for the navigation of the minor dissertation is also provided. Chapter 2 then provides a review of relevant literature related to the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter provides the theoretical underpinnings of the research carried out in this study and a review of relevant literature. A broad reflection on the nature of misconceptions as a key focus area is provided coupled with a discussion of a multi-theoretical framework which combines the principles of constructivism (learning by active participation and experimentation), Technological Pedagogical Content Knowledge (TPACK) (Koehler & Mishra, 2009) and the cognitive theory of multimedia learning (Mayer, 2011).

2.2 Misconceptions

There are two perspectives which emerged from the analysis of learners' conceptions in science teaching and learning (Hammer, 1996). The first perspective views learners' conceptions as misconceptions while the second perspective considers learners' conceptions as phenomenological primitives (p-prims). Misconceptions or naïve conceptions are often referred to as alternative conceptions. The term "misconception" was adopted for use in this research study. Griffiths and Preston (1992) describe a misconception as any conceptual idea whose meaning deviates from the one commonly accepted by scientific consensus. This research study is predicated on the definition of a misconception as proposed by Griffiths and Preston (1992). Misconceptions have an adverse impact on science teaching and learning. Thus, there is a crucial need for science teachers to be concerned with how misconceptions are brought about and the manner in which they affect science teaching and learning (Millar, Gott, Lubben & Duggan, 1993). Furthermore, misconceptions have an effect on learners' perception of reality in everyday life (Hammer, 1996). It is therefore important for teachers to firstly ascertain which misconceptions are common among the learners within their classroom contexts and also guide those learners through a pedagogical sequence which will develop an understanding of learners about science concepts (Doran, 1972). It is imperative for science teachers to adopt appropriate innovative pedagogical strategies when addressing misconceptions in science classrooms. To this end, the efficacy of computer simulations as an innovative intervention to address acid-base misconceptions of South African grade 11 Physical Sciences learners in township schools is explored in this research study. This empirical investigation ought to be informed by a clear understanding of the origin of misconceptions.

2.3 Origin of misconceptions

It is a known fact that learners come to the classroom with different beliefs, customs and cultural knowledge. Thus, they do not come to a science classroom as empty vessels. Sheets (2009) posits that children bring to the classroom culturally mediated, historically developing cultural knowledge, practices, values, and skills. This knowledge includes science misconceptions. Pfundt and Duit (2006) argue that misconceptions affect learning when they are incorporated into cognitive structures of learners. Acquiring new knowledge requires a connection between the learner's prior cultural knowledge and the new knowledge being taught and learned (Sheets, 2009). Zirbel (2006) asserts that misconceptions depend on learners' prior knowledge as they have a direct bearing on how learners store and consolidate conceptual information for making their own views.

Models of teaching underpinned by tasks promoting effective learning can be used as a means to identify acid-base misconceptions held by grade 11 Physical Sciences learners within the context of this research study. These models may be helpful in alleviating poor performance in science in particular. Researchers such as Posner, Striker, Hewson and Gertzog (1982) and Stepans (2008) argue that only instructional models of instruction which utilize tasks that bring about a theoretical change can engender meaningful conceptual understanding. This notion underscores the significance of adopting appropriate innovative pedagogical strategies geared towards the enhancement of technology-enhanced learning to meaningfully address misconceptions in science teaching and learning.

2.4 The effect of language on misconceptions

As a medium of instruction, language plays a pivotal role in science teaching and learning. Limited vocabulary stifles meaningful learning in science subjects (Heugh, 1999). In support of this notion, Rutherford, Clerk and Goudemond (1999) maintain that science frequently emerges as one of the most linguistically demanding subjects for second language learners. Rollnick (2000) contends that learners who are second language speakers have a dual challenge as they have to master a language, i.e. English, and science content in English. It is important to point out that English is not a mother tongue for a vast majority of learners in South Africa and this reality poses enormous instructional challenges in science teaching and learning. By virtue of their profile, learners who participated in this research study were doing English as a First Additional Language. They received science instruction in English and came from disadvantaged backgrounds.

2.5 The use of computer simulations in science teaching and learning

Khan (2011) describes an interactive simulation “as a computer program that attempts to simulate a model of a particular system” (p. 216). Simulations are useful as they allow learners to visualise aspects of science and to manipulate variables in multiple ways to observe changes which occur as a result of interactions (Khan, 2011). In addition, simulations help learners to make sense of real-world experiences, use multiple representations and provide opportunities to indulge in productive collaborative activities as well as provision of opportunities for teachers to build on learners’ prior knowledge for purposes of addressing misconceptions (Wieman, Adams, and Perkins, 2008). Osborne and Hennessy (2003) argue that computer simulations provide perfect, sparkling and pictorial demonstrations of physical phenomena as well as experimentations that may be hazardous, overpriced or else not practicable in the school laboratory. Several research studies demonstrated that the use of computer simulations serves to improve the performance of learners (Baggott la Velle, Bang, 2003; Chang, Chen, Lin & Sung, 2008; Ufondu, 2008; Zacharia, 2007).

At another pragmatic level, the use of computer simulations can serve to improve learner performance in science by demystifying abstract concepts. Khan (2011) postulates that simulations are worthwhile in the sense that they allow learners to envisage aspects of a scientific discourse by using scientific variables in a variety of ways. Osborne and Hennessy (2003) assert that computer simulations provide meaningful platforms to carry out experimentation that could be hazardous, expensive or infeasible to be conducted in a school laboratory. In addition, computer simulations are perceived to provide opportunities for learners to produce expeditious and quality feedback when doing science (Barron *et al.*, 1998).

The use of technology in science teaching and learning has been promoted as a key curriculum imperative in South Africa (Department of Basic Education, 2011). Innovative use of various learning technologies as alternative pedagogical tools for enhancing learner interest, visualisation of abstract concepts and motivation in science subjects has been a key curriculum goal in recent years in South Africa. The use of virtual laboratory simulations in demystifying abstract scientific concepts and facilitation of visualisation cannot be over-emphasised. However, a substantial number of schools in South Africa are still under-resourced (Naidoo & Paideya, 2015). The availability of traditional science laboratories at some schools is not a panacea for this predicament as most teachers are not adequately skilled to use these laboratories to perform meaningful practical work for the benefit of learners (Trundle & Bell, 2010). Negative dispositions in this regard can be attributed to the fact that teachers perceive laboratory processes as incomprehensible, equipment difficult to use or not available and the instructional guidance provided usually not enough to scaffold understandings of certain concepts (Potkonjak, Michael, Victor, Mattila, Petrovi & Kosta, 2016).

By their very nature, virtual laboratory simulations developed by the Physics Education Research Project team at the University of Colorado in the United States of America take the form of low immersion virtual reality which can be used to enhance visualisation ((Potkonjak, Michael, Victor, Mattila, Petrovi & Kosta, 2016; Makranskya, Terkildsena & Mayer, 2017). By contrast, high immersion virtual reality involves technologies where the user becomes more immersed in the simulations by using an interactive device or headgear which creates an impression to the mind as though the virtual experience is real (Lee & Wong, 2014). The Physics Education Technology is a virtual laboratory simulation package that was used in this study as an intervention to address misconceptions of grade 11 Physical Sciences learners at South African township schools.

The virtual laboratory simulations provide students with meaningful platforms to experiment and manipulate different variables and this would not be possible using traditional and rote memorization learning strategies (Clark, Tanner-Smith & Killingsworth, 2016; Merchant, Goetz, Cifuentes, Kenney-Kennicutt & Davis, 2014). While the practical pedagogic benefits of virtual laboratory simulations are widely reported, few studies provide insights into the possible roles of the teacher and the pedagogical strategies that can be adopted when using virtual laboratory simulations (Khan, 2011). Several studies have established that virtual laboratory learning (immersive or non-immersive virtual reality and augmented reality) has positive impact on learners' attitudes and motivation towards science learning in general (e.g. Chua & Karpudewan, 2017; Hsu, Lin, & Yang, 2017). In support of this notion, Arvind and Heard (2010) assert that the use of virtual laboratories serves to simplify complex physics concepts and changes learners' negative perceptions of the physics course in particular. According to Tüysüz (2010), learners who are comfortable with the use of virtual laboratories often show a more positive attitude towards learning chemistry concepts. However, a study conducted by Faour and Ayoubi (2018) on the assessment of grade 10 learners' attitudes towards physics following a virtual laboratory intervention found no significant attitude differences.

2.6 Limitations of using computer simulations as assessment tools for diagnosing misconceptions in science teaching and learning

According to Smith, Disessa and Roschelle (1994), a narrow interpretation of misconceptions offers a view of learning which only focuses on the erroneous qualities of learners' prior knowledge while disregarding the notions of learners which according to constructivism may be the basis for learners to attain and build a good scientific and mathematical understanding. They further contend that misconceptions should be reconceived as faulty extensions of productive knowledge and are not always resistant to change and instruction that confronts misconceptions with the hope of replacing them is misguided and unlikely to succeed. While Smith, Disessa and Roschelle (1994) provide a critical viewpoint about misconceptions, they however fall short of contributing to a discourse on the undesirable impact of misconceptions on the learning and teaching of abstract scientific concepts.

One of the disadvantages of computer simulations is that they only present a demonstration of the end product (Steinberg, 2000). In addition, Steinberg (2000) argues that computer simulations provide an insignificant chance for learners to participate in all the steps that occur in a scientific process. This implies that learners do not participate actively in a simulated activity as they would do if they were conducting an experiment practically. Thus, the use of computer simulations cannot not replace real experiences provided by traditional laboratories. Computer simulations can cause and perpetuate learner misconceptions particularly if the nature of scientific phenomena is inappropriately demonstrated by the inherent features of the simulation package. At another pragmatic level, computer simulations can provide learners with fallacious understanding of the actual life challenges due to their over-simplification of difficulties associated with these actual life challenges (Heinich *et al.*, 1999). Another key concern expressed about the use of computer simulations is the extent to which they are effective in activating learners' prior conceptions (Jaakkola, 2012). Thus, computer simulations do not provide opportunities for the incorporation of prior knowledge into the learning process.

Diagnostic tools and instruments are utilized for assessing persistent or regular learning challenges including misconceptions (Gronlund & Linn, 1990). According to Gronlund and Linn (1990), diagnostic tools and instruments include multiple choice tests, interviews, concept maps as well as multiple-tier tests. These diagnostic instruments and tools are characterised by inherent disadvantages and advantages (Kaltakci & Eryilmaz, 2010). Multiple choice tests are not time-consuming as compared to interviews and are easier to administer and mark (Tamir, 1990). The use of multiple choice tests proved to be a convenient method of identifying learners' misconceptions (Tamir, 1990). Treagust (1988) asserts that the use of diagnostic tools comprising of two and three-tier multiple choice questions can make a meaningful contribution towards the improvement of teaching and learning as well as the sustainable enhancement of learners' interest when engaging with scientific concepts. Two-tier multiple choice questions and interviews were employed to identify acid-base misconceptions held by grade 11 Physical Sciences learners at South African township schools within the context of this study.

2.7 Teacher professional development in the use of computer simulations

The use of technology in teaching and learning is largely regarded as a key curriculum imperative by the South African Department of Basic Education. To this end, Rules for Instructor Preparing and Proficient Improvement in Technology Advancement Manual has been made available to teachers to guide professional development initiatives geared towards the development of skills in technology integration. This profound initiative is in many ways a significant step in creating technology savvy teacher workforce. Lack of reliable data on the utilisation of information and communication technologies by teachers in rural schools in particular represented a fundamental dilemma that required considerable attention (Department of Education, 2007).

A substantial number of schools in South Africa are still grappling with fundamental challenges such as lack of internet access. These challenges make it increasingly difficult for both learners and teachers to access open educational resources thereby hindering teacher professional development in technology (Herselman, 2003). The White Paper on e-learning serves as a blueprint for guiding the provision of training in technology integration in the classrooms (Department of Education, 2004). One of the envisaged outcomes of the White Paper on e-learning is the development of teachers' professional skills so that they are able to use information and communication technologies as key instructional resources. The acquisition of professional skills in this regard would pave the way for teachers to harness the affordances of computer simulations with a view to enhance meaningful teaching and learning by providing meaningful opportunities for self-directed learning. The development of 21st century skills remains a key strategic imperative that ought to underpin continuous teacher professional development going forward. It is for this reason that Browne and Ritchie (1991) stipulate that teacher training should cultivate the skills and knowledge required to implement new technologies in the classrooms.

2.8 Theoretical framework

The study is underpinned by a multi-theoretical framework which combines the principles of constructivism (learning by active participation and experimentation), technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009) and the cognitive theory of multi-media learning (Mayer, 2011). The TPACK framework emphasises the interaction between pedagogical knowledge, content knowledge as well as technological knowledge (Koehler & Mishra, 2009). In addition, the TPACK framework advocates that learning can be facilitated when technology is used to complement teaching using appropriate pedagogical approaches (Koehler & Mishra, 2009; Swallow & Olofson, 2017). TPACK is defined by Koehler, Mishra and Cain (2013), as "the basis of effective teaching with technology requiring an understanding of the representation of concepts using technology" (p. 16). As illustrated in Figure 1 below, the TPACK framework delineates the intersection between technological knowledge, content knowledge, pedagogical knowledge and pedagogical content knowledge.

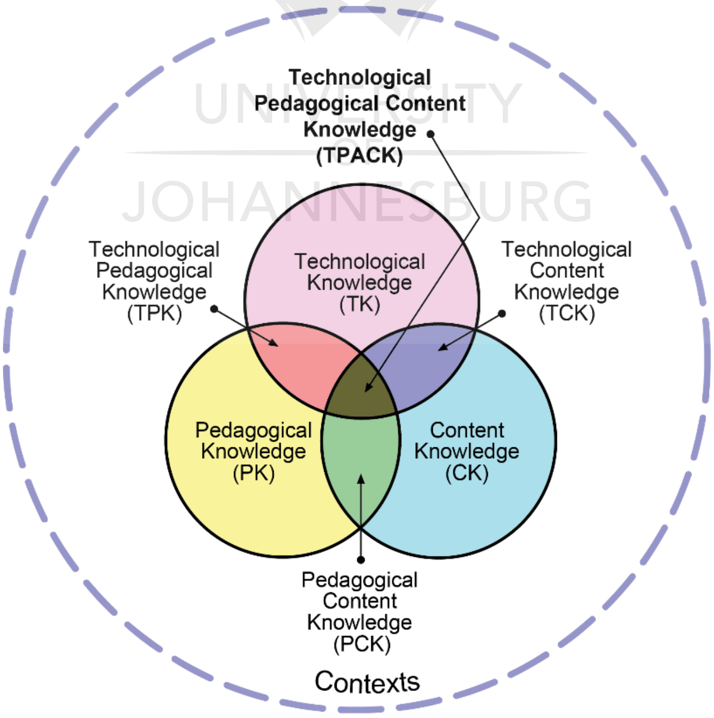

Figure 1: The components of the TPACK framework (Koehler & Mishra, 2009, p. 63)

The theory of multi-media learning posits that multiple media (auditory and visual) can be used in teaching and learning as a tool for facilitating the visualisation of abstract concepts and the formation of mental schemas (Mayer, 2011). Constructivist theories postulate that experiential and experimental learning have the ability to significantly enhance cognition and provide the basis for learning science as inquiry (Bruner, 1990). The multi-theoretical framework adopted in this study is relevant for purposes of providing insightful elucidation into the efficacy of computer simulations as an innovative intervention to address misconceptions. McKenney and Reeves (2012) posit that an intervention "encompasses different kinds of solutions that are designed" (p. 14). The solutions may include educational tools, policies, programs, and workshops. Within the context of this study, the intervention includes interactive cycles of virtual laboratory inquiry workshops for grade 11 Physical Sciences learners in township schools. The TPACK framework served to provide insightful elucidation into the affordances of computer simulations in alleviating grade 11 learners' misconceptions associated with acids and bases. Computer simulations represented the technology used, acids and bases represented content knowledge area investigated and technology integration and the use of various pedagogical strategies represented pedagogical content knowledge.

2.9 Chapter summary

Chapter two describes the underlying theoretical framework that underpins this research study and a review of relevant literature. In addition, this chapter provided a reflection on misconceptions as the primary focus of the empirical investigation in this study. Chapter 3 then provides a broad overview of the research methodologies used to explore the efficacy of computer simulations as an innovative intervention to address misconceptions of grade 11 Physical Sciences learners in South African town schools.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter describes the research design and methodology adopted in this study. It also reflects on the justification of the research methods employed in executing the research. The study investigated the extent to which computer simulations can be used as an innovative intervention to address acid-base misconceptions of grade 11 Physical Sciences learners in two schools located in Mamelodi Township in the Gauteng Province of South Africa. Accordingly, the following research question was formulated:

- To what extent can computer simulations be used as an intervention to address acid-base misconceptions of Physical Sciences learners in South African township schools?

The study was underpinned by the following concomitant objectives:

- To identify acid-base misconceptions held by grade 11 Physical Sciences learners in township schools.
- To explore the effect of computer simulations as an intervention to address acid-base misconceptions of grade 11 Physical Sciences learners in township schools.

3.2 Research design and methodology

This study adopted a mixed-method approach as part of a case study. The mixed-method approach is appropriate as it aims to draw on the strengths and reduce the weaknesses of the quantitative and qualitative methods (Johnson & Onwuegbuzie, 2004). A reflection on target population, sampling, data collection methods and data analysis is provided below.

3.2.1 Target population

According to Van den Broeck, Sandøy and Brestoff (2013), the population of interest is the study's target population. As it is not appropriate or feasible to recruit the entire population of interest, a sample from the population of interest was recruited for participation in the study. This enabled the investigator to achieve the objective of the research study which is to generalize the study findings from the sample to the population of interest. The target population in this study comprised of grade 11 Physical Sciences learners at two South African township schools.

3.2.2 Sample

The study involved purposively selected grade 11 Physical Sciences learners from two South African township schools. The two township schools were largely under-resourced and this predicament justified the exploration of virtual laboratory simulations as an alternative means to alleviate learners' misconceptions associated with acids and bases in Physical Sciences classrooms. Purposive sampling is a strategy in which participants are selected deliberately in order to provide important information that cannot be obtained from other choice (Taherdoost, 2016).

3.2.3 Data collection methods

Quantitative data was collected by means of a validated instrument which was administered as part of control group-experimental group design. A quantitative research approach provides opportunities for researchers to use numbers obtained from experiments to represent research findings. According to Henning, Van Rensburg and Smit (2004), a quantitative approach can be linked and supported by a quasi-experimental (numerical) method. McMillan and Schumacher (2001) posit that a quantitative research approach is based on the gathering as well as questioning of data numerically. Furthermore, a quantitative research is characterised by a provision of statistics based on numbers (i.e. numerical findings). Qualitative data was collected through semi-structured interviews with the participants.

3.2.3.1 Questionnaires

Validated questionnaire was used to collect quantitative data. The validated instrument used for collection of quantitative data is *Acids-Bases Chemistry Achievement Test* developed by Damanhuri, Treagust, Won and Chandrasegaran (2016).

3.2.3.2 Interviews

Semi-structured interviews were conducted with the participants. The interviews were conducted to provide elaboration on trends that emerged from quantitative data.

3.2.3.3 Observations

According to Majid (2018), observational studies involve the investigators observing the context, environment, and behaviours in the real-world without participation or manipulation. In this study, lesson observations served to provide valuable insights into the nature of pedagogical strategies adopted by teachers when integrating technology and how learners interacted with technology to enhance their understanding of acids and bases as a key knowledge area in Physical Sciences.

3.2.3.4 Data analysis

SPSS Version 25 was used to analyse quantitative data. Quantitative data was analysed by using descriptive and inferential statistics. Atlas.ti was used to analyse qualitative data. Analysis of qualitative data was guided by the Coding Manual for Qualitative Researchers developed by Saldana (2009). Denzin and Lincoln (2005) define qualitative research as an approach in which the researcher investigates the phenomena directly in the field and then utilises tools to gather and interpret data from the field.

3.3 Validity and reliability

The internal reliabilities of the instrument were evaluated by calculating Cronbach's alpha for each item. Cronbach's alpha is used as an indicator of scale reliability or internal consistency (Taber, 2017). This is the degree to which the items that make up the scale are all measuring the same underlying attribute (Pallant, 2007). In respect of qualitative data, the following validity and reliability checks proposed by Merriam (1998) were adhered to:

- Triangulation: Claims and tentative interpretations were triangulated through multiple meetings that were held with the participants during the research process and the use of multiple and different data collection methods.
- Member checks: Data collected and tentative interpretations were discussed during reflection sessions and were confirmed by the participants.
- Peer review: There was ongoing dialogue and critical reflection with other researchers on the research process and tentative interpretations.
- Reflexivity: The researchers engaged in critical self-reflection regarding anything that may bias the interpretation of data e.g. hidden assumptions, own worldview, theoretical orientation and interrelationships. Biases and assumptions were made explicit.
- Audit trails: A detailed account of methods, procedures and reasons for decisions taken was compiled.
- Rich description: A detailed description of events characterizing the research process was provided to contextualize the study and to judge the extent to which the findings apply to the research situation.

3.4 Ethical considerations

Prior to data collection, I applied for ethical clearance from the Faculty of Education at the University of Johannesburg in line with research protocol. The research proposal was approved in accordance with stipulated Faculty regulations. Permission to conduct research at the selected township schools was obtained from the Gauteng Provincial Education Department. Other ethical requirements pertaining to the execution of the research study were strictly adhered to. There was no harm or discomfort associated with the participation of teachers or learners. However, potential risks involved the participants' strong conflicting views, bias and opinions about technology integration in Physical Sciences teaching and learning. In cases where such feelings arose, the participant were not be obliged to answer questions and complete withdrawal from the study was guaranteed without any repercussions. The study did not take away any teaching time or interfere with the coverage of intended content. Administration of questionnaires and conducting of interviews were done outside teaching time. Confidentiality was ensured at all times to protect individual responses.

3.5 Chapter summary

This chapter reflected on the research design and the justification of the research methods employed in this study. In particular, this chapter provided a reflection on the research methodologies used to explore the efficacy of computer simulations as an innovative intervention to address misconceptions of grade 11 Physical Sciences learners in South African town schools. Chapter 4 then provides a reflection on the results emanating from this research study.

CHAPTER 4: RESULTS

4.1 Introduction

This chapter reflects on the key findings that emerged from this research study. The results emanating from the research carried out in this study are presented coupled with a discussion of the implications of the key findings that emerged.

4.2 Findings

Quantitative data was collected by means of *Acids-Bases Chemistry Achievement Test (ABCAT)* developed by Damanhuri, Treagust, Won and Chandrasegaran (2016).

4.2.1 Comparison of pre-test and post-test performances in the ABCAT

Data was analysed to compare learners' understandings of acid-base concepts in the pre-test and post-test using the ABCAT. The control group was not exposed to the use of virtual laboratory simulations while the experimental group was exposed to the use of virtual laboratory simulations. Table 1 below depicts the performance of the control group in relation to the two sections constituting the questionnaire. There was no significant difference between the pre-test and post-test scores for both sections in relation to the control group.

Table 1. Pre-test and post-test scores for the control group (N = 27)

Pre-test		Post-test		Effect size
Mean	**SD**	**Mean**	**SD**	**(Cohen's *d*)**
5.4	2.0	5.9	2.4	0.61

$**p < 0.01$

Table 2 below depicts the performance of the experimental group in relation to the two sections constituting the questionnaire. The post-test scores were significantly higher than the pre-test scores for both sections in relation to the experimental group.

Table 2. Pre-test and post-test scores for the experimental group (N = 26)

Pre-test		Post-test		Effect size
Mean	**SD**	**Mean**	**SD**	**(Cohen's *d*)**
5.2	2.0	7.7	2.9	0.89

$^{**}p < 0.01$

It is imperative to point out that the strength of the difference between the pre-test and post-test mean scores was determined by computing the effect size, Cohen's *d*. Cohen (1988) defines the effect size as being small when $d = 0.2$, medium when $d = 0.5$ and large when $d = 0.8$. The Cohen's *d* values suggest that the difference between the means was small for the control group while the difference between the means was large for the experimental group.

The overall performance of the individual participants in the control group is illustrated in Figure 2 below. There was no significant improvement in the overall performance of the individual participants in the control group. This can partly be attributed to the inadequacy of traditional instruction. Pedagogic innovation is required to bring about fundamental change to such an unpalatable outcome. The performance of the control group remained largely steady which suggests that traditional instruction was not effective as an intervention to enhance conceptual understanding by dispelling misconceptions. This underscores the need for the adoption of appropriate innovative instructional strategies geared towards the inculcation of cognitive and reflective skills. The redundancy of teacher-centred pedagogical approaches has to be viewed in a serious light with a view to sensitise teachers to adopt and implement learner-centred pedagogical approaches which can essentially be used to foster technology-enhanced learning. The integration of technology in science teaching and learning provides opportunities for teachers to embrace pedagogical innovation in its broadest sense in their quest to become reflective practitioners. Digital transformation is an inevitable reality and teachers have to be implored to sharpen their technological skills through sustainable professional development opportunities. Learners readily embrace the use of technological devices and this willingness ought to be harnessed for purposes of providing quality education. Technology integration in science teaching and learning has to be fully embraced by both teachers and learners alike as key participants in the teaching and learning process. This crucial step can serve to unlock opportunities to harness the pedagogic value of reflective activities in order to promote classroom inquiry.

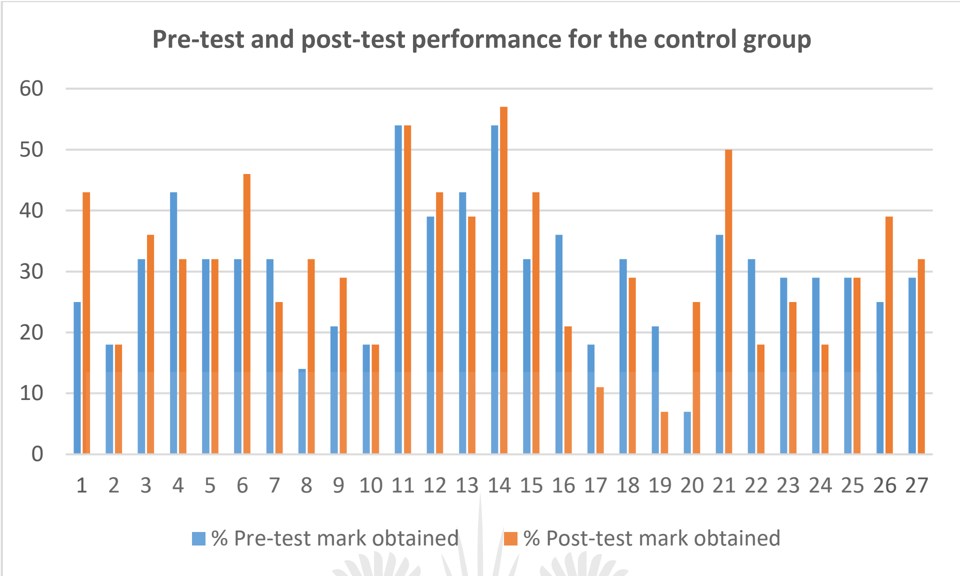

Figure 2: Overall performance of the individual participants in the control group

The overall performance of the individual participants in the experimental group is illustrated in Figure 3 below. There was a moderate improvement in the overall performance of the individual participants in the experimental group. This implies that the use of virtual laboratory simulations may be a panacea for alleviating learners' misconceptions when pursued more vigorously. The performance of the experimental group improved as a result of the implementation of the virtual laboratory simulations as an innovative intervention to address learners' misconceptions. This performance improvement suggests that virtual laboratory simulations can be used as an innovative intervention to enhance understanding of abstract scientific concepts by dispelling misconceptions. As a complex dichotomy, the advent of the fourth industrial revolution poses enormous challenges while providing practical pedagogical benefits for science teaching and learning within the broader South African educational context. While the need to integrate technology as a catalyst for pedagogic innovation in science teaching and learning is paramount, considerable attention ought to be devoted to meaningful teacher professional development on the effective utilization of appropriate information and communication technology tools. However, harnessing the affordances associated with technology-enhanced learning may be logistically difficult to realize in under-resourced township schools. Thus, the Department of Basic Education in South Africa faces the key imperative to provide essential resources to enable meaningful implementation of technology-enhanced learning.

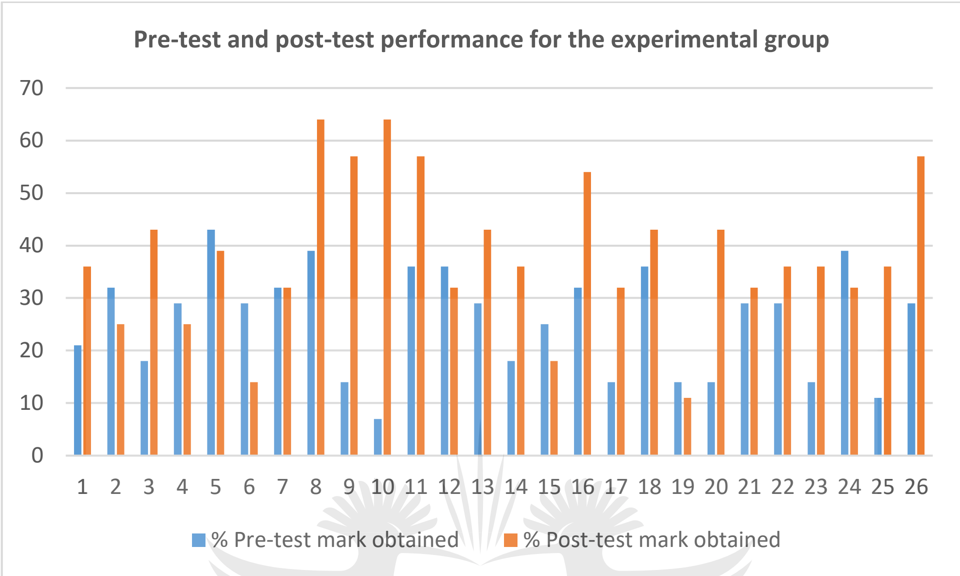

Figure 3: Overall performance of the individual participants in the experimental group

Table 3 below provides the comparison of percentage of learners in the control group who provided correct responses to each of the items in the ABCAT in the pre-test and the post-test. The distribution of correct responses appeared to be a function of the level of difficulty associated with the questionnaire items. The distribution of correct responses painted a gloomy picture about the adequacy of traditional instruction as an intervention to enhance conceptual understanding by dispelling misconceptions. The dismal performance of the learners points to conceptual difficulties with acids and bases as a Physical Sciences key knowledge area. Abstract scientific concepts associated with acids and bases cannot be demystified through traditional instruction as the performance of the learners in the control group seems to suggest. Hence, there is a need to adopt innovative instructional strategies that can provide the capacity to demystify complex chemical phenomena such as titration. This imperative calls for innovative capacity on the part of teachers as key agents of educational change.

Table 3. Comparison of percentage of students who provided correct responses to each of the items in the ABCAT in the pre-test and the post-test (control group) (N = 27)

Item No	Correct response	%Pre-test	%Post-test
A1	A	74	56
A2	A	22	48
A3	B	11	26
A4	B	33	37
A5	B	15	19
A6	D	7	7
A7	B	44	37
A8	D	19	26
A9	C	33	30
A10	C	30	26
B1	D2	17	24
B2	C2	17	22
B3	A3	39	28
B4	B1	11	13
B5	A3	46	46
B6	A1	35	57
B7	A3	56	46
B8	C1	22	22
B9	B1	30	20

(Note: A1 – A10 are Section A multiple-choice items; B1 – B9 are Section B two-tier multiple-choice items)

The comparison of percentage of learners in the control group who provided correct responses to each of the items in the ABCAT in the pre-test and the post-test is illustrated in Figure 4 below. The top symbols represent correct answers and the bottom symbols represent questionnaire items on the horizontal axis. The distribution of correction responses for the control group demonstrates that the participants struggled with the cognitive demands of the test administered.

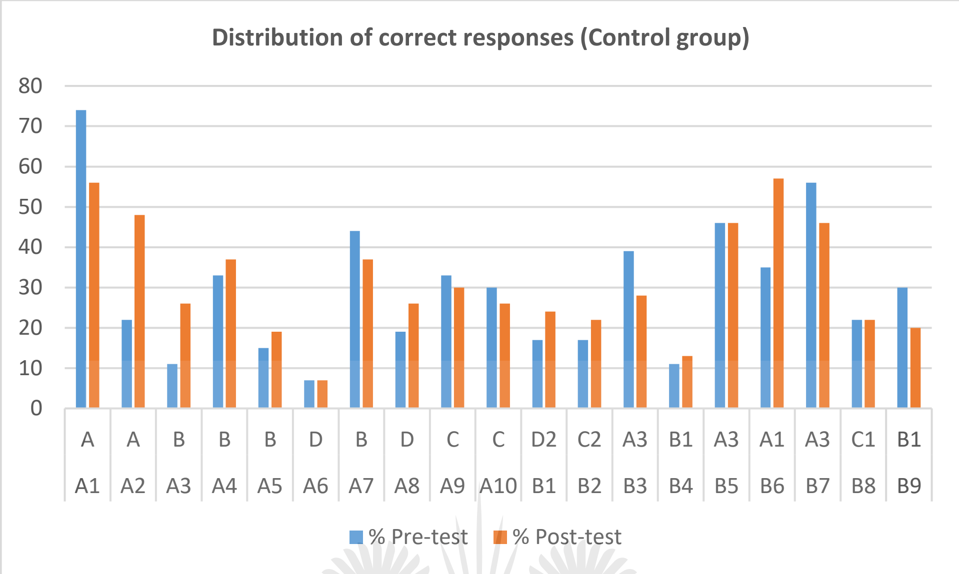

Figure 4: Distribution of correct responses (Control group)

Table 4 below provides the comparison of percentage of learners in the experimental group who provided correct responses to each of the items in the ABCAT in the pre-test and the post-test. Once again, the distribution of correct responses appeared to be a function of the level of difficulty associated with the questionnaire items. There was an improvement in the performance of the experimental group as a result of the implementation of the virtual laboratory simulations as an innovative intervention. However, the distribution of correct responses painted a gloomy picture about learners' conceptual grasp of acids and bases. The use of virtual laboratory simulations as an innovative intervention to enhance conceptual understanding by dispelling misconceptions appears to be a promising pedagogic approach. Hence, there is a need to harness the affordances of virtual laboratory simulations with a view to adequately address conceptual hurdles associated with acids and bases as a Physical Sciences key knowledge area. Virtual laboratory simulations can essentially be used to demystify abstract scientific concepts associated with acids and bases as the performance of the learners in the experimental group seems to suggest.

Table 4. Comparison of percentage of students who provided correct responses to each of the items in the ABCAT in the pre-test and the post-test (Experimental group) (N = 26)

Item No	Correct response	%Pre-test	%Post-test
A1	A	50	81
A2	A	31	15
A3	B	23	27
A4	B	31	58
A5	B	15	35
A6	D	4	8
A7	B	58	65
A8	D	50	58
A9	C	42	38
A10	C	4	19
B1	D2	10	19
B2	C2	23	31
B3	A3	21	40
B4	B1	12	27
B5	A3	33	46
B6	A1	25	92
B7	A3	29	44
B8	C1	38	33
B9	B1	17	37

(Note: A1 – A10 are Section A multiple-choice items; B1 – B9 are Section B two-tier multiple-choice items)

The comparison of percentage of learners in the experimental group who provided correct responses to each of the items in the ABCAT in the pre-test and the post-test is illustrated in Figure 5 below. The top symbols represent correct answers and the bottom symbols represent questionnaire items on the horizontal axis. The distribution of correction responses for the experimental group demonstrates that the participants in this group also struggled with the cognitive demands of the test administered.

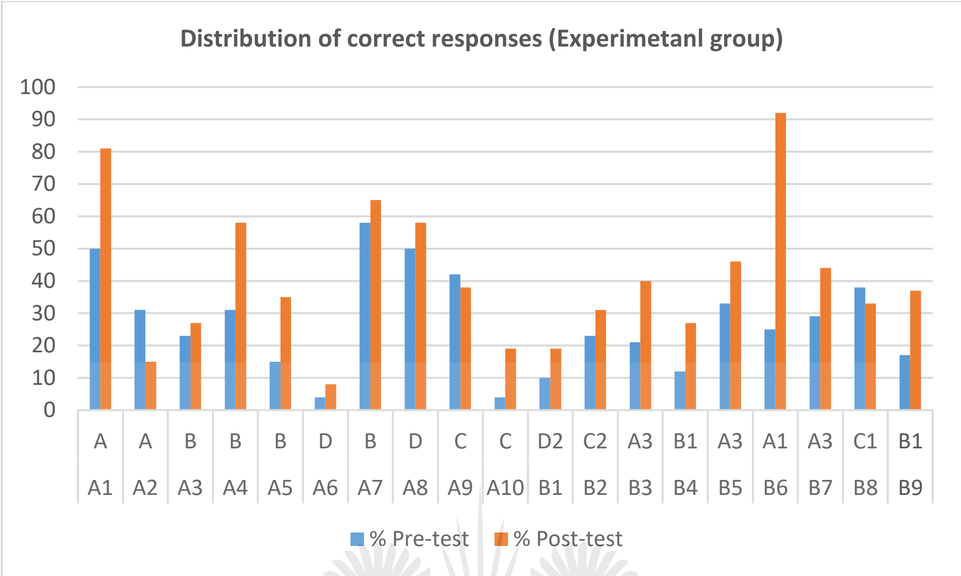

Figure 5: Distribution of correct responses (Experimental group)

Table 5 below provides a summary of misconceptions about acid-base concepts held by the learners in the control group. The learners in the control group exhibited a variety of misconceptions about acids and bases. The learners demonstrated inadequate understanding of the relationship between molarity, molar mass and concentration. This implies that a firm grasp of these concepts must first be developed before they are used in mathematical equations. In addition, the learners demonstrated inadequate understanding of the effect of the dilution of a standard solution of specific concentration on the number of moles of solute. Other misconceptions exhibited by the learners involved the nature of acid-base reactions and the differentiation between strong acids and strong bases as well as differentiation between weak acids and weak bases. The conceptual inadequacies exhibited by the learners would potentially render meaningful understanding of acid-base reactions and complex chemical phenomena such as titration difficult to realise. Learners cannot make significant strides in conceptual understanding in the face of pervasive knowledge gaps. These pervasive knowledge gaps must first be adequately addressed to pave the way for learners to have epistemological access to various knowledge domains. This mission can be accomplished through pedagogic innovation that is responsive to the fundamental challenges posed by the advent of the fourth industrial revolution as a game-changer.

Table 5. Summary of misconceptions about acid-base concepts held by the learners in the control group

Item No	Response option	% Pre-test	% Post test	Misconceptions
A2	B	30	22	The equation "Molarity (mol dm^{-3}) $=\frac{Molar\ mass\ (g\ mol-1)}{Concentration\ (g\ dm-3)}$" correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})
A9	**A**	**22**	33	When a standard solution of specific concentration is diluted, the concentration of the solution will increase, while the number of moles of solute present will decrease.
A9	**B**	**33**	15	When a standard solution of specific concentration is diluted, the concentration of the solution will increase, while the number of moles of solute present will remain constant.
A9	**D**	**12**	15	When a standard solution of specific concentration is diluted, the concentration of the solution will decrease, while the number of moles of solute present will also decrease.
A10	**B**	**59**	41	Aqueous potassium hydroxide reacts with aqueous sodium chloride to produce a salt and water.
B4	**A3**	**37**	37	Both sulfuric acid and ethanoic acid are strong acids because they ionise completely in water to produce H^+ ions.
B5	**B2**	**15**	15	HCl and CH_4 are both acidic because they contain H atoms in their molecular formulas.
B7	**A1**	**15**	19	Soaps and detergents as well as household cleaners contain alkaline chemicals that are able to wash away stains because alkalis are soapy.
B8	**C2**	**11**	19	Slightly acidic soil promotes the growth of grass. So, lime is added to change the pH of soil to a value greater than 7.
B9	**A2**	**30**	26	Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis because they are only partially ionised in water.

Table 6 below provides a summary of misconceptions about acid-base concepts held by the learners in the experimental group. The learners in the experimental group also exhibited a variety of misconceptions about acids and bases. The learners demonstrated inadequate understanding of the relationship between molarity, molar mass and concentration. They also demonstrated inadequate understanding of the effect of the dilution of a standard solution of specific concentration on the number of moles of solute. Other misconceptions exhibited by the learners involved the nature of acid-base reactions and the differentiation between strong acids and strong bases as well as differentiation between weak acids and weak bases.

Table 6. Summary of misconceptions about acid-base concepts held by the learners in the experimental group

Item No	Response option	% Pre-test	% Post-test	Misconceptions
A2	B	23	23	The equation "Molarity (mol dm^{-3}) $= \frac{Molar\ mass\ (g\ mol-1)}{Concentration\ (g\ dm-3)}$," correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})
A9	**A**	**27**	12	When a standard solution of specific concentration is diluted, the concentration of the solution will increase, while the number of moles of solute present will decrease.
A9	**B**	**19**	38	When a standard solution of specific concentration is diluted, the concentration of the solution will increase, while the number of moles of solute present will remain constant.
A10	**B**	**73**	46	Aqueous potassium hydroxide reacts with aqueous sodium chloride to produce a salt and water.
B1	**B2**	**15**	12	Sodium hydroxide dissolved in propane ionises to produce OH^- ions.
B3	**C3**	**27**	12	A measuring cylinder is the main apparatus that is used in the preparation of a standard solution because it can measure a fixed volume of solution accurately.
B4	**A3**	**31**	35	Both sulfuric acid and ethanoic acid are strong acids because they ionise completely in water to produce H^+ ions.
B5	**B2**	**23**	23	HCl and CH_4 are both acidic because they contain H atoms in their molecular formulas.
B7	**A1**	**19**	35	Soaps and detergents as well as household cleaners contain alkaline chemicals that are able to wash away stains because alkalis are soapy.
B9	**A2**	**23**	15	Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis because they are only partially ionised in water.

4.2.2 Examples of Physics Education Technology (PhET) simulations used as part of the intervention

The Physics Education Technology (PhET) developed by the Physics Education Research Team at the University of Colorado in the United States of America encapsulates a variety of interactive virtual laboratory simulations. Interactive virtual laboratory simulations related to acids and bases were used as part of the intervention implemented in this study to address misconceptions of grade 11 Physical Sciences learners at South African township schools. A screenshot of an interactive simulation based on acid-base solutions is illustrated in Figure 6 below.

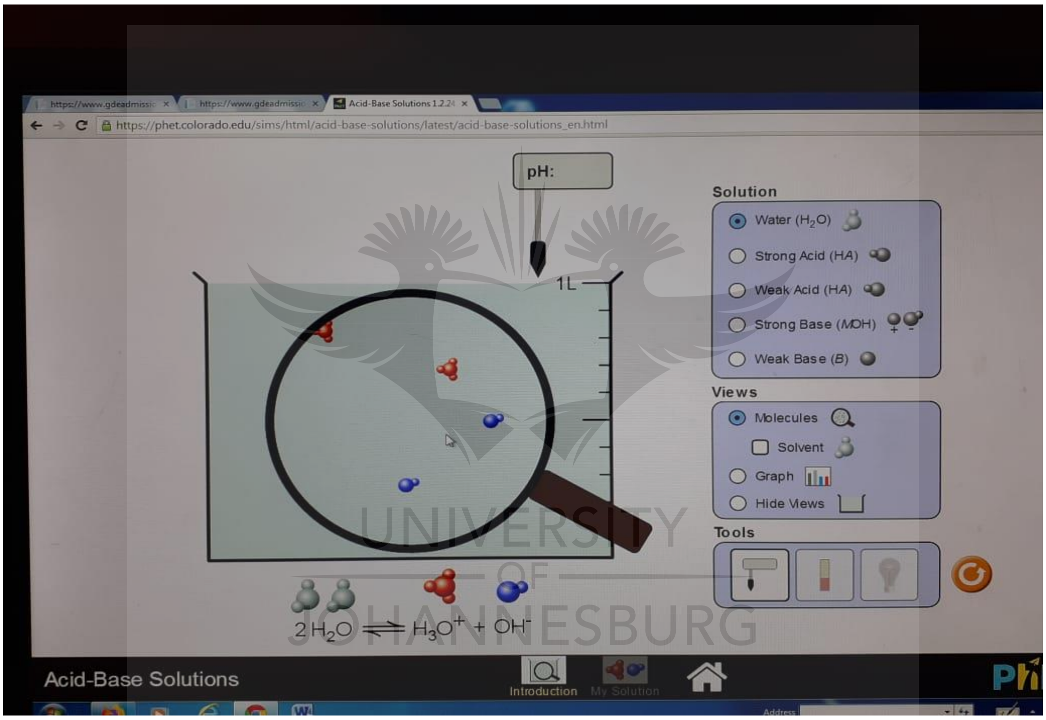

Figure 6: Interactive simulation based on acid-base solutions

The participants in this study demonstrated inadequate grasp of molarity as a key concept required for meaningful understanding of acid-base reactions. A screenshot of an interactive simulation based on molarity which was used as part of the intervention is illustrated in Figure 7 below.

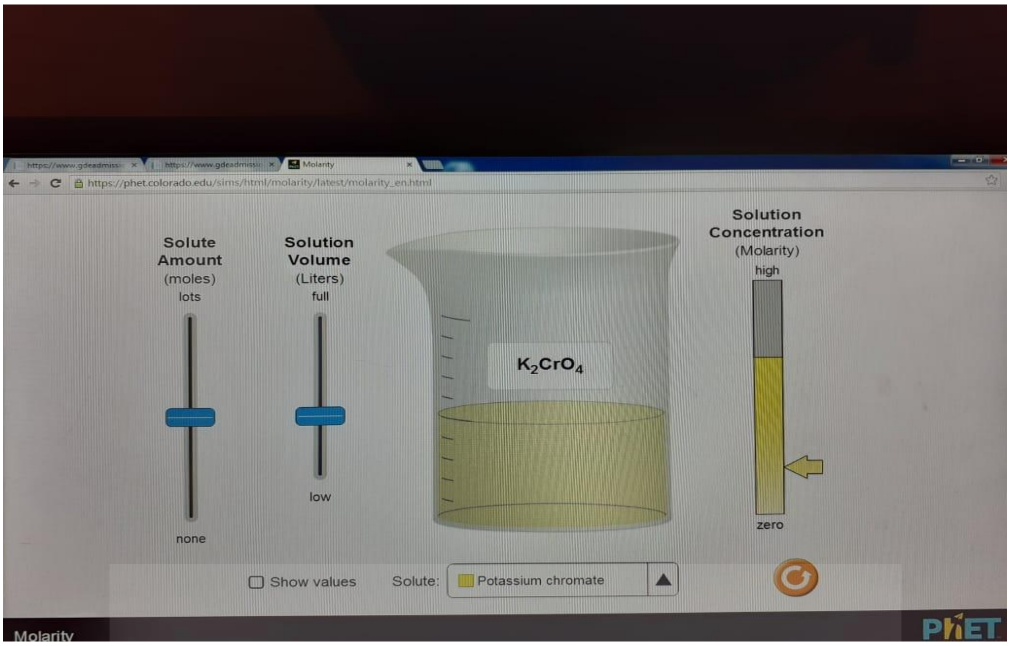

Figure 7: Interactive simulation based on molarity

Differentiating between the properties of acids and bases as chemical substances was a pervasive conceptual hurdle for the participants in this study. Interactive simulations based on the use of the pH Scale were used to demystify the complexity of the nature of acids and bases in view of their practical applications in everyday life. A screenshot of an interactive simulation based on the use of the pH Scale is illustrated in Figure 8 below.

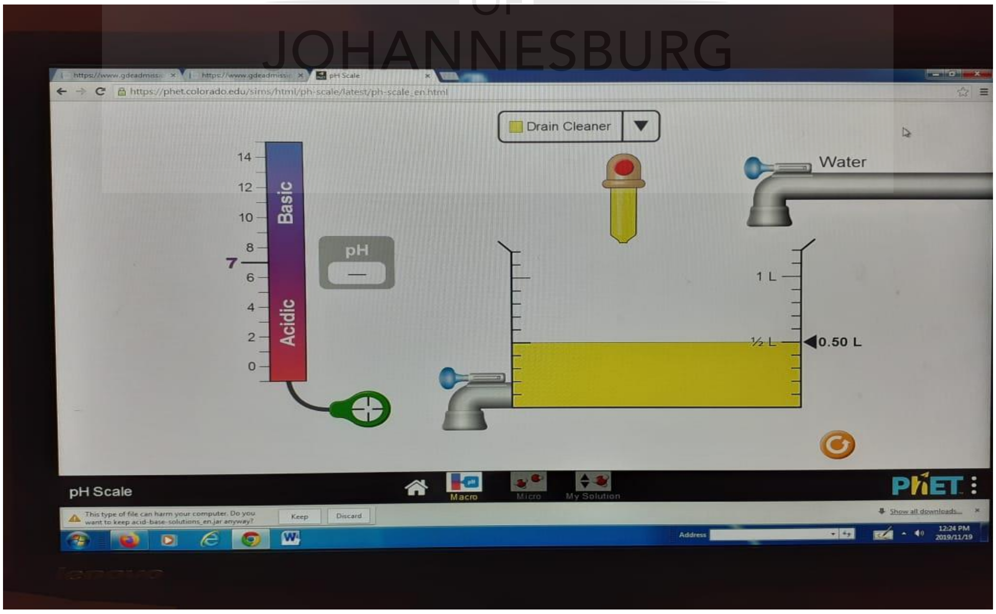

Figure 8: Interactive simulation based on the use of the pH Scale

4.2.3 Excerpts from semi-structured interviews

Table 10 below provides interview schedule and some of the responses provided by the participants. The categories generated from transcribed data are also provided. The categories generated included effectiveness of virtual laboratory simulations and activities, autonomy, affordances, increased confidence, convenience, misconceptions, information and communication technology (ICT) addiction, lack of authenticity and enhancement of conceptual understanding. The learners were largely pleased with the efficacy of virtual laboratory simulations and concomitant activities. Active and sustained involvement in virtual laboratory simulations and activities afforded learners opportunities to learn from mistakes and served to enhance their confidence. The learners felt that virtual laboratory simulations provided meaningful opportunities for self-directed learning. At another pragmatic level, virtual laboratory simulations provided meaningful platforms for demystifying complex scientific phenomena. Moreover, the learners indicated that the use of virtual laboratory simulations is not hindered by time constraints and allowed them to work on the activities at their own pace. According to the participants, some of the disadvantages of virtual laboratory simulations include perpetuation of misconceptions when they are not carefully used by teachers, addiction resulting from prolonged periods of use, lack of tangible reality as well as limited opportunities for development of science process skills.

Table 7. Excerpts from semi-structured interviews

Interview questions	**Codes**	**Categories**
How did you find the PhET simulation laboratories and the activities? Provide a brief explanation.	*I found it very effective and more virtual than chalk and talk.* *I enjoy the simulation labs more*.	Effectiveness of virtual simulation laboratories and activities
After the intervention classes, did you need help with the activities associated with the PhET simulation laboratories? Explain your reasoning.	*I could easily work independently on the simulation activities.* *I could work on the activities with minimal assistance and supervision* *The simulations provide opportunities for collaborative learning while I am able to work on activities independently.*	Autonomy

What were some of the gains you observed with using PhET simulations?	*I think they are a good way of teaching learners what they see theoretically, they are able to see experiments done practically as well.* *The simulations provide safe environment for working with harmful chemical substances such as acids and bases.* *The simulations promote self-directed learning.*	Affordances
	The simulations afforded me opportunities to learn from my mistakes. *My confidence grew as I worked on more activities* *I did n't have to worry about traditional laboratory hazards.* *The simulations provide comfortable working environment.*	Increased confidence
	Use of simulations is not hindered by time constraints. *Simulations allow me to work at my own pace anywhere.*	Convenience
What were some of the disadvantages of using the PhET simulation laboratories?	*The simulations can potentially perpetuate misconceptions when used in an incoherent manner* *The simulations ought to be carefully used.*	Misconceptions
	The use of PhET can be addictive as it generates excitement. *Prolonged period on the of PhET can lead to addiction*	ICT addiction
	The simulation does not provide tangible reality. *The simulation can complement traditional laboratory and not replace.* *The simulation provides limited opportunities for development of science process skills.*	Lack authenticity

Did the PhETs improve your conceptual understanding of the concepts associated with acids and bases? Explain your reasoning	*Yes, I could visualize abstract scientific phenomena such as the occurrence of titration.* *For me, yes, because I could differentiate between acids and bases.* *Yes, because I could differentiate between the properties of acids and bases.* *Yes, because I could explain the role of acids and bases in everyday life.*	Enhancement of conceptual understanding

4.3 Discussion

The key findings in this research study pointed to the inadequacy of traditional instruction as a means to enhance meaningful conceptual understanding by dispelling misconceptions. The use of virtual laboratory simulations as an innovative intervention to address misconceptions appears to be a promising pedagogic approach in view of the overall improved performance demonstrated by the participants in the experimental group in particular. The use of virtual laboratory simulations provides learners with meaningful platforms to experiment and manipulate different variables and such opportunities are not provided by the use of traditional and rote memorization learning strategies (Clark, Tanner-Smith & Killingsworth, 2016; Merchant, Goetz, Cifuentes, Kenney-Kennicutt & Davis, 2014). Several studies have established that virtual laboratory learning (immersive or non-immersive virtual reality and augmented reality) has positive impact on learners' attitudes and motivation towards science learning in general (e.g. Chua & Karpudewan, 2017; Hsu, Lin, & Yang, 2017).

While the participants in this study were largely pleased with the efficacy of virtual laboratory simulations as an innovative intervention to address misconceptions, they cautioned that virtual laboratory simulations cannot supersede traditional laboratories in view of their critical role in the development of science process skills. Arvind and Heard (2010) assert that the use of virtual laboratory simulations serves to simplify complex physics concepts and changes learners' negative perceptions of the physics course in particular. According to Tüysüz (2010), learners who are comfortable with the use of virtual laboratory simulations often show a more positive attitude towards learning chemistry concepts. However, a study conducted by Faour and Ayoubi (2018) on the assessment of grade 10 learners' attitudes towards physics following a virtual laboratory intervention found no significant attitude differences. Additional benefits provided by the use of virtual laboratory simulations include provision of meaningful opportunities for self-directed learning and visualization of complex scientific phenomena.

The study is underpinned by a multi-theoretical framework which combines the principles of constructivism (learning by active participation and experimentation), technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009) and the cognitive theory of multi-media learning (Mayer, 2011). Within the context of this study, learners actively participated in the use of virtual laboratory simulations and were afforded opportunities for experimentation. Learning was essentially predicated on the interaction between pedagogical knowledge, content knowledge as well as technological knowledge as postulated by Koehler and Mishra (2009). In addition, learning was facilitated through the use of technology to complement appropriate pedagogical approaches (Koehler & Mishra, 2009; Swallow & Olofson, 2017). Technology integration involved the use of computers, tablets and mobile phones to foster multi-media learning. The theory of multi-media learning posits that multiple media (auditory and visual) can be used in teaching and learning as a tool for facilitating the visualisation of abstract concepts and the formation of mental schemas (Mayer, 2011). To this end, the participants were afforded opportunities to learn from their own experiences and experimentation. Provision of these opportunities was informed by considerable emphasis placed by constructivist theories on experiential and experimental learning by virtue of their ability to significantly enhance cognition and provide the basis for learning science as inquiry (Bruner, 1990). The multi-theoretical framework adopted in this study was relevant as it served to provide insightful elucidation into the efficacy of computer simulations as an innovative intervention to address misconceptions.

4.4 Chapter summary

This Chapter provided a discussion of the key findings that emerged from this study. A reflection on the implications of the findings for the consolidation of curriculum reform efforts within the broader South African educational context has also been provided. Chapter 5 outlines summary of findings, conclusion and recommendations arising from the study.

CHAPTER 5: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This study investigated the extent to which computer simulations can be used as an innovative intervention to address misconceptions of Physical Sciences learners in South African township schools. This chapter provides summary of findings, conclusion and recommendations arising from the study.

5.2 Summary of findings

The use of virtual laboratory simulations as an innovative intervention to address misconceptions appears to be a promising pedagogic approach that can be adopted in various instructional settings. While the participants in this study were largely pleased with the efficacy of virtual laboratory simulations as an innovative intervention to address misconceptions, they cautioned that virtual simulation laboratories cannot supersede traditional laboratories in view of their critical role in the development of science process skills. Additional benefits provided by the use of virtual laboratory simulations include provision of meaningful opportunities for self-directed learning and visualization of complex scientific phenomena. The dismal performance of the participants in the *Acids-Bases Chemistry Achievement Test* reflected pervasive conceptual hurdles associated with acids and bases as a Physical Sciences key knowledge area.

5.3 Insights gleaned from the key findings that emerged from the study

The dismal performance demonstrated by the participants on acid and bases serves as a wake-up call for teachers to adopt innovative instructional strategies to adequately address misconceptions associated with various Physical Sciences key knowledge areas. Traditional instruction can no longer be a panacea for addressing conceptual inadequacies and pervasive knowledge gaps which stifle meaningful science teaching and learning. The realisation of curriculum outcomes requires innovative capacity on the part of teachers as key agents of educational change. Prevalence of learners' misconceptions may be viewed as one of the factors responsible for the complexity of the articulation gap between school and higher education in South Africa. The key findings in this study demonstrated that a substantial number of learners have shaky conceptual foundation and this does not auger well for meaningful development of scientific literacy.

At another pragmatic level, the dismal performance demonstrated by the participants in this study signifies the erosion of the quality of basic education in South Africa. Meaningful development of scientific literacy underpinned by the creation of a scientifically literate citizenry ought to be the hallmark of the provision of quality education in a global sense. This key strategic imperative hinges to a large degree on the coherent adoption of innovative instructional strategies that promote technology-enhanced learning. This imperative underscores the need for progressive realisation of the envisaged key curriculum outcomes through pedagogic innovation.

It is imperative to point out that the complexity of the articulation gap between school and higher education in South Africa is a fundamental dilemma which requires far-reaching curriculum reforms. This fundamental dilemma serves to stifle smooth transitional and epistemological access to higher education in particular. Key challenges in this regard are manifested in the form of student under-preparedness for tertiary studies to which various institutions of higher learning responded by implementing extended curriculum programs. Thus, the adoption of innovative instructional strategies would go a long way towards promoting plausible access to scientific literacy as a key curriculum goal.

5.4 Recommendations arising from the study

The dismal performance demonstrated by the participants on acids and bases calls for adoption of innovative instructional strategies that are responsive to the critical needs of learners in line with the key imperatives of meaningful curriculum reform. The promotion of technology-enhanced learning is crucially imperative. Pursuit of this noble goal will serve to ensure that South Africa as a member of the global community of nations provides a globally competitive curriculum that is responsive to the acceleration of socio-economic development. This mission can be accomplished through technology integration in science teaching and learning. Dispelling misconceptions by using the conceptual change model would be an extremely difficult and complex undertaking without coherent adoption of appropriate instructional strategies underpinning meaningful pedagogic innovation. This implies that schools ought to be the epicentre of pedagogic innovation with teachers playing a key catalytic role. The Department of Basic Education in South Africa faces the key imperative to provide essential resources required for the realisation of this noble goal.

The advent of the fourth industrial revolution provides opportunities for teachers as key agents of educational change to fully embrace digital transformation in its broadest sense with a view to foster pedagogic innovation. As a complex dichotomy, the advent of the fourth industrial revolution poses enormous challenges while providing practical pedagogical benefits for science teaching and learning within the broader South African educational context. While the need to integrate technology as a catalyst for pedagogic innovation in science teaching and learning is paramount, considerable attention ought to be devoted to meaningful teacher professional development on the effective utilization of appropriate information and communication technology tools.

5.5 The limitations of the study

The study involved a limited sample of learners from two South African township schools. Therefore, the findings of the study cannot be generalised to a larger sample. However, key findings emanating from the study may have profound implications for curriculum reform within the broader South African context and elsewhere in the global arena.

5.6 Strengths and weaknesses of the study

The limited scope of the study is mitigated by the richness of the data obtained and the profound nature of the key findings that emerged. While the research carried out in this study was confined to two South African township schools, the key findings would certainly serve as a call to action and inform the consolidation of curriculum reform efforts within the broader South African educational context. The study provides insightful elucidation into the efficacy of virtual laboratory simulations as an innovative intervention to enhance meaningful conceptual understanding by dispelling misconceptions. In the final analysis, the study serves to demystify opportunities associated with the advent of the fourth industrial revolution.

5.7 Recommendations for further study

Inadequate learner performance in Physical Sciences has been a key area of concern for education practitioners over the years. The use of virtual laboratory simulations as an innovative intervention to address misconceptions appears to be a promising pedagogic approach as evidenced by the findings in this research study. Further studies can explore the impact of gender differences on learner performance achieved as a result of the implementation of virtual laboratory simulations as an innovative intervention. Teachers' and learners' perceptions of the pedagogic value of technology-enhanced learning can be explored with a view to investigate the extent to which they are willing to embrace technology integration in science teaching and learning. Moreover, a structural equation modelling can be used to understand the factors affecting the use of virtual laboratory simulations in South African township schools.

5.8 Conclusion

The use of virtual laboratory simulations as an innovative intervention to address misconceptions appears to be a promising pedagogic approach as evidenced by the findings in this research study. There is a crucial need for teachers to adopt innovative instructional strategies that are responsive to the critical needs of learners. Sustained commitment to such key endeavours can potentially serve to demystify opportunities associated with the advent of the fourth industrial revolution as a game-changer.

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APPENDICES

APPENDIX A – ETHICS CLEARANCE

NHREC Registration Number REC-110613-036

UNIVERSITY OF JOHANNESBURG

ETHICS CLEARANCE

Dear Kgoboki James Mphafudi

Ethical Clearance Number: Sem 1 2019-070

The use of computer simulations as an intervention to remedy acid-base misconceptions of South African Grade 11 Physical Sciences learners in township schools

Ethical clearance for this study is granted subject to the following conditions:

- If there are major revisions to the research proposal based on recommendations from the Faculty Higher Degrees Committee, a new application for ethical clearance must be submitted.
- If the research question changes significantly so as to alter the nature of the study, it remains the duty of the student to submit a new application.
- It remains the student's responsibility to ensure that all ethical forms and documents related to the research are kept in a safe and secure facility and are available on demand.
- Please quote the reference number above in all future communications and documents.

The Faculty of Education Research Ethics Committee has decided to

☒ Grant ethical clearance for the proposed research.
☐ Provisionally grant ethical clearance for the proposed research
☐ Recommend revision and resubmission of the ethical clearance documents

Sincerely,

Dr David Robinson
Chair: FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE
31 October 2019

APPENDIX B – GDE RESEARCH APPROVAL LETTER

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	15 July 2019
Validity of Research Approval:	04 February 2019 – 30 September 2019 2019/145
Name of Researcher:	Mphafudi K.J
Address of Researcher:	Mogodi Ga-Mphahlele
	House Number 419
	0745
Telephone Number:	084 361 2230
Email address:	mphafudikj@gmail.com
Research Topic:	The use of computer simulations as an intervention to remedy acid-base misconceptions of South African Grade 11 Physical Sciences learners in township schools.
Type of qualification	Masters in Science Education
Number and type of schools:	Two Secondary Schools
District/s/HO	Tshwane South

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

15/07/2019

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Mr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: ...15/07/2019...............................

APPENDIX C - APPROVAL FORM TO CONDUCT RESEARCH FROM DISTRICT DIRECTOR AT SCHOOL A

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

Enquiries: Lucky Rapudi
Tel: (012) 401 6317
Fax: 0866 522 388
Email: Lucky.Rapudi@gauteng.gov.za

TO: **The Principal**
Gatang Secondary School

FROM: **Mrs. Hilda Kekana**
District Director: Tshwane South

DATE: **29th July 2019**

SUBJECT : PERMISSION TO CONDUCT RESEARCH AT AN EDUCATION INSTITUTION

Dear Sir/ Madam

Permission is hereby granted to **K.J. Mphafudi** to conduct an academic research at your institution.

The researcher shall make arrangements for research with the school management. The school staff, learners and SGB are requested to co-operate with and give support to the researcher. Research findings and recommendations are critical for policy review in public education sector.

The researcher may however not disrupt the normal school programme in the course of research. The research may only take place between the months of February and September. Attached are other conditions to be observed by the researcher.

The school may request for the research outcome presentation directly from the researcher or obtain research document from Research & Knowledge Management Directorate at GDE Head Office.

Regards

Mrs H.E. Kekana
District Director: Tshwane South
Date: 30 / 07 / 2019

Making education a societal priority

Office of the District Director: Tshwane South
(Mamelodi/Eersterust/Pretoria East/Pretoria South/Atteridgeville/Laudium)
President Towers building, 265 Pretorius Street, Pretoria, 0002
Private Bag X198, Pretoria, 0001 Tel: (012) 401 6317; Fax: (012) 401 6318
Website: www.education.gpg.gov.za

APPENDIX D - APPROVAL FORM TO CONDUCT RESEARCH FROM DISTRICT DIRECTOR AT SCHOOL B

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

Enquiries: Lucky Rapudi
Tel: (012) 401 6317
Fax: 0866 522 388
Email: Lucky.Rapudi@gauteng.gov.za

TO: **The Principal**
Lehlabile Secondary School

FROM: **Mrs. Hilda Kekana**
District Director: Tshwane South

DATE: **29th July 2019**

SUBJECT : PERMISSION TO CONDUCT RESEARCH AT AN EDUCATION INSTITUTION

Dear Sir/ Madam

Permission is hereby granted to **K.J. Mphafudi** to conduct an academic research at your institution.

The researcher shall make arrangements for research with the school management. The school staff, learners and SGB are requested to co-operate with and give support to the researcher. Research findings and recommendations are critical for policy review in public education sector.

The researcher may however not disrupt the normal school programme in the course of research. The research may only take place between the months of February and September. Attached are other conditions to be observed by the researcher.

The school may request for the research outcome presentation directly from the researcher or obtain research document from Research & Knowledge Management Directorate at GDE Head Office.

Regards

Mrs H.E. Kekana
District Director: Tshwane South
Date: 30/07/2019

Making education a societal priority

Office of the District Director: Tshwane South
(Mamelodi/Eersterust/Pretoria East/Pretoria South/Atteridgeville/Laudium)
President Towers building, 265 Pretorius Street, Pretoria, 0002
Private Bag X198, Pretoria, 0001 Tel: (012) 401 6317; Fax: (012) 401 6318
Website: www.education.gpg.gov.za

APPENDIX E - LETTER OF CONSENT TO SCHOOL A PRINCIPAL

P.O Box 79053
Rethabile
0122
18 July 2019

MR Thage JM

The Principal

Gatang Secondary School

Dear Sir

Request for permission to conduct research at your school

I am currently doing a second year in science education Masters at the University of Johannesburg. I hereby request for permission to conduct a research at your school. The topic of my research is *"The use of computer simulations as an intervention to remedy acid-base misconceptions of South African Grade 11 Physical Sciences learners in township schools".* I would like to administer a diagnostic questionnaire as a pre- and post-test to approximately 40 of grade 11 learners at your school in this third term of the academic year 2019. Meanwhile, I would like to conduct interviews with approximately 6 learners and these interviews will be based on the simulation lesson. After speaking and requesting you that I should give the grade 11 learners consent letters, which were needed by the Government Department of Education for giving me permission to conduct a research at your school, I requested a written permission from the grade 11 learners and their witnesses, such as their parents/guardians, to participate anonymously and voluntarily in this study. In a letter written, I officially requested permission and also elucidated the benefits of participating in the research.

I am attaching the following documents:

- A copy of the Approval Form from Head Office granting me a permission for this research.

- A copy of the University of Johannesburg's Ethical Clearance Certificate for me to do this research.

Looking forward to your positive response.

Yours faithfully

Mphafudi KJ

Physical Sciences and Natural Sciences teacher

Tshwane South D4

Cell: 0843612230

Email address: mphafudikj@gmail.com

Permission granted / not granted

Concerns regarding participation (if any):

____

____

____

____

____

__________________   __________________

Principal's signature   **Date**

APPENDIX F - LETTER OF CONSENT TO SCHOOL B PRINCIPAL

P.O Box 79053
Rethabile
0122
18 July 2019

Mr ____________

The Principal

____________Secondary School

Dear Sir

Request for permission to conduct research at your school

I am currently doing a second year in science education Masters at the University of Johannesburg. I hereby request for permission to conduct a research at your school. The topic of my research is *"The use of computer simulations as an intervention to remedy acid-base misconceptions of South African Grade 11 Physical Sciences learners in township schools".* I would like to administer a diagnostic questionnaire as a pre- and post-test to approximately 40 of grade 11 learners at your school in this third term of the academic year 2019. After speaking and requesting science departmental head, that was delegated to help me with my research at your school in the second term of this academic year 2019, she gave grade 11 learners consent letters, which were needed by the Government Department of Education for giving me permission to conduct a research at your school. Thus, I requested a written permission from the grade 11 learners and their witnesses, such as their parents/guardians, to participate anonymously and voluntarily in this study. In a letter written, I officially requested permission and also elucidated the benefits of participating in the research.

I am attaching the following documents:

 A copy of the Approval Form from Head Office granting me a permission for this research.

 A copy of the University of Johannesburg's Ethical Clearance Certificate for me to do this research.

Looking forward to your positive response.

Yours faithfully

Mphafudi KJ

Physical Sciences and Natural Sciences teacher

Tshwane South D4

Cell: 0843612230

Email address: mphafudikj@gmail.com

Permission granted / not granted

Concerns regarding participation (if any):

____

____

____

____

____

____________________ ____________________

Principal's signature **Date**

APPENDIX G - LETTER OF CONSENT TO GRADE 11 PHYSICAL SCIENCES LEARNERS AND THEIR PARENTS/GUARDIANS

UNIVERSITY OF JOHANNESBURG

Statement of Voluntary Consent

Date: 23/05/2019

Dear Participant

I am from the Department of Mathematics, Science, Technology and Computer Education at the University of Johannesburg. I would like to involve you as a participant in a research project on "Indicate" for the duration stipulated as follows: twice a week for six weeks, 45 minutes per day. The main purpose of the research project is to contribute to practice and theory of physical science teaching in South African secondary schools.

Activities in which you will be involved include participation in physical science lessons at the school and active engagement with the learners. In addition, participants will further be requested to be interviewed and to fill in questionnaires. The focus group will mainly comprise physical science learners in an active engagement in the classroom. There is no risk or harm involved in these activities.

Your participation in this project is completely voluntary. Only participants willing to participate will do so, and may stop taking part at any time. You are free to withdraw your participation at any time and for any reason without penalty. These decisions will have no effect on your future relationship with the school as a learner/teacher/principal/Departmental official.

The information obtained during this research project will be kept strictly confidential and will not become part of the school record. Any sharing or publication of the research results will not identify any of the participants by name.

Data collected will be stored in a safe place within the Faculty of Education at the University of Johannesburg and disposed of once the research has been completed.

Please indicate whether you do or do not want to participate in this research project.

I look forward to working with you. I trust that my research will be enjoyable for the participants and will help them to learn more about physical science as a key subject.

Please keep the attached copy of this letter for your records.

Sincerely, Researcher's Signature

Mphafudi KJ ………………

Contact Information: Tel: E-mail:

____ I do/do not (circle one) give consent ……………………………………….. (name of participant) to participate in the research project described above.

____

Signature…………………. Date …………………………

Signature (Witness)…………………. Date …………………………….

APPENDIX H - *ACIDS-BASES CHEMISTRY ACHIEVEMENT TEST (ABCAT)*

(* represents the correct answer)

SECTION A

Instruction: Each item in this section consists of four alternative responses A, B, C and D. For each item, choose one answer only and **circle** your answer in this test booklet.

1. An acid displays its properties when it…..

A. ionises in water to produce H^+ ions. *

B. ionises in propane to produce H^+ ions.

C. ionises in water to produce OH^- ions.

D. ionises in propane to produce OH^- ions.

2. Which of the following equations correctly describes the relationship between concentration (g dm^{-3}) and molarity (mol dm^{-3})?

A. Molarity (mol dm^{-3}) = $\frac{Concentration\ (g\ dm{-}3)\ *}{Molar\ mass\ (g\ mol{-}1)}$

B. Molarity (mol dm^{-3}) = $\frac{Molar\ mass\ (g/\ mol)}{Concentration\ (g\ /dm{-}3)}$

C. Concentration (g dm^{-3}) = $\frac{Molarity\ (mol\ dm{-}3)}{Molar\ mass\ (g\ mol{-}1)}$

D. Concentration (g dm^{-3}) = $\frac{Molar\ mass\ (g\ mol{-}1)}{Molarity\ (mol\ dm{-}3)}$

3. Which of the following solutions has the lowest pH value?

A. 20 cm^3 of 2.0 mol dm^{-3} sulfuric acid

B. 20 cm^3 of 3.0 mol dm^{-3} sulfuric acid*

C. 50 cm^3 of 2.0 mol dm^{-3} sulfuric acid

D. 100 cm^3 of 2.0 mol dm^{-3} sulfuric acid

4. Distilled water is added to 50 cm^3 of 2 mol dm^{-3} potassium hydroxide solution to produce 250 cm^3 of potassium hydroxide solution. What is the concentration of the potassium hydroxide solution produced?

A. 0.3 mol dm^{-3}

B. 0.4 mol dm^{-3}*

C. 0.5 mol dm^{-3}

D. 0.6 mol dm^{-3}

5. Which of the following is not a step in the procedure to prepare a solution with a specified concentration using the dilution method?

A. Distilled water is added to the volumetric flask until the graduation mark.

B. A few drops of universal indicator solution are added into the volumetric flask.*

C. The volume of stock solution required is calculated.

D. The required volume of stock solution is transferred into the volumetric flask using a pipette.

6. Which of the following apparatus might **not** be needed for a titration experiment?

A. Pipette

B. White tile

C. Retort stand

D. Test tube*

7. Which of the following equations most accurately describes the neutralisation reaction between the acid, HA, and magnesium hydroxide?

A. $Mg(OH)_2 + HA \rightarrow MgA_2 + H_2O$

B. $Mg(OH)_2 + 2HA \rightarrow MgA_2 + 2H_2O$*

C. $MgA_2 + H_2O \rightarrow Mg(OH)_2 + HA$

D. $MgA_2 + 2H_2O \rightarrow Mg(OH)_2 + 2HA$

8. A group of chemistry students carried out an experiment in the school laboratory to determine the concentration of a hydrochloric acid solution by titration. In order to do that, they added a few drops of phenolphthalein indicator solution into 25 cm^3 of 1.5 mol dm^{-3} sodium hydroxide solution. The alkali solution was then titrated with the acid solution. The average volume of the hydrochloric acid solution used for this experiment was found to be 28.15 cm^3. What is the concentration of the hydrochloric acid solution used in this experiment?

A. 2.35 mol dm^{-3}

B. 2.30 mol dm^{-3}

C. 1.82 mol dm^{-3}

D. 1.33 mol dm^{-3}*

9. When a standard solution of specific concentration is diluted, the concentration of the solution will _____, while the number of moles of solute present will be _____.

A. increase; decrease

B. increase; constant

C. decrease; constant*

D. decrease; decrease

10. Aqueous potassium hydroxide reacts with _____ to produce a salt and water.

A. Glacial acetic acid.

B. Aqueous sodium chloride.

C. Dilute nitric acid.*

D. Aqueous magnesium hydroxide.

Total Mark for Section A: 10

SECTION B

Instruction: Each item of this section has two parts, a multiple-choice content response followed by a multiple-choice reason response. For each item, choose your most appropriate response from the first part and **circle** your answer A or B or C, etc. Then choose one of the reasons from the second part that best matches your answer to the first part and **circle** your answer 1 or 2 or 3, etc. If you do **not** agree with any of the given reasons, please write your reason in the space provided.

1. Chemical X shows the following properties:

√ Tastes bitter and feels soapy.

√ Turns red litmus paper blue.

√ Reacts with an acid to produce a salt and water.

√ Produces ammonia gas when heated with an ammonium salt.

√ Reacts with an aqueous salt solution to produce a metal hydroxide.

Which of the following is most probably chemical X?

A. Dry ammonia gas.

B. Sodium hydroxide dissolved in propane.

C. Glacial acetic acid.

D. Aqueous calcium hydroxide.*

The reason for my answer is:

1. Chemical X ionises in water to produce H^+ ions.

2. Chemical X ionises in water to produce OH^- ions.*

3. Chemical X ionises to produce OH- ions in the absence of water.

4. Chemical X is soluble in water.

5. Other reason:

____

____

2. The table shows the pH values of four aqueous solutions, P, Q, R, and S.

Solution	P	Q	R	S
pH value	13	7	3	9

Which of the following solutions will react with calcium carbonate to produce carbon dioxide gas?

A. P

B. Q

C. R*

D. S

The reason for my answer is:

1. The solution contains a higher concentration of OH^- ions than H^+ ions.

2. The solution contains a higher concentration of H^+ ions than OH^- ions.*

3. The solution contains equal concentrations of H^+ and OH^- ions.

4. Other reason:

____

____

3. What is the main apparatus that is used in the preparation of a standard solution?

A. Volumetric flask*

B. Beaker

C. Measuring cylinder

The reason for my answer is:

1. It is easier to dissolve the solute by shaking.

2. It prevents the solution from splashing out.

3. It can measure a fixed volume of solution more accurately.*

4. Other reason:

____

____

4. Both sulfuric acid and ethanoic acid are strong acids.

A. True

B. False*

The reason for my answer is:

1. Sulfuric acid ionises completely in water to produce H^+ ions, while ethanoic acid ionises partially in water to produce H^+ ions.*

2. Ethanoic acid ionises completely in water to produce H^+ ions, while sulfuric acid ionises partially in water to produce H^+.

3. Both acids ionise completely in water to produce H^+ ions.

4. Both acids ionise partially in water to produce H^+ ions.

5. Two common substances that have the formulas HCl and CH_4 both contain the element hydrogen. However, only HCl has acidic properties while CH_4 does **not**.

A. True*

B. False

The reason for my answer is:

1. CH_4 completely ionises to produce more H^+ ions in water than HCl.

2. Any substance that contains H atoms in its molecular formula is acidic.

3. Only HCl ionises to produce H^+ ions in water.*

4. Other reason:

____

____

6. What is a property of citrus fruits like oranges and lemons?

A. Acidic*

B. Basic

C. Neutral

The reason for my answer is:

1. Citrus fruits have pH value less than 7*

2. Citrus fruits have pH values greater than 7

3. Citrus fruits have pH values equal to 7

4. Other reason:

____

____

7. Soaps and detergents as well as household cleaners for floors, ovens and glass windows contain alkaline chemicals like sodium hydroxide and ammonia, but **not** acids.

A. True*

B. False

The reason for my answer is:

1. Alkalis are soapy and so are able to wash away stains.

2. Acids are more corrosive than alkalis and so are more effective in removing stains.

3. Alkalis dissolve grease and oils present in dirt more readily than acids.*

4. Acids are able to neutralise alkalis present in dirt.

5. Other reason:

____

____

8. If soil is too acidic, it is not likely to support the healthy growth of grass. What chemical would you add to the soil to promote the growth of grass?

A. Common salt

B. Vinegar

C. Lime (calcium oxide)*

D. Caustic soda

The reason for my answer is:

1. The basic substance neutralises the acidic soils*

2. The basic substance changes the soil acidity to a pH value greater than 7

3. The acidic substance changes the pH of soil closer to the ideal pH

4. Other reason:

____

____

9. Aqueous solutions of potassium hydroxide as well as ammonia are both weak alkalis.

A. True

B. False*

The reason for my answer is:

1. Aqueous potassium hydroxide is completely ionised in water, while aqueous ammonia is only partially ionised.*

2. Potassium hydroxide and ammonia are only partially ionised in water.

3. Aqueous ammonia, NH_3, is not an alkali because it does not contain OH^- ions in its formula.

4. Potassium hydroxide and ammonia ionise completely in water.

5. Other reason:

____

____

(Correct answers are indicated with an asterisk *)

Total mark For Section B: 9+9=18

Grand Total Mark for section A and Section B: 10+18 = 28

APPENDIX I - INTERVIEW SCHEDULE

1. How did you find the PhET simulation laboratories and the activities? Provide a brief explanation.

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2. After the intervention classes, did you need help with the activities associated with the PhET simulation laboratories? Explain your reasoning.

………………………………………………………………………………………………

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3. What were some of the gains you observed with using PhET simulations?

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4. What were some of the disadvantages of using the PhET simulation laboratories?

……………………………………………………………………………………………….....

………………………………………………………………………………………………..

5. Did the PhET simulations improve your conceptual understanding of the concepts associated with acids and bases? Explain your reasoning.

………………………………………………………………………………………………..

………………………………………………………………………………………………..