Acids-Bases Threshold Concepts: A Case of First-Year Students' High Failure and Dropout Rate

by

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DECLARATION

I declare that this thesis is my own unaided work. It is being submitted for the degree of Doctor of Philosophy in the University of the Witwatersrand, School of Chemistry, Johannesburg, South Africa. It has not been submitted before for any degree or examination in any other university.

Royda C. Kampamba

Date: 31/03/21

DEDICATION

I dedicate this thesis to the fire and chariots of my family that believed in me and gave me the reason to persevere.

To my mother who made me a teacher and gave me a life which she never had.

To God Almighty for giving me the strength throughout this study.

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ABSTRACT

Many higher institutions of learning are concerned about freshmen failure and dropout in science programmes. University dropout affects the society, university and the individual student. It is a loss of skilled manpower; brain drain and a waste of government resources. Statics have revealed that chemistry has a higher failure and drop-out rate than other sciences in institutions of learning. In the context of students' challenges in learning chemistry, this study investigated threshold concepts of acids-bases reactions because it is a topic that students in the researcher's institution claimed was a challenge. Acids-bases chemistry is also one of the Threshold Concepts (TCs) of chemistry and is connected to many chemical reactions in chemistry and other science topics. This study investigated the first-year students' experiences in learning TCs of acids-bases, first-year educators' experiences in teaching TCs of acids-bases, causes of high failure and drop-out rates and how they can be ameliorated in the researcher's institution. Informed and guided by the pragmatism paradigm, this study employed qualitative methodological approaches to study chemistry freshmen failure and drop-out rates. The participants were purposely sampled and included five first-year chemistry educators and five classes of first-year students (47) of the sampled educators. Qualitative data were derived from educators' questionnaires, interviews, lesson observations and post-lesson conversations. Interview questions were not the same as they emanated from an individual educator's response to a questionnaire and from lesson observations. In addition, data were collected from students' focus group discussions. Thematic analysis was used to analyse qualitative data. The main findings of the study revealed that students' learning and studying strategies and their prior knowledge of acids-bases conflicted with the university's teaching strategies hence creating challenges. On the other hand, challenges led some students to construct their own meaning and to generate collaborative learning, for example, learning from more knowledgeable others (Zone of Proximal Development (ZPD)), studying late into the night with colleagues and watching online chemistry tutorials. The findings also revealed that the educators' challenges emanated from students' weak prior knowledge, hands-on and mind-on learning and too many students in a class. Students' preconceived ideas that chemistry is difficult and their inconsistency in attending lessons also contributed to educators' challenges. The challenges were alleviated by a handbook comprising out-lines and tasks on the first-year chemistry course.

Furthermore, it was reported that the university's assessment and progression policy was too demanding on students. Every academic year, students are examined in six courses. Students regard the 50% pass mark in all courses to proceed to the second year as too high. Recommendations are made for educators to employ student-centred pedagogical practices and formulate TCs of acids-bases module as a foundation course.

Key Words: Acids-Bases, threshold concepts, failure, dropout, freshman, teaching-learning experience.

PUBLICATIONS AND CONFERENCE PRESENTATIONS EMANATING FROM THIS THESIS PUBLICATION: CONFERENCE PAPERS

Publications

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- Kampamba, R. (2019). The nature of threshold concepts of Arrhenius, Bronsted-Lowry and Lewis acids-bases reactions in freshmen's chemistry. A paper presented at 27th Conference of SAARMSTE, 15–17 January, University of Natal, South Africa.

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ABREVIATIONS

AT/CHAT	Activity Theory/Culturally Historical Activity Theory
CoP	Community of Practice
GCE	General Certificate of Education
ICE	Initial, Change, Equilibrium
LPP	Legitimate Peripheral Participant
MKO	More Knowledgeable Other
TCs	Threshold Concepts
ZPD	Zone of Proximal Development

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Introduction

This chapter introduces and explores the study of threshold concepts of Acids-Bases: A case of freshmen's challenges in teaching-learning chemistry within a Zambian context. The study investigated the chemistry educators' perspectives of teaching Threshold Concepts (TCs) of acids-bases, first-year students' perspectives of learning TCs of acids-bases, and how the challenges could be ameliorated. Presented in this chapter are background and purpose, rationale and research questions of the study. It includes an overview of the study, the methodology, review of related literature, analysis and findings. The chapter closes with positionality of the researcher, study limitations and layout of the thesis.

This study explores the first-year General Chemistry students in Zambia and what is needed to ameliorate this seemingly national problem because of its social and economic impacts. The centrality of high drop-out rates in general chemistry among first-year students seems to be focused on the teaching-learning of the concept of acids-bases. Chemistry scholars have identified acids-bases reactions as one of the threshold concepts (TCs) in chemistry (Timofte, 2015; Furió-Más et. al., 2012). It also affects the learning of other chemical reactions within the discipline and biology and physics concepts (Cooper et. al., 2016). Hence, one of the basic chemistry concepts are the acids-bases reactions. Furthermore, one of the cornerstones of science, technology, and industry which contributes to our existence, our culture, and our quality of life is chemistry (Sadhul et al., 2017). Other studies have revealed that students experienced challenges in understanding and applying acids-bases theories from secondary school through graduate school (Bretz & McClary, 2015). Researchers have documented student misconceptions concerning acids and bases (Pinarbasi, 2007 citing Zoller, 1999; Cross et al., 1986). First-year university students may have a good knowledge of formal descriptions of acids-bases but may have inadequate conceptions of concrete phenomena such as heat being released during an acids-bases reaction. In addition, Bretz and McClary (2015) observed that some students had modified their concepts to replace their former descriptive definition of acids and bases with a more scientific definition. Hence, the acids-bases theory is an abstract chemistry basic concept which involves understanding through to a microscopic level (Sadhul et al., 2017).

Due to the use of multiple models of Arrhenius, Bronsted-Lowry and Lewis's conceptualisations of acids-bases, students learning acids-bases chemistry often find it challenging (Bretz & McClary, 2015). Arrhenius presents a substance in a solution which yields hydrogen ions as an acid while a base produces a hydroxide ion. Arrhenius's definition is the concrete model that focuses on matter. According to Arrhenius's definition, a strong acid dissociates readily into hydrogen ions and anions, while a weak acid dissociates much less (Kelly & Akaygun, 2016). This definition can be problematic for students when they are asked to apply it to classify acidic solutions as strongly acidic or weakly acidic. Many students struggle to understand the acids ionic nature. Bronsted-Lowry and Lewis theories definitions describe acids with bases in reactions context (Kelly & Akaygun, 2016). Bronsted-Lowry redefined acids and bases as donors and acceptors of protons whereas a Lewis acid is an electron pair acceptor and a base is an electron-pair donor (Kelly & Akaygun, 2016). Bronsted-Lowry theory explains the acids-bases strengths from the viewpoint of proton migration. Lewis's description of acids-bases as donation and acceptance of an electron pair describes many chemical phenomena. Furthermore, Lewis's generalisation, "which combines acidity, basicity, electrophilicity, and nucleophilicity within a broad integrated scheme opens a new set of difficulties" (Pinarbasi, 2007, p. 24 citing Zoller, 1999; Cross et al., 1986). Lewis's acids-bases model provides an introduction into reasoning about chemical reactions from a mechanistic view by helping students to understand how reactions occur. Students are less likely to make the connection between acids-bases reactions and other chemical reactions if they do not consider how the transfer happens. Moving flexibly among the three models requires an understanding of the theories limitations and applying the right theory that can predict and explain acids-bases reactions. Hence, students must master the acids-bases scientific models as ways of thinking that are not direct representations of reality but rather are ways to abstract the important components of a system. This means that the students must move from "what is an acid or base concept" to acids-bases reactions which involves transfer of protons. There are "many chemical concepts involved in acids-bases chemistry such as energetics, concentrations, electronegativity, resonance and mechanisms" (Stoynovich, Ghandi & Flyn, 2015, p. A). Although, acids-bases chemistry being central and prevalent in many chemical reactions, many students, struggle in many ways, including making errors and holding misconceptions (Stoyanovich, Ghandi & Flyn, 2015). Acids-bases chemistry continues to present difficulties for university students studying related courses such as biochemistry and organic chemistry. Students need to master acids-bases key concepts because of the prevalence of Arrhenius, Bronsted-Lowry and Lewis's acids-bases in reactions. If students do not have a firm grasp on threshold concepts, they fail to learn complex chemical reactions (Stoyanovich et al., 2015) because acids-bases reactions are a major component of chemistry. If students internalise acids-bases chemistry pretexts, they will be able to predict and explain the outcomes of many related and unrelated reactions.

Background to the Study

The drop-out rate among first-year chemistry students in higher institutions of learning in Zambia, particularly at the researcher's institution, is alarming. Dropout rates are much more in chemistry than in any other subject, such as biology, mathematics and social sciences. In 2016, three students graduated in physics, 21 students in mathematics, 44 in biology; and nine students graduated in chemistry. In 2017, 10 students graduated in physics, 18 students in mathematics, 43 students in biology and three students in chemistry. The low figures in chemistry in 2016 and 2017 were caused by most students changing their majors to pure biology or chemistry education (School of Mathematics and Natural Sciences, 2018). However, numbers of students who graduated in chemistry education in 2016 and 2017 (23 and 15 respectively) were lower than in mathematics, biology and physics. According to a chemistry lecturer in South Africa, less than 50% of first-year students pass chemistry on their first attempt (Marais, 2011). In evaluating low pass rates, the university senate identified chemistry as one cause of the problem. Studies conducted in Germany also revealed that, in 2010, 45% of chemistry students left university without getting a degree while 55% changed studies, and less than 50% of those who changed studies graduated (Intorp & Waitz, 2013). It was also reported in Spain that, during the 2009–2010 academic year, the drop-out and exchange rates of students were higher in the sciences. In the United States of America, a comparative study that was done at Stanford and Berkeley Universities revealed that chemistry was the main factor that discouraged students from continuing premedical studies (Barr, Matsui, Wanat, & Gonzalez, 2010). At Berkeley, 20 of 29 premedical students and 12 of 22 non-medical chemistry students interviewed ranked chemistry as " the most discouraging course" next to biology and mathematics (Barr et al., 2010). Hence, first-year chemistry students' dropout is a global issue. The table below depicts the number of students who registered and completed chemistry at my institution.

Table 1. *Summary Statistics of Registered Students (2016/2017)*

NO.	PROGRAM	YEAR	1ST YEAR	2ND YEAR	3RD YEAR	4TH YEAR
1	BSc. NQ	2016	556			
		2017	1224			
2	BSc. Biology	2016	27	55	42	44
		2017	1	107	48	43
3	BSc. Biology ED	2016		42	24	21
		2017		29	37	25
4	BSc. Chemistry	2015		4	8	5
		2016	55	25	4	9
		2017		90	23	3
5	BSc. Chemistry ED	2016		17	11	23
		2017		34	15	15
6	BSc. Mathematics	2016	22	35	15	21
		2017		61	27	18
7	BSc. Mathematics ED	2016	197	62	74	94
		2017	254	63	54	78
8	BSc. Physics	2016	9	19	10	3
		2017		25	18	10
9	BSc. Physics ED	2016		14	17	21
		2017		12	14	18

Source: School of Mathematics and Natural Sciences (2018)

The Purpose of Study

This study seeks to explore the teaching and learning of acids-bases as threshold concepts by chemistry educators. The study investigates how and where lecturers of first-year students were experiencing difficulties in teaching threshold concepts in the curriculum. There are three major threshold concepts in acids-bases, the Arrhenius, Bronsted-Lowry and Lewis concepts. According to Arrhenius definition, an acid is a substance that ionises in water to produce hydrogen ions as the only positively charged ions while a base as a substance that produces hydroxide ions as the only negatively charged ions. Oxide ions are also produced by metallic oxides which are partially soluble in water. Arrhenius's threshold concepts interpret the concept of dissociation of solutions, such as in a buffer solution, where two or more weak acids are dissociating and producing hydrogen ions, and two or more weak bases are also dissociating and producing hydroxide ions in their solutions, respectively. The balancing of chemical equations, writing of ionic equations and acids-bases equilibrium in Arrhenius are TCs. Acids are substances which donate hydrogen ions or are proton donors, and substances that accept hydrogen ions or proton acceptors are bases. It is the donating and receiving of the hydrogen ion and acids-bases equilibrium which are the TCs where two or more substances are reacting. Lewis's acid receives an electron lone pair and a base donates a lone pair electron. The key or threshold concepts are the transfer of electrons, ionic bonding and atomic structure. Students need to master acids-bases chemistry from this dimension after which students' progress to mastering weak acids and bases, constants of acids and bases, finding of pH and pOH values, conjugating acids and bases, neutralisation, buffer solutions, and acids-bases chemical equilibrium which are connecting ideas in the three definitions.

Teaching threshold concepts is fundamental to students' learning of chemistry, which also transforms the learning of chemistry, without which chemistry educators will not be able to teach students effectively. Threshold concepts (TCs) of acids-bases chemistry are related to other topics in chemistry, as in other science disciplines, which the lecturer and students must learn and master. The understanding of TCs and their connections influences the approach to teaching acids-bases. By focusing on students' learning of TCs, educators (lecturers) can maximise teaching and learning and student's achievement in the classroom (Meyer & Land, 2003). Educators are aware that acids-bases are taught at secondary school level and that students bring these concepts into higher education. Chemistry educators should teach and learn acids-bases as threshold concepts so that they are able to impart this knowledge to students.

Rationale and Motivation

My motivation for conducting this study was to explore first-year students' high failure rate in general chemistry and to try to remediate the problem. Acids-bases chemistry was selected because it is an important concept for many chemical reactions; and it is one of the threshold concepts in chemistry teaching and learning. It is also a topic where most students experience challenges. My hopes are to remediate first-year chemistry high dropout rates by exploring the learning environment. The learning environment was chosen because it shows how educators interact with students and with the acids-bases curriculum, students' interactions with educators and with the acids-bases curriculum, and students' interactions among themselves.

The Research Questions

Three research questions guided this study that investigated challenges first-year students and first-year chemistry educators experience in teaching-learning of threshold concepts of acids-bases reactions. The questions also explored the causes of the high failure and drop-out rates of first-year chemistry students. This information was then used to find out how the challenges and causes of high failure and drop-out rates could be ameliorated.

Research question 1. What challenges do first-year chemistry students experience in learning the threshold concepts of acids-bases reactions?

Research question 2. What challenges do educators experience in teaching threshold concepts of acids-bases reactions to first-year students and how can these challenges be ameliorated?

Research question 3. What are the causes of high failure and drop-out rates in first-year chemistry and how can can they be ameliorated?

Research Objectives

Considering the research questions, this study sought to achieve the following objectives:

1. To investigate challenges experienced by first-year students in learning threshold concepts of acids-bases reactions;
2. To explore challenges educators experiences in teaching threshold concepts of acids-bases chemistry to first-year students and how these challenges could be ameliorated;
3. To investigate the causes of high failure and drop-out rates and how they could be ameliorated.

The Study Context

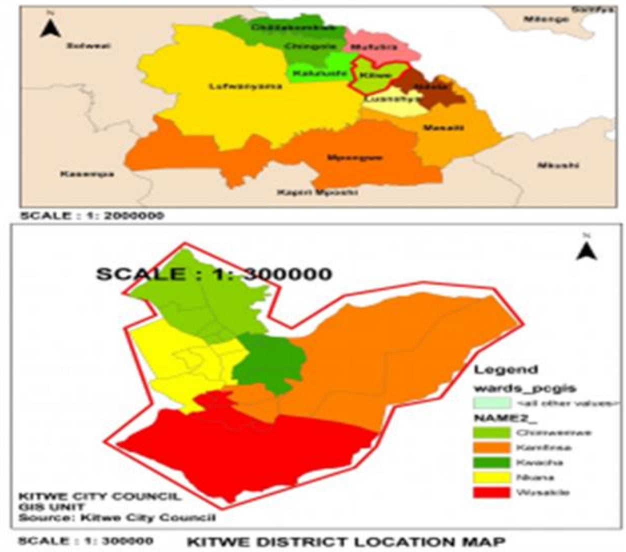
This section contains a brief history of the institution where the research was conducted. Zambia, a former British colony had one of the most poorly developed education systems at independence in 1964. However, the government has invested heavily in education. In 1966, the University of Zambia was opened in Lusaka (Chauhan, et al., 2013). The Copper-belt University existed as a satellite campus of the University of Zambia. The campus had only two schools, the Schools of Business and Industrial Studies (SBIS) and, Environmental Studies (SES) (Chauhan et al., 2013). The campus, was referred to as the University of Zambia at Ndola (UNZANDO), was at Kitwe and was housed by the Zambia Institute of Technology (ZIT) which opened in 1970. In 1987, the Copper-belt University was established by integrating ZIT and UNZANDO. The university has grown from only two schools to ten (Chauhan et al., 2013). This study was conducted in the School of Mathematics and Natural Sciences.

Location of Kitwe. The city of Kitwe is in the Copper-belt Province. It is the second-largest city in Zambia. It was founded in 1936. Kitwe is the main industrial and commercial centre of the Copper-belt region. Mining is the main driver of the Zambian economy (Chauhan et al., 2013). Agricultural activities also sustain the country's economy.

Culture and language. Mines are the driving force of the development and expansion of Copper-belt Province. There are 73 ethnic groups present in this region. Bemba language is spoken and taught in schools in this region. This is because the Bemba tribe is the largest homologous ethnic group in the country and so, the Bemba language dominates the Copper-belt Province. The society in Kitwe is homogenised. However, the language of communication in institutions of learning for this locality is English.

Figure 1.

Map of Kitwe, Zambia (2010). Source: Kitwe City Council



Overview of the Study

The centrality and prevalence of acids-bases reactions in chemistry makes it indispensable in many courses and careers. Nonetheless, acids-bases concept is problematic for students to grasp fully (Tibell & Harms, 2017). Scholars, such as Massi and Villani (2015), Cooper, Grove, Underwood and Klymkowsky (2010), Stoyanovich et al. (2015), and Marais (2011), have investigated the issue of first-year students' high failure and drop-out rates in chemistry and ways to reduce them.

Massi and Villani's (2015) study added insights to examining first-year students' challenges in learning chemistry. The authors conducted in-depth interviews about students' strong sense of belonging and membership. They investigated whether the students' habitus and those of the institution influenced the students' integration model in order to explain the low drop-out rates. The results showed that, although some students were partially integrated, some were not integrated and were not taken care of by the university, for a combination of social and academic integration was fundamental for the low drop-out.

Stoyanovich et al. (2015) claimed that an outcomes-based approach to teaching and learning focuses on what the student knows and can do after instruction. Mastering organic acids-bases knowledge is essential for success. According to Stoyanovich et al. (2015, p. A), “Energetics, concentrations, electronegativity, resonance and mechanism” are some of the many chemical concepts involved in acids-bases reactions. Intended Learning Outcome (ILO) approach was expected to improve student learning and encourage student mastery of acids-bases concepts.

At Tshwane University of Technology (TUT), South Africa, Marais (2011) revealed that less than 50% of first-year students pass chemistry on their first attempt. Chemistry was identified by the university senate as a cause for the low pass rates. To alleviate this, Marais (2011) introduced a foundation programme in which the proposed model used Lego blocks as tactile tools. The Lego blocks and worksheets were applied to help improve students’ understanding of molecular behaviour as many first-year students at TUT thought that water turns into hydrogen gas and oxygen gas in the vapour stage. Marais (2011) and other educators used the model as a starting point to solve challenges experienced by first-year students with phase changes in water and reactions of atoms and molecules. Educators hoped that, by starting with concrete tools, the abstract concepts would readily be understood. The results showed that first-year students demonstrated an understanding that no chemical bonds are broken during physical change. It was assumed that the tools enhanced students’ understanding of the inter-molecular bonds between atoms of hydrogen and oxygen in water molecules.

Threshold Concepts

"The idea of threshold concepts could be a theory of difficulty that appreciates the contingent, contextual, historical and contested nature of any concept in any discipline" (Cousin, 2006, p. 2). The value of the theory of threshold concepts is its ability to prompt thinking about questions of mastery through the lens of the subject. Its insistence that learning is about cognition is important. According to Piaget (1951), learning is about identity disturbance and formation. The idea of acids and bases, as threshold concepts, is important to the teaching and learning of acids and bases in general chemistry classes. The centrality and prevalence of acids-bases reactions in chemistry make the concept indispensable in many courses and careers. In addition, acids-bases reactions provide challenges for students to grasp it fully. There seem to be key concepts that impede the conceptual understanding of fundamental threshold concepts for teaching and learning of acids-bases (Tibell & Harms, 2017).

Threshold concepts are a discipline-specific focus on understandings of the subject and can be used to transform learners' (students') views of the content to be learned. They open new and previously inaccessible ways of thinking about entities and processes. Also, they are schema because they embrace a web of interrelated but hidden assumptions (Talanquer, 2015; Cousin, 2006). The "contingent, contextual, historical, and contested nature of any concept in any discipline" is appreciated by the knowledge of threshold concepts which is a knowledge of difficulty (Cousin, 2006, p. 2). The value of the knowledge of threshold concepts is in its ability to prompt thinking about the questions of mastery through the lens of the subject and in its insistence that learning is about cognition. According to Piaget (1951), learning is as much about identity disturbance and formation. A threshold concept represents a transformed way of understanding, interpreting or viewing something without which the student may not be able to make needed progress (Talanquer, 2015; Cousin, 2006). According to Cousin (2006), threshold concepts are key ideas that are central to a discipline but may be difficult for most students to grasp. Students who have not yet internalised a threshold concept may be learning new ideas in a fragmented way and are apt to harbour misconceptions. The student who has acquired a threshold concept can transform her/his use of the ideas because s/he can integrate ideas into her or his thinking. Students must get threshold concepts for the core disciplinary knowledge to make sense. An internally transformed view of the subject matter, subject setting or even world view is brought about by mastering a threshold concept. The transformation from mastering threshold concepts may be swift or it may be prolonged over a period of time. A threshold concept is defined as "concepts that bind a subject (matter) together, being fundamental to ways of thinking and practising in that (particular) discipline" (Land et. al., 2005, p. 2). It is a cornerstone that holds the subject together, theoretically and practically. The threshold metaphor invokes doorway, a transitional point or intersection rather than a space. Hence, "thresholds may be seen in this way as leading the learner on through a transformational landscape in a kind of epistemological steeple chase, towards a pre-ordained end" (Meyer & Land, 2005, p. 8). Learning a TC may mean internalising a concept. The acquisition of a TC is intrinsic to grasping other aspects of the discipline – ways in which experts think and practice. This results in the transformation of students' use of ideas in the subject by integrating them into their thinking. It also leads to identity transfiguration and the extended discourse. Students who have not yet internalised the TC have to learn new ideas in fragments. It is the integration of TCs into other aspects of the discipline that may cause problems for students.

Failure to master the threshold concepts in a discipline results in the students being unable to make sense of the concepts, hence students exist in unstable cognitive conditions. Students existing in unstable cognitive situations may try to learn by memorising which could lead to misconceptions. Students who fail to make sense of the Bronsted-Lowry acid and base concept, for example, may have knowledge of “accepting” and “donating” of the proton but would also have to learn that a substance can receive a proton if there is a donor. An acid can only donate a proton if there is a receiver. Such a student would also need to learn how the proton exchange takes place at a molecular level. She/he may fail to grasp this acid and base reaction because she/he either have no prior knowledge or fail to integrate the new information into her/his existing framework or cognitive schema. These conceptual misalignments may also arise from a failure by the educator to teach using an appropriate pedagogical knowledge needed for the concept that takes the cognitive ability and knowledge level of the student into consideration. Moss, Greenall, Rockcliffe, Crowley and Mealing (2014) refer to this situation as “a null learning impediment” which occurs when the student fails to make sense of new ideas due to poor prior knowledge which could result in learning not taking place as intended. Students may also find themselves in a “*substantive learning impediment*” (emphasis as in the original) where misconceptions are both more difficult to detect and more persistent. Nonetheless, other studies for example Bretz and McClary (2015) reported that “*high school students, advanced chemistry students, undergraduate organic chemistry and graduate organic chemistry students invoke mental framework to predict, explain and justify trends in acid strength*” (my emphasis). This shows that not all students experience the same learning difficulties for the same concept.

The process of mastering the threshold concepts in a discipline, such as chemistry, could be difficult. Mastering requires the student to analyse both the old and new concepts to find their meaning. Then, the student must integrate the processed ideas into an existing schema, forsake the earlier thinking and meanings, leave his/her comfort zone and encounter a less familiar zone. This represents a moment of deep learning that enables further deep learning (Cousin, 2006). The process of acquiring threshold concepts could also be stressful, confusing and tiresome as a student uses his or her experiences and basic knowledge to grasp the key concepts (Cousin, 2006). “Learning involves the occupation of a liminal space during the process of mastery of a threshold concept” (Land & Meyer, 2006, p. 22). Students who enter a liminal space are “engaged with the project of mastery, unlike” those “who remain in a pre-liminal space in which understanding is, at best, vague” (Land & Meyer, 2006, p. 22). In such a liminal space, the student is engaged with the process of internalising a threshold concept. According to Timofte (2015, p. 85), liminal space is the “transition period between the moment in which students did not grasp a threshold concept and the moment of grasping the threshold concept”. The liminal space is unstable and the learner is likely to be moving between the old and emergent understandings. This space is like the one occupied by adolescents who ossiculate between adult and child. Land et al. (2005, p. 55) define a liminal space as a space where

> “students remain stuck in an ‘in-between’ state in which they oscillate between earlier, less sophisticated understandings, and the fuller appreciation of a concept that their tutors require from them. This in-between state we have termed a state of ‘liminality’, from the Latin meaning ‘within the threshold”.

Liminality, according to Turner (1977), is a Latin word meaning “boundary or threshold” that characterises traditional rites of passage which are conducted within a given space of time. For instance, the wedding ceremony is a threshold and the honeymoon a liminal (Trubshaw, 2021). Liminality emphasises transition from one psychosocial state to another. Firstly, the states of liminality are transformative. An individual or group are being transformed from one state into another. Secondly, new knowledge, new status and identity is acquired by the participating individuals. However, the transition is often not easy, it involves the humbling of the participant because “in order to do so, he/she must strip away, or initiators have stripped from them, the old identity. The period in which the individual is naked of self is neither fully in one category nor another, is the liminal state” (Goethe, 2003, p. 5). Thirdly, the transformation may extend over period of time and may involve oscillation between states. There can be no full return to the pre-liminal state once an individual enters the liminal state.

This in-between state is where “some people encounter a threshold concept and master it immediately, while others will take a few steps back before crossing; yet others will sit down in one spot for weeks when the threshold comes into view” (Townsend et al., 2015, p. 1). The spaces “in-between” are said to be liminal and socio-material assemblages or webs of relations between people, spaces and things. Kraftl (2013, p. 113) and Bauer (2015, p. 620) argue that “it is precisely the spaces in-between, the in/formal boundary zones that are the most illuminating fields to study”. Mulcahy (2017) considers these spaces in-between to be liminal. Liminal refers to “occupying a position at, or on both sides of, a boundary” (Mulcahy, 2017, p. 3). It is more of a space where the initial stage of process and activities integrate new ideas into the schema. Mansaray (2006, p. 175) notes that the liminal “is an open form of internal differentiation and refers to relations in which the final condition is not pre-set, but rather is potentially negotiable and contestable”.

The point of departure for any analysis of liminality when dealing with an in-between position, must be a spatial perspective where the learner and the space itself can be active agents of change. The temporal perspective includes the role of non-human aspects of the liminal learning encounter (e.g. material objects, architecture, and natural forces) and their contribution to the geography of learning and education. It could also be troublesome due to conflicts and configurations involved in constructing new meanings of complex concepts such as Lewis acids. The experiences of the individuals passing through a liminal space are different due to individual differences, such as intellect, ability, cognitive-developmental stage and well-prepared prerequisite conceptual knowledge by well-versed conceptual teachers.

Individuals bring with them sociocultural and language to a classroom that may influence their learning. Therefore, a student has her or his own *truth* and *beliefs* that *justify* (emphasis as in the original) her or his actions in a learning situation (Sedumedi, 2013). This explains why, in the same classroom environment, some learners (students) tend to internalise threshold concepts faster and others slower, while some may not learn the deep knowledge of that concept at all.

While individuals spend more or less time in the liminal space, some seem not to have any threshold concept problems and others may not leave the liminal space or, worse still, some may not attempt to enter the liminal space at all (Townsend et al., 2015). According to Lonergan’s (1990 cited in Heading & Loughlin, 2018) dynamic concept of learning, being “stuck” in the liminal space:

> “Is a reluctance or inability of the learner to move from common sense or old knowledge to theoretical or new knowledge. The oscillation of the student between new and old understanding in threshold concept theory can be equated with Lonergan’s (1990 pp. 664-65 cited in Heading & Loughlin, 2018) account of the process of moving from common sense or familiar understanding to a theoretical one or new theory”.

Mental models or schema are unique to a context and to an individual and that could be why students are at different points in the liminal space while others are at the pre-liminal stage. Since the students' experiences are different, there cannot be common points of confusion on a learning adventure. The lecturer (educator) must consider teaching and learning methods that engage all the learners in order to enable them to master the threshold concepts.

As students build and move through a conceptual threshold they require the construction of basic concepts and ideas to facilitate learning. Students bring in their own meanings of the concept in the liminal space without having a clear idea of where and when the exit will appear (Talanquer, 2015). Many students in the process of transforming old ways of knowing the concept to the desired conceptual area are often stuck at different points along the way. Those most at risk of failing or quitting are the students who are still in the pre-liminal state to whom the threshold concept is vague. Once, the transformative process starts there appears to be no re-winding. Hence, it is often assumed that, if a student takes longer in the pre-liminal state, the student may become frustrated and desperate to move on so s/he may devise methods to overcome the difficulty or troublesome knowledge by resorting to mimicry or plagiarism to pass a course (Cousin, 2006). This kind of learning is factual and is often retrieved only to pass the examinations without changing the old ways of thinking. The worst outcome is where the student loses confidence in him/herself and gives up on the course (Land et al., 2005). This may be one of the causes of many students failing the first-year general chemistry course.

Constructivism. Since learning is not impartation or transmission of knowledge but transformation of thinking and identity of learners through mastering the concepts (Cousin, 2006), the pedagogical approach and conceptual knowledge of the acids-bases thresholds concept should also be explored by the educators. In constructivism, a teacher provides the opportunities and contexts for learning to the students. S/he “is a guide, facilitator, and co-explorer who encourages students to question, challenge and formulate their own meaning” from the concept being taught (Ültanir, 2012, p. 195). Constructivism, is an epistemology, is a learning or meaning-making concept that explains the “nature of knowledge and how human beings learn” (for instance, knower and the known) (Ultanir, 2012, p. 195). Students create their new learning and new meanings through the interaction of their prior knowledge and the current ideas, events and activities. The real learning emanates from the construction of meaning of learner’s prior knowledge and background. Most students construct mental structures or schema irrespective of whether they are given complete or partial information (Ültanir, 2012). However, students must actively engage in meaning-making, individually and/or cooperatively, co-generatively.

Critics have refuted the effectiveness and efficiency of constructivism. According to Kirschner, Sweller and Clark (2006, p. 75), “discovery, problem-based inquiry, experiential and constructivist” learning require minimal guidance but place a huge demand on mental structures. These learning approaches also do not contribute to the accumulation of long-term memory because they search for solutions to problems. Learning is when the long-term memory (mental framework) is altered during conscious processes in the working memory which is a cognitive structure (Kirschner et al., 2006).

The threshold concept, constructivist, and minimal guidance approaches all agree that learning occurs if there is a transformation in the schema which affects the thinking and identity of the student. Students are likely to dismantle, set aside, or separate existing assumptions and merge assumptions with new concepts to construct new learning and generate meaning in concepts under study. As indicated by the literature, it is important to explore the learning of threshold concepts of the “Arrhenius, Bronsted-Lowry, and Lewis” thinking of acid and “base chemistry” by first-year students in the university concerning the conceptual knowledge and pedagogical practices of the educators (Kelly & Akaygun, 2016). Thus, my study focused on the lecture room activities of educators and the interactivities of classes.

First-Year University Dropout. Terms used for describing the mobility processes of students and drop-out rates in the higher education system are shrinkage and shrink balance “Shrink rate can be defined at the level of the degree programmes, the subjects, the institutions and the overall system” (Heublein, 2014, p. 2). All first-year students who leave the programme without obtaining an academic degree, whether due to change in a degree programme within the higher education institution, a change to a different institution, or drop out are referred to as the “shrink” at the level of the degree programme. Student dropout is a type of shrinkage where students leave the higher education system without obtaining a (first) degree and do not complete their studies at a later stage (Heublein, 2014). Hence, there are different types of shrinkage that include “degree programme or subject changes, interruptions in studies and the change of institutions” (p. 498). According to Heublein (2014), research carried out at German Universities between 2008 and 2009 on first-year students indicated that mathematics and natural sciences lost 39% of students while engineering registered a loss of 36% in their bachelor’s degree programmes. A 40% drop-out rate was “found in mathematics, computer science, physics and chemistry, as well as in mechanical, electrical and civil engineering”. “Biology, geography and architecture registered below-average drop-out rates” while “educational sciences, psychology, law, economics and social science” had low drop-out rates (Heublein, 2014, p. 500).

Similarly, Coates and Ransom (2011) investigated the interactions between the students and the institution that would influence them to continue or drop out of their studies. This was referred to as “attrition” that is “a complex and multifaceted phenomenon which incorporates transitions such as cross-institutional mobility, ‘drop-out’ from higher education, course transfer, temporary deferral, and academic failure” (Coates & Ransom, 2011, p. 3). First year studies in 2010 revealed that the “institution, narrow field of study and average overall grade were the strongest correlates, explaining around 2.1 percent, 1.4 percent and 1.0 percent of the variance in departure intentions” (Coates & Ransom, 2011, p. 3). Early departure intentions that were depicted by the field of education may be due to the competitiveness of entry and career prospects. The study showed “natural and physical sciences to have 27%, earth sciences 26%, biological sciences 23% and chemical sciences 14% of first-year intentions to drop out” (Coates & Ransom, 2011, p. 4). Demographic characteristics show that “male 28% and female 27%, first in the family to be at university 26% and not the first 29%, socioeconomic status; low 28% middle 28% and high 26%” (Coates & Ransom, 2011, p. 5). Students’ tendency to depart from studies was influenced by academic performance. First-year students who intended to depart due to low grades were “biological sciences 22%, earth sciences 10%, natural and physical sciences 14% and chemical sciences 16%” (Coates & Ransom, 2011, p. 10).

Theoretical Frameworks and Learning Theories

Activity Theory (AT) or Cultural-Historical-Activity Theory (CHAT) is object-driven activity theory (Engeström, 2009). AT provides a philosophical framework to investigate, illuminate and describe communities of practice (Wenger, 1998), it was used in this study to explain the classroom interactions and unpack research findings. Three generations of activity theory were employed in this study. Vygotsky’s (1978) formulation of a socio-historical perspective was characterised by the mediated task as Vygotsky believed that learning occurs through social interaction. Leont'ev (1978 as cited in Barnard, 2010) formulated what is known as the "first-generation of AT". Following unfinished work of Vygotsky, Leont'ev (1978) expanded the work from individual action to collective activity, known as "second-generation of AT". The three salient features of Leont'ev's (1981, p. 46) model are that "activity is significant, activity is social, and activity is systematic". On the other hand, Engeström (1987 cited in Barnard, 2010) points out that Leont'ev did not graphically expand Vygotsky's (1978) original model of the activity system. Engeström (1987 p. 195) developed Leont'ev's original model "by mapping the social foundations of activity between individuals" because social rules influence individual and collective activity. The third-generation model (Engeström, 1987) developed conceptual tools to explore the expanded transformations that occur when two activity systems collaborate to bring about co-constructed outcomes. The theoretical frameworks guide the researcher to confine the theories, choice of research design, data analysis, research approach, analytical tools, and procedures, and make the research meaningful and generalisable.

An activity is a cultural-historical phenomenon in which human beings understand their world (Vygotsky, 1978). A triangle represents activity theory or cultural-historical theory. All features of the CHAT triangle are distinguished to ameliorate the high failure and drop-out rates of the first-year chemistry students. Firstly, the resources are acids-bases concepts, the language of chemistry, the language of instruction and the classroom resources that are useful for achieving the goal. In a teaching and learning process, students should have an objective to expand their understanding of the classroom tasks designed by the educator. Secondly, the goal of learning TCs of acids-bases chemistry provides for both educator and student intending to master the chemical reactions and concepts. As acids-bases reactions are related to many chemical reactions in chemistry and other science disciplines, mastery of TCs of acids-bases may enable students to connect to related chemistry topics. Thirdly, to address failure and drop-out rates, educators strategize to motivate students to participate individually or collectively in learning activities. Students' objectives are to experience teaching and learning activities that may lead to succeeding in chemistry for both students and educators. Chapter three discusses the CHAT theoretical framework in detail.

Overview research methodology. Qualitative research methodology was employed because it assisted me to immerse fully in a range of data. In qualitative research, the researcher aims to acquire first-hand knowledge of the sociocultural setting. To gain an understanding of a setting is to maximise the "advantage of personal insight, feelings and life perspectives to understand social life" (Neuman, 2014, p. 168). It means not allowing preconceptions, own views and prior assumptions to influence the study and reporting on findings. In qualitative study, the researcher's openness and integrity are important (Neuman, 2014).

Qualitative method of research examines social processes and cases in their social context and studies interpretations or meanings in a specific socio-cultural setting. In addition, to explain how people construct identities social life is examined from multiple points of view. Therefore, action, case-study and phenomenology research designs were employed in this study as Chapter Four described in detail. The researcher was assisted to immerse fully in a range of data. The researcher was aware of new insights, such as feelings and the texture of dynamic social life, throughout the process of gathering data (Neuman, 2014).

Action, case-study and phenomenology methods. Action research embeds the researcher in a social context as a consultant or an organisational member to initiate an action or intervention in response to a real problem. It allows the researcher to examine how her/his action influences the phenomena under study (Bhattacherjee, 2012). McNiff (2002, p. 344) called action research "a practitioner-based research" (cited in Cohen, Manion & Morrison, 2011).

An in-depth description and analysis of a bounded system is referred to as case-study method (Merriam, 2009). A case-study method is an "empirical inquiry that investigates a contemporary phenomenon within its real-life context; especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 2003, p. 13). Case studies are "exploratory, descriptive or explanatory" (Yin, 2003, p. 2 citing Yin, 1981). Exploratory case studies strategy develop hypotheses of propositions for further inquiry. Descriptive case studies "investigates the sequence of interpersonal events, overtime describes a subculture and discovers key phenomena", while explanatory case studies tend to generalise a whole variety of complex phenomenon (Yin, 2003, p. 4)). Descriptive case study strategy was employed in this study.

Phenomenology studies lived experiences from the perspectives of individuals as a way of understanding the meaning of life around us. Consciousness is always conscious of something. It explores what people experiences and how they experience the phenomena and what their lived experiences mean. Therefore, it is conducted with human judgement, perceptions and actions (Denzin & Lincoln, 2000). In this study, I focussed on the experiences of chemistry educators and first-year chemistry students.

Instruments of collecting data and analysis. In the first phase of the study, a survey questionnaire was completed by chemistry educators (lecturers) on their knowledge of threshold concepts (TCs) of acids-bases, experiences of teaching acids-bases to first-year students, and their perspectives of formulating TCs of acids-bases as a foundation course.

Five (5) first-year chemistry educators completed the questionnaires. Then, I had in-person interviews with the educators. The goal provided an opportunity to probe further and complement the answers they provided in the questionnaires. However, the interview questions were not the same in some instances because they depended on the responses to the questionnaires. Face-to-face interview questions emanated from the responses each lecturer gave in the questionnaire. The researcher elaborated on interview questions where respondents asked for clarification. Similarly, I also asked the respondents to clarify some of their answers to both the questionnaires and interview questions. Findings from educators' interviews influenced the activities of the workshop. Furthermore, classroom observations were guided by the lecturer's presentation of the key concepts in acids and bases, her/his interactions with the students, students' activities with each other and the key concepts. A conversation was held with each educator to review the lessons by watching some segments of the video-recorded lessons. In addition, a total of 47 students from the sampled classes, which were taught by each of the five sampled lecturers, were interviewed. Educators' and students 'activities were video-recorded. The participants were purposively sampled. Qualitative data were coded and presented in the form of themes, categories and narratives. Chapter Five engages with the research findings. The three research questions guided the results of the study. The findings of research questions 1 and 2 helped the researcher to answer research question 3.

Overview of findings. This section, which was referred to in Chapter Five, presents detailed findings of the study. The students who participated in the research represented the views of their groups. Each class numbered about three hundred and fifty students (350) and is of mixed gender. I focused on the students' experiences and perspectives in their classrooms. CHAT was used to explain the teaching and learning process. In activity theory, there is an interdependence of artefacts which are rules, roles and resources that direct teaching and learning. A classroom is an intersection of the activity systems of educators, students and curricular materials. This intersectionality or classroom is referred to as a "third space". As educators and students interacted with acids-bases reactions tasks and with each other, constraints and affordances were generated. Teaching techniques employed by university educators, much detailed chemistry content, sudden changes in the schedule, and academic workload created constraints for some students and generated affordances to other students to enter the Zone of Proximal Development (ZPD) (Vygotsky, 1978) and liminal space (Meyer & Land, 2003). Intuitively, students plan subsequent actions and a series of activities to address challenges. Students in the ZPD sought assistance from the educators and more knowledgeable others inside and outside the classroom. Study groups emerged with fellow students as peer teachers or enablers or MKO (More Knowledgeable Others). In this way, students adjusted their study schedules, roles, rules, and resources, and often formed a collective study groups. At the same time, students were adapting to the university culture and expanding their knowledge through research and collaborative learning. They saw challenges as opportunities to learn as it was their responsibility to succeed. Students shared common objectives and that was to succeed in chemistry.

On the other hand, student diversities created constraints for some educators. Educators explained that students were at different chemistry knowledge levels and hence learnt at their own pace. These constraints generated affordances for some educators to adjust the rules, roles, and resources which, in turn, transformed the classroom culture. The educators were no longer using teacher-centred but student methods that resulted in more interactions between students-students and students-educators. Objectives or roles of the educators were to help students to succeed in chemistry.

Definitions of Operational Concepts

Threshold concepts (TCs), liminal hotspots, acids-bases reactions, general chemistry, third space, university dropout, failure, withdrawal, persistence and teaching-learning experiences were key terms defined in the study.

The term threshold concepts (TCs) used in this study represents concepts in chemistry that can be considered as akin to a portal that opens a new and previously inaccessible ways of thinking (Meyer & Land, 2003). TCs also present transformed ways of thinking that may allow the learner to progress well. TCs can lead to “troublesome” knowledge (Perkins, 1999 cited in Meyer & Land, 2003).

Liminal hotspots refer to a position in which a student is interacting with a TC and seems trapped. Liminal hotspots generate great affective domain that may lead to creativity, mimicry or quitting (Greco & Stenner, 2017).

The term “acids-bases reactions” refers to a topic in chemistry that students find troublesome or challenging (Timofte, 2015; Furió-Más et al., 2012). Acids-bases chemistry is connected to the learning of other chemical concepts in chemistry, biology and physics (Cooper et al., 2016). According to Cartrette and Mayo (2011), mastering key foundational concepts is important to learning chemistry across different contexts. Acids-bases reactions of molecules are a foundational principles. However, it is a topic that gives students challenges up to the graduate level of Chemistry.

General chemistry refers to the curriculum of chemistry for all first-year students preparing for science careers, including teaching and learning. The Bronsted-Lowry theory, also called the “theory of acids and bases”, is stressed in general chemistry because it leads to studying equilibrium and kinetics. Lewis acid-base theory is applied at higher level chemistry especially in organic chemistry (Cartrette & Mayo, 2011).

The intersection of educators' activity system and that of students' activity system or communities of practice is referred to as a third space represented in a Venn diagram. A third-space is a form of liminal or an in-between space (Meyer & Land, 2003), ZPD or a problem-shared space (Vygotsky, 1978) where educators and students meet to negotiate learning. In the third space, there are rules of engagement that are part of culture; that are shared resources and roles. The classroom is a type of third space where teaching-learning takes place in a socio-cultural/socio-academic space. Learning involves the occupation of liminal space (Meyer & Land, 2003). While mastering TCs, students may experience challenges and require assistance from the educator or a more-abled peers (MKO) (Vygotsky, 1978).

"University dropout" is the term used to describe a situation where a student leaves the university before obtaining a undergraduate degree. Other terms that describe university dropout are "dropout, departure, withdrawal, academic failure, non-continuance, and non-completion" (Jones, 2008, p. 1 cited in Larsen, Sommersel, & Larsen, 2013). Involuntary removal is when a student drops out of study because of his/her failure to meet the academic requirements demanded by the university. Contrary, when a student transfers in pursuit of another subject of study or in another university within the system of higher education, the situation is referred to as a voluntarily dropout of the university study. Furthermore, a student can drop out of the university due to external circumstances, such as financial difficulties, family-related or personal problems. There is also dropout at the institutional level where a student transfers from one subject of study to another within the same faculty and university.

“Failure” refers to a grade that a student receives that is lower than the passing grade, for example, in some institutions, the grades D, E and F are failing grades (Wullur, 2012). In the researcher’s institution, grades D+ and D are failing grades. Grade D+ is marked from 45% to 49% and D is measured from 0% to 44% (Copper-belt University [CBU], 2007).

“Withdraw” is a term that describes a student who decides to exit from a course or programme with permission. Likewise, a student may decide to stop attending lectures without permission (Ulriksen et al., 2010).

“Persistence” occurs when a student graduates regardless of transferring to another programme or university. Positive experiences and hands-on, mind-on approach to studying by students influences persistence in chemistry (Lastusaari, Laakkonen, & Murtonen, 2019).

Teaching-learning experiences are interactions between student-educator, student-student, and student-acids-bases chemistry within and outside the classroom (Engeström, 1997). Teaching experiences were used to investigate educators’ experiences and perspectives of teaching first-year chemistry, causes of high failure and drop-out rates, and how the causes and challenges could be alleviated. Students’ learning experiences were used to explore the challenges and perspectives of learning acids-bases reactions.

Limitations to the Study

The Witwatersrand University Research Ethics Committee (non-medical) delayed granting me a clearance in 2018. The academic calendar of the institution chosen to collect data is different from that at Witwatersrand University. This institution’s calendar starts from October to August of the following year. The topic of acids-bases reactions is taught in the third term. By the time the clearance was granted in August 2018, the institution was on recess. When the university reopened in October 2018, I administered survey pen-paper questionnaires to educators, did member checking, and conducted interviews between November 2018 and January 2019. Since acids-bases requires prerequisite topics, such as chemical equilibrium, educators had to adjust the curriculum. Furthermore, students were given time to settle into a new environment before I could engage them as co-researchers. Hence, little was done in their first term. To overcome this limitation, the first-year chemistry educators and I had to agree on rescheduling the acids-bases reactions courses to the second term in March 2019. This gave educators ample time to teach the prerequisite topics of acids-bases. The arrangement also allowed students to settle in their new institution.

The second limitation was the go-slow (workers' strike) by junior educators and students which began during classroom observations and students' focus group discussions. There were times when I could not observe classroom activities nor could meet with students because teaching was suspended. To overcome this constraint, I agreed with research participants to continue with the research. The educators followed their teaching timetables while focus-group discussions were held after the lessons.

Thirdly, the lockdown due to the COVID-19 pandemic restricted my full access to university facilities in terms of internet, face-to-face meeting with my supervisor and use of the library. In the case of the internet, there were no suitable electronic books, only hard copies; sometimes the internet reception was weak; and, on several occasions, online supervision was not guaranteed.

The researcher overcame this limitation by obtaining permission to allow me to use the university internet connections through my school of chemistry when the lockdown nation-wide was relaxed to level three from five. Since I could not get into the library for hard copies of textbooks, I cited authors who had cited original authors. Finally, when the failure of online supervision became inevitable, I resorted to social media (WhatsApp) interaction and email communications.

Researcher and Her Positionality

I present my positionality by describing my perspectives concerning exploring acids-bases threshold concepts here. It is about in a case of first-year students' challenges in teaching-learning threshold concepts of acids-bases chemistry. As the qualitative researcher, I was conscious of myself as a researcher and wrote about participants' lived experiences from an insider's point of view. Quinn (2016) defines positionality as a researcher's practice in delineating her/his own stand-point epistemology (position) in relation to her study, knowing that the position may influence some aspects of the study, for instance, "the data collected or the way in which data is interpreted" (Quinn, 2016, p. 1). My position as a researcher sought to clarify my expectations that shaped the research and made the reflexivity that informs the analysis of my theorising process transparent. England (1994 cited in Bourke, 2014, p. 1) refers to research as a space shared and "shaped by both researcher and participants" whose identities "have a potential impact on the research process". Identities manifest through the researcher's perspectives of participants and how the researcher expects the participants to perceive her/him. Through our personal biases, we gain insight into how a researcher might approach a research setting, members of a group, and engagements with the participants (Bourke, 2014). Kezar (2002, p. 96) cited in Bourke (2014) stated that, "within the positionality theory, people have multiple overlapping identities" and "make meanings from various aspects of their identity".

Issues of positionality in qualitative research. I was born in a typical indigenous Zambian family of Bemba-speaking parents with strict Christian values. My father was a politician, academic and building contractor. I was born and grew up in Ndola, Copper-belt region. The vision of my parents was to get all their children to graduate with at least a certificate from a credible higher institution. As a result, we valued education and worked hard at it. I attended extra lessons to gain excellence in reading and numeracy during lower primary school days. I spent more time at school assisting my classmates who were struggling. Before grade 7, I had read several extra (supplementary) books. As a result, my teachers and family noticed my academic abilities. At the age of 13, I qualified for a Girls Christian Boarding School where I excelled in mathematics and chemistry. I grew up believing that I was meant to excel academically.

During my school days in the 1970s and 1980s, Zambia was surrounded by countries that were fighting for independence from their colonisers. Zambia was one of the front-line states that championed the liberation struggles of Southern Africa (Ntomba, 2018). The government hosted liberation movements because Dr Kenneth Kaunda, the first president, was an uncompromising nationalist, pan-Africanist, leader of the front-line states and an outspoken critic of apartheid. He believed that Zambia’s freedom was meaningless if its neighbours were not liberated. Zambia supported liberation struggles from 1966 to 1990. The country paid with her own resources and security personnel even though the country suffered counter attacks from the colonisers that led to colossal loss of life and properties (Ntomba, 2018). Zambia’s act of self-sacrifice resulted in the underdevelopment of many sectors, for example, the University of Zambia which was opened in 1966. The university managed many satellite colleges as the population increased. I attended the Copper-belt College of Education that trained mathematics, science, and home economics teachers. I studied science education and graduated in chemistry as a single major. Chemistry, rather than physics or biology, had been my strength since my secondary schooling. In 2001, I pursued further studies in science education in the United Kingdom.

These experiences influenced my current chemistry teaching and learning perspectives. I believe that students who enter a university intending to study for science careers can succeed if they work hard and seek assistance from educators and peers, in essence, collaborative learning. My interest in chemistry motivated me to investigate the first-year chemistry students' high failure and drop-out rates in my institution gaining an insight into the challenges that educators and students experience and how to alleviate them. Chemistry, being a prerequisite course for all students aspiring to science programmes, may deter many from attaining their dreams. As a chemistry educator, the findings of the study and recommendations, if implemented, may lead to students' increased interests and successes in the field chemistry.

Reflections during research: I acted as both insider and outsider in the chemistry department. As insider in the sense that I work in the school of mathematics and natural science (SMNS) and chemistry department is in the SMNS. As outsider, I belong to mathematics and science education department housed in SMNS. The researcher crossed the boundary into chemistry department so that educators and first-year students would collaboratively work with her as co-researchers. Consent forms, information sheets and questionnaires were distributed to all members of chemistry department. These were received with mixed feelings by some educators as they thought they were being monitored. This was reflected by number of people who signed and completed the questionnaires. Out of eighteen (18) total number of chemistry educators, eight (8) signed consent forms and completed the questionnaire. Five (5) of the eight were first-year chemistry educators while three (3) were not. Nevertheless, some of them who did not consent to research with me attended the professional development workshop. Students were more eager to share their learning experiences of threshold concepts of acids-base chemistry than their educators. They were more concerned about their success in general chemistry and proceeding to second-year programmes.

During this research, I experienced challenges in conducting interviews as some educators were not willing to share/contribute their time. I found that I had to fit into the participants' schedules. It is not easy to talk about teaching-learning without going personal or sharing personalised experiences. So, I had to review my plans and the schedules I had drafted. When students became antagonistic and vilify educators, I gently guided them to the focus of the interview. Taking notes directed me to take time in documenting and reflecting on the research questions and quality of the data being collected. Field notes also helped me to remember words and segments of video-recorded conversations that I could not transcribe due to bad audio and containing important information needed for analysis. Information that I collected from educators helped me to have a glimpse of what happens in the classrooms and the challenges that constrained them from providing better teaching.

It has been a learning experience for me as a doctoral student. My greatest challenge was to complete data collection by February 2019; however, I must follow the university term calendar. In the first round of data collection, I administered survey questionnaires and had face-to-face interviews with lecturers in December 2018 and January 2019, respectively. The second time around was in March and April 2019, focusing on classroom activities and student focus-group interviews. The transcribing of videos, coding of data, and classifying them by themes was difficult for me and I found that I often get stuck at one point for a while.

Repeating this study: If I was given another chance of gathering data, I would have organised the workshop through the directorate of Centre for Academic Development (CAD) during the university recess. Most of the educators failed to attend or consent due to pressure of work and Christmas holidays. Also, I would have collected data from three government universities and university colleges to have a better understanding of the causes of first-year high dropout and failure rates in chemistry. For intervention, I and the co-researchers would have formulated a foundation course on TCs of acids-bases as proposed by chemistry educators.

Thesis Lay-out

This section gives a summary of the focus of each of the chapters in this thesis.

Chapter One: Introducing the Study and the Study Overview

In this Chapter One, introduction to the study, background of identified research problem, purpose, rationale and motivation of the study, research questions, and objectives were discussed. Operational concepts are articulated and positionality of the researcher is presented, in this chapter. The overview of the methodology, analysis, and findings of the thesis were laid out so that the reader may be conversant with the trains of thought. Chapter One ended with the thesis layout and summarised.

Chapter Two: The Literature Review

The literature that informs the study where were reviewed in Chapter Two. It reviewed literatures in relation to, but not confined to TCs, the challenges of teaching-learning chemistry and the socio-cultural impacts. These were reviewed. under the following headings: threshold concepts, liminal space, community of practice, constructivism, university failure and drop-out rates, and research in chemistry education, to mention a few. Previous researchers were acknowledged, those who have explored the challenges experienced by students in acids-bases chemistry, before. The related and relevant literatures are discussed with the purpose of alleviating high failure and drop-out rates of first-year university students in chemistry.

Chapter Three: Theoretical Frameworks

In Chapter Three, I discussed how I intended to use theoretical frameworks understanding linked with teaching and learning theories. I also defined what the theoretical frameworks are and their purposes in research. The justifications of employing the theoretical frameworks and teaching and learning theories in the study were discussed in details.

Chapter Four: Research Methods and Data Collection

Chapter Four explained how and why I collected data. It described the qualitative method used in action and case study designs by describing the study, data collection methods, and their strengths and weaknesses. The research design and justification of why a generic qualitative paradigm was chosen were discussed. It also described how participants were selected and the thematic analysis of data that were used in identifying and reporting themes. The results are triangulated; and the ethical issues for both the researcher and the participants were discussed.

Chapter Five: Findings, Analysis, and Interpretations

The research concerning educators and students perspectives were explored and discussed in this chapter. I discuss the constraints that are involved in the third space. I identify how the diversity of students generated constraints and how the participants (educators and students) turned them into affordances. Individual educators' designed classroom interactions were discussed. Discussion of research findings are based on the three research questions were explicated. Findings revealed that employing AT, linked with theories, such as social reproduction (Bourdieu, 1977), use of multiple pedagogical methods (Kincheloe, 2008), critical pedagogy (Freire, 2005) and ZPD (Vygotsky, 1978) can generate ways of understanding students' experiences in mastering threshold concepts. Chapter Five closes with the analysis and interpretations.

Chapter Six: Conclusions and Recommendations

This Chapter concluded my thesis and presented recommendations to designing threshold concepts concerning foundation course in acids-bases chemistry for first-year students. Chapter six closes with the conclusion and reflections of the researcher and consolidated the study that directly responds to the research questions.

Chapter Summary

An overview of the study was provided in this chapter. I presented the background to the study, introduction of threshold concepts of acids-bases, an overview of the purpose of the study, and rationale. The chapter has discussed operational definitions of key concepts and key terms. An overview of the research methodology, theoretical frameworks, study limitations and the thesis structure were outlined. Next, review of interrelated literatures are presented in chapter two.

Chapter Two

Literature Review

Introduction

A review of related literature is “the selection of available documents on the topic that contain information, ideas, data and evidence” concerning the research undertaken (Hart, 2018, p. 13). A review of related literature provides insight into the topic under study, what has already been done previously on the matter, key issues found, and gaps left for further research. It also contributes to a researcher’s intellectual ability to think critically about the topic and research (Hart, 2018). Numerous documents have been studied that pertain to the challenges experienced by first-year students in learning threshold concepts of acids-bases chemistry. So, literature which informed the study is presented in this chapter. I examine the threshold concepts in general and in chemistry specifically. Limitations of threshold concepts were presented as well. I also look at the liminal space and what takes place in the liminal space as examined by scholars. The second section of the chapter is an exploration of university’s first-year chemistry drop-out rate, study exchange and the probable causes of student dropout. In the third part of the literature review, I present constructivism and its implication for teaching and learning and relatedness to my study. I also interrogated the community of practice and situated learning. Lastly, I examined various research in science education.

Threshold Concepts

According to Meyer and Land (2003), TCs are key ideas in a discipline which are “conceptual gateways” or “portals” that lead to previously inaccessible, and initially “troublesome”, way of thinking about something. Once TCs are mastered, students may be transformed in understanding, interpreting, or thinking of the subject matter. Hence, Meyer and Land (2003) characterise TCs by suggesting that TCs may be transformative, irreversible, integrative, troublesome and bounded. They may be troublesome for certain students because transformations demand letting go of previous ideas and comfortable positions, and entering less familiar new territories and the integration of new ideas (Land et al., 2005). Transformation also leads to a change in identity and the adoption of extended discourse. Mastering threshold concepts brings about a shift in the students’ ontological understanding of disciplinary knowledge. Hence, there “may be transformed internal view of subject matter, subject landscape, or even world-views” (Land, et al., 2005, p. 53). The transformed view or landscape represents how experts think in a particular discipline (Meyer & Land, 2003). The threshold concepts open up a new way of thinking, that was previously inaccessible, for instance, the understanding and application of core concepts of acids-bases reaction chemistry. These core concepts can be likened to portals to comprehend complex concepts. Threshold concepts connects to related or opens ways into the knowledge of a discipline. Crossing through conceptual threshold transforms the thinking about a discipline or topic because students are able to integrate them in their schema. The individual acquires the ability and ways of thinking of the experts in that field, for example, many people say that science is a difficult subject but once the language of science is acquired, then the person can learn. This may change the individual’s thinking and attitudes towards learning science. The transition could be difficult but once learning has taken place; the learner becomes more inquisitive to explore the discipline.

Characteristics of threshold concepts. Threshold concepts have all or some of the following characteristics. TCs are:

1. Transformative as one’s perception of the area of study or part of it is altered by the concept. This gives the student the ability to successfully handle unknown complex situations not previously seen .
2. Integrative when the learner can make sense of disparate aspects of learning.
3. Irreversible because, once the threshold concepts are well learned, it is difficult to look back across threshold concepts because the transformation involves a shift in values and attitudes.
4. Troublesome as concepts may be challenging and troublesome if they are incompatible with previous concepts.
5. Bounded, as threshold concepts that outline the conceptual space may have terminal frontiers that serve to demarcate between disciplinary areas (Baillie, Bowden, & Meyer, 2013).

Talanguer (2015), discussed the characteristics of threshold concepts demand new ways of thinking, practice and outlined of critical cognitive elements. TCs lead students on a transformational journey of the epistemological process. A TC occurs where students experience doubt and confusion about acids-bases reactions that require them to adjust their perspectives. When a student encounters a TC, cognitive and affective processes are involved. These affective dimensions disturb the schema and lead the student to respond by taking control of the learning process, leading to new insights. However, a lack of emotional and cognitive investment results in some frustration and stress, leading perhaps to exhaustion and depression, and a student may want to quit (Land, 2016) while unstable cognitive conditions mean that the student is forced to memorise.

Disciplinary Threshold Concepts

Disciplinary TCs are portals to learning more complex concepts. They rely on the transformation of basic TCs that a student should integrate into the conceptual structure. Disciplinary TCs are revealed consensually over time within the community of the discipline (Land, Meyer, & Baillie, 2010) that is, the disciplinary constructs that have emerged as definable abstractions. They are concepts that are central to a discipline and serve as "targets of the questions, problems, and judgements" (Land et al., 2010, p. x). The awareness of TCs can guide the educators in prioritising "what should be taught, how it should be taught and how it should be best assessed" (Land et al., 2010, p. xi). Educators could also provide roadmaps to students of how TCs can be internalised so that individually may overcome barriers to learning by having a better grasp of the interconnectedness and interdependence between disciplinary topics (Wright & Hibbert, 2015). For example, using acids-bases reactions to identify TCs that are interrelated subtopics in acids-bases in the chemistry discipline. To understand the core TCs in acids-bases reactions fully, a student must understand the questions raised by TCs about atomic structure, chemical bonding, chemical equilibrium and stoichiometry. However, mastering the concepts raised by core topics may not enhance learning of a subject.

First chemical reaction learned by organic chemistry students is the Bronsted-Lowry model (Stoyanovich et al., 2015). Every step in organic reaction demands an acids-bases reaction. Unless the students have mastered the TCs of acids-bases reactions, they may not progress as they should because it is these points of intersection or interrelatedness and prior learning where students are likely to encounter challenges to learning.

Liminal Space

The process of mastery of TCs requires one to enter a liminal space. Liminal space is the "transition period between moments in which students did not grasp a threshold concept and the moment of grasping the TC" (Timofte, 2015, p. 85). The liminal space could be troublesome, perplexing and paralysing space due to the conflicts and configurations involved in constructing new meanings of complex concepts and identities. It is also unstable space where learners may oscillate between old and new understandings while training their minds to suspend belief. Students also have to discard old knowledge to cope with the new threshold concept and to integrate it into their mindsets. Through oscillations, students "may experience desolation, confusion, frustrations, stress and a stages of intermediate knowledge which are often followed by the clarity of entry into a community of practice" (Cousin, 2006, p. 22). Land (2014) looks at the nature of liminality as a kind of unrest. Encountering a threshold concept causes the liminality to make things fluid, less certain than the threshold concept thereby starting to transform the learner/student. It is a space that calls for transformation of the prior schema (mental structure) to gain new ways of seeing things. Mastering new concepts depends on the student bringing together the old and the new knowledge in a systematic relationship. Incorrect ideas are poorly understood, whether old or new, and students may find difficulties in blending (Land, 2014). The liminal space is a space of transformation that is directly connected to emergent ideas, thoughts, attitudes and concepts that are at higher-level cognitive states (Lewis, 1875, cited in Land, 2014).

Liminal space is a space shared by the actors of transition "seeking new explanations, visions and meanings of the known" but it is also a place where people often can "get stuck" (Land et. al., 2010, p. xxxvi). In the liminal space, students may find challenges integrating new ideas or replacing previous ideas with new ones that can cause them to get stuck temporarily

(Cousin, 2008). Greco and Stenner (2017) call these positions where students get stuck liminal “hotspots” where students are “trapped” in between and simultaneously unbound from internalising TCs. Liminal hotspots may lead to creativity, mimicry or quitting (Greco & Stenner, 2017). The transitional phase is an ontological indeterminacy which is characterised by affective instability. Persons in transition are ready for transformation, while the actuality of transformation is still fluctuating and indeterminate. The liminal phase maximises the predisposition for becoming affected so that old identities are challenged and may be relinquished, and new ones acquired, and personal dispositions may be aligned with the requirements of individual’s new roles (Greco & Stenner, 2017). Students come into interactions with resources, new enabling/learning cultures and new/enabling discourses, which are possibilities of knowing teaching and learning (Mulcahy, 2017). However, creativity in the liminal state does not happen in isolation but it is about people participating in social practice and social life (Lave & Wenger, 1991).

Similarly, is Vygotsky’s (1978) theory of Zone of Proximal Development (ZPD) is the distance between the actual developmental level as determined by independent problem solving and the level of potential development. This developmental level is determined through problem-solving under guidance or in collaboration with capable peers. Learning takes place socially in the liminal space through tutorials, small group discussions and peers consultations that provide collaborative learning.

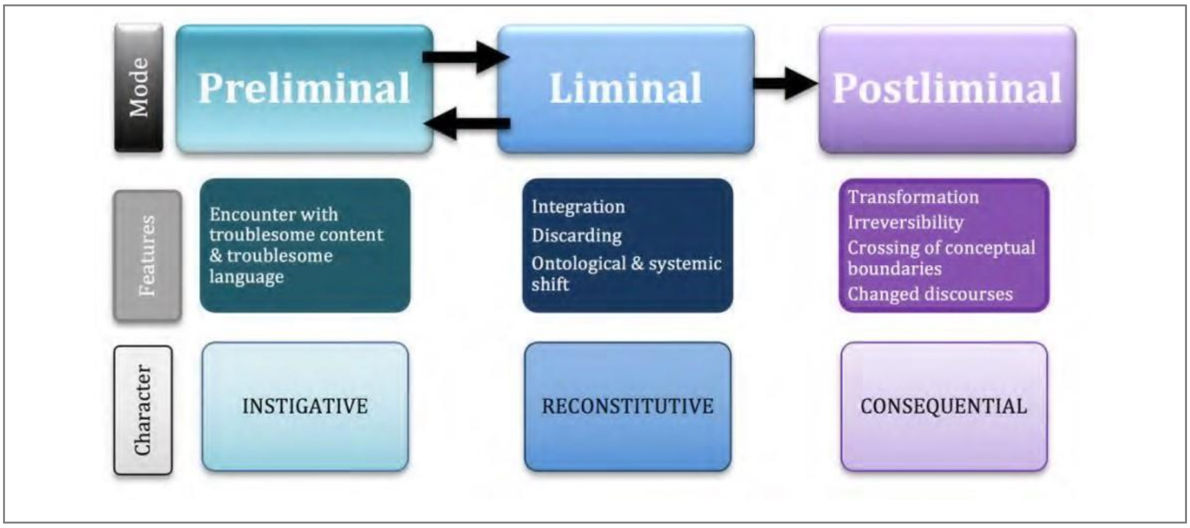
Vygotsky (1986, p. 188) describes the ZPD as “a tool through which the internal course of development can be understood” and that “the only good kind of instruction is that which marches ahead of development and leads at; not so much at the ripened fruit, but as at the ripening functions” of learning. It does not matter at what stage the student is in the liminal space, whether they walk through or oscillate or seem to be stuck, but it is a process of cognitive development. Despite the challenges in the process of mastering the threshold concepts, students are not fixed to a particular point of cognitive development. Vygotsky (1978) explains that learners can work within and outside ZPD if given appropriate scaffolding, and when they make use of the affordances within the immediate environment to external thinking. Thus, perceptual processes and cognitive processes are activated by external representations and internal representations. The end of learning process in a liminal space is the mastering of the threshold concepts and transforming it.

Stages in the liminal space

Variations between different students are observed in the liminal state and in all phases of the process. When a student initially perceives the TCs is referred to as the pre-liminal phase (Meyer, Land, & Davies, 2008) where the student engages with the concept to construct meaning. As the student interacts with the TCs, affective emotions disturb the schema and lead the student to respond. This stage is characterised by “instigation” (Thompson, 2019) and may usher the student into the liminal phase. In the liminal phase, students negotiate with TCs, analyses his/her current knowledge, integrates the new concepts into the schema, and discards prior thinking. This is known as “reconstitutive phase” (Thompson, 2019). The student is transformed when s/he successfully integrates the new ideas, changes his/her perceptions of the subject matter, sees things differently, and thinks differently. Then, the student exists the liminal space, which is referred to as “consequential” post-liminal phase (Thompson, 2019; Nicola-Richmond et al., 2018). This process requires the provision of varied teaching and learning opportunities designed to meet students who may be at various stages within the liminal space. The learning process is summarised in Figure 2.0.

Figure 2.0

Reconstitutive Nature of the Learning Journey across the Liminal Space



Source: Based on Land et al. (2005; 2010, p. xii); Thompson (2019).

Implications of liminality in teaching-learning: Cognitive and affective processes are involved in encountering TCs. “Some people encounter a threshold concept and master it immediately, while others will take a few steps back before crossing; yet others will sit down in one spot for weeks when the threshold comes into view” (Meyer & Land, 2003). Once, the students are in the liminal space there is no return. Students in the liminal space appears to be constrained, but the constraint generate affordances to learn from able peers and educators (Vygotsky, 1978). Liminal spaces can also be viewed as zones of proximal development (Vygotsky, 1978). ZPDs and liminal spaces are disharmonious and hybrid (Bhahba, 1994; Hall, 2002). Hybridity captures the struggle of transformation and differences in the learning contexts where cultural, socio-economical, and epistemologies collide. Transformative learning has a strong affective dimension which consists of an amount of anxiety and risk. These affective dimensions disturb the schema and lead the student to respond; and may change to a sense of new insight. This process requires the provision of varied teaching and learning opportunities designed to meet students who may be at various stages within the liminal space.

Limitation of Threshold Concepts

Walker (2013) questions the advocates of threshold concepts who claim that as a concept it incorporate and represent several abstract ideas. Shinners-Kennedy (2008, p. 120 cited in Walker, 2013) contends that there is a temptation to see threshold concepts as "big" and that "a pattern is evolving that appears to favour what might be considered everyday concepts". These threshold concepts can be small and immaterial or large and significant, making the task of identifying them even more difficult.

Critics argue that "transformative, irreversible, integrative, bounded and troublesome" are not necessary characteristics for threshold concepts (Baillie et.al., 2013, p. 229). Grasping a TC does not give rise to ability because learning is practice and there are multiple concepts that are both complex and simple. The transformative and integrative nature of TC are questionable because what is transformative or integrative to one person may not be transformative or integrative to another person. Hence, TC is in different spaces for two different individuals. This means what experts or teachers consider as TCs and think about them, students may not consider and think the same (Walker, 2013). A threshold concept is "seen as a portal through which students pass to reach understanding, but it ignores the observable fact that there may be many paths to the portal". Additionally, "every student's path may well be different" (Heading & Loughlin, 2018, p. 660). Certain concepts resemble passing through a portal enabling things firmly not perceived come into view but are not TCs. Furthermore, there is limited empirical research evidence for "threshold crossing". Teaching may "describe a path or paths to the portal, but may not ensure that the student passes along it”. Thus, TC fails to refer to schema theories of learning (Heading & Loughlin, 2018, p. 660)).

University Failure and Dropout Rates

University failure rate. Failure rate is one of the biggest problems in education among students. If 15% or more of the students are not able to pass a class, it has a high failure rate (Wullur, 2012). Failure rate is the gauge of student drop-outs who failed to receive passing grades/marks during the term/semester. The failure rate is categorised into “(a) withdrawal from the class, (b) falling short of the passing grade, (c) incompletion of fulfilling class requirements or (d) failing the class” (Wullur, 2012, p. 1). Incompletion refers to the end of a term/semester grade or mark given by the teacher to a student who has not finished all the requirements for passing the class. Withdrawal refers to an intentional act of pulling out of the class and is tied to the term dropout. Falling short is receiving grades lower than the passing grade in a class. Depending on the institution, C, D, E, or F are falling short grades (Wullur, 2012, p. 3). It is the lowest achievement in the class and is gauged between 0% and 40%. Contrary, academic success is achievement based on course grades and grade point average.

The failure rate is higher in general chemistry than in other introductory courses (Cooper & Pearson, 2012). Hence, general chemistry has been referred to as a “gatekeeper” course that about 25% of freshmen do not always pass. It is “a gateway course that many students must pass before they can enrol in more advanced science courses” (Cooper & Pearson, 2012, p. 197). Generally, general chemistry is a barrier to success for many first-year chemistry students.

University drop out. High drop-out rates in the sciences are a serious problem in public universities (Massi & Villani, 2015) as it represents a waste of economic and human resource. It further worsens the problem of a lack of science teachers, scientists, engineers and doctors (Massi & Villani, 2015). In an attempt, to understand students ‘drop out, the researchers (Massi & Villani, 2015) explored the Student International Model (SIM) based on the concept of habitus (Bourdieu, 1983). According to Bourdieu (1983, p. 65), habitus is “a system of rules, ways of perceiving, feelings, doing and thinking that lead us to act in a certain way in a given circumstance”. Massi and Villani (2015) conducted interviews and questionnaires on the institution and the students. Data were analysed on drop-out rates in Brazilian chemistry courses to compare with the drop-out rates of the institution under study. The study showed that the average drop-out rate for the period 1996 to 2005 was 46%. The average drop-out rates in 1997 were “32% for first-year, 52% for undergraduate and 75% for postgraduate” (Massi & Villani, p. 982). Number of enrolled students from 1961 to 2010 was compared to the number of students who completed the course. Information was used to calculate the overall drop-out rate. Filho (2007, p. 42) cited in (Massi & Villani, 2015) states that “the overall drop-out rate measures the number of students who, after entering a given course, in a higher education institution (HEI) or the education system, failed to obtain a diploma after a certain number of years”. The overall drop-out rate was found to be 22%.

In Finland, changing majors in chemistry is a severe problem (Lastusaari et al., 2019) as teaching students who eventually drop out is waste of money and opportunities. Around 30% of students drop out of university studies in Europe. Whereas 5.3% is the overall drop-out rate in Finland but for chemistry education, it is about 20% (Lastusaari et al., 2019). Finnish students take entrance examinations before being admitted to a university. This prevents the admission of students with weak prior knowledge of chemistry to cope with university studies in that subject. Chemistry being a training course for entry examinations to medical school has contributed to higher overall drop-out rate in chemistry (Ruuska, 2010; Nykanen, 2013 cited in Lastusaari et al., 2019). The 2018, statistics in Finnish universities reported that the drop-out rate varied from between 50% and 70%. Students either dropped out completely or scored high marks in order to enter medical departments after one or two years. This means that chemistry students' attributed rate is important in Finland.

The drop-out rate. The drop-out rate refers to students who leave a programme which includes those who leave the university, change their studies or leave for other higher institutions of learning (Arce et al., 2015). Larsen et al. (2013) describe university dropout as when the student leaves the university study in which s/he is enrolled without graduating. "Dropout" is a term used to describe students leaving their studies before passing their final examination (Ulriksen, Madsen, & Holmegaard, 2010) while in Britain the terms "non-completion" or "non-continuing students" are used (Hovdhaugen, 2009). "Leaky pipeline" is another term that describes the "loss of students from science, technology and mathematics studies to other careers" (Ulriksen et al., 2010, p. 209).

There are also different forms of student departure. There is institutional departure where students transfer from one higher institution to another. In most cases, students also change programmes. Departure could reflect students' mobility between programmes within the same institution. Also, there is a system departure in which students leave the education system completely while some students return to higher institutions after a period of withdrawal (Hovdhaugen, 2009).

Students use the terms "departure, dropout, withdraw, academic failure, non-continuance and non-completion" to describe university dropout (Jones, 2008, p. 1 cited in Larsen, et al., 2013). Non-completions or dropouts are students who do not complete at least one undergraduate degree within six years of first enrolment. Aulck, Velagapudi, Blumenstock and West (2016) studied term one examination results in technology, engineering, and maths (STEM) to determine predictors of dropout. STEM subjects are entry-level physics, chemistry, biology, and maths classes, which are studied by all first-year students. These subjects are referred to as "gatekeeper" courses in science. The results revealed that maths, English, chemistry and psychology were among the strongest individual predictors of student retention. Furthermore, Arce et al. (2015) classified the terms study drop-out rate, study exchange and university system drop-out rate. The exchange rate represents the percentage of students who have transferred to other programmes. The university drop-out rate measures the percentage of students who leave the university before obtaining their degrees. It was reported in Spain (2009–2010) that the drop-out rate and exchange rates were higher in sciences than in health science, engineering and literature (Arce et al., 2015).

First-year American students that receive grade D or F withdraw from first attempt at a course in the first semester (Popejoy & Asala, 2013). According to Popejoy and Asala (2013), half of all first-year students who begin physical sciences or biological sciences drop out by senior years compared to a 30% drop-out rate in humanities and social studies. Similarly, empirical data proves that the drop-out rate is higher in chemistry than the drop-out rate in social science (Heublein, 2014).

Persistence in Studies

According to Leppel (2001, p. 328), persistence occurs when

> "a student enrols in one programme and graduates within that same programme, a student enrols in one programme, but transfers to another programme, at the same university, graduating from the second programme, or a student graduates from a university other than the one at which he or she initially began studies".

Lastusaari et al. (2019) chose to study the first point on persistence which is when a student enrols in one programme and graduates in the same programme because it most influences new output of chemistry graduates. The study explored the connection between persistence in chemistry major and learning approaches. Researchers assessed students' course grades to find out if there was a connection between learning approaches and persistence. This was to generate information about students who drop out of their studies (Lastusaari et al., 2019).

In Finland, data were collected through questionnaires from 733 first-year students pursuing chemistry as major or minor in four universities. Findings highlighted groups of students who "intended to change chemistry major and changed was 24%, 23% intended to change chemistry major and did not change, 10% did not intend to change chemistry major but changed, 38% did not intend to change chemistry major and did not change". However, "5% of chemistry major students dropped out and 82% of those who changed their chemistry major changed to medicine" (Lastusaari et al., 2019, p. 14).

Factors that influence dropout: Researchers explained that students' experiences influenced their persistence, for example, students who dropped out experienced a negative experience, such as insufficient learning resources, during studies while those who persisted had a positive experience such as learning from more knowledgeable colleagues. Results also showed that a practical deep approach to studying by students influenced persistence most in those taking chemistry as a major. Surface approach on the other hand, influenced students to change majors or drop out from the university. Students' course grades did not play a major role in persistence for those who persisted or changed majors but revealed those who intended to change chemistry major but did not. The major reason for changing chemistry major was the learning process. It showed that teachers who focused more on learner-centred learning approaches helped their students to perform better. According to Lastusaari et al. (2019), dropping out was not connected with learning approaches.

Students may leave the university due to failure to adapt academically and socially to the university system. Findings revealed that university conditions, academic and social integration were fundamental for explaining the high drop-out (Massi & Villani, 2015). Also, “financial difficulties, family-related or personal problems” can cause a student to drop out early or late in the year (Larsen et al., 2013, p. 5). Students’ departure from universities is also caused by “academic under-match” that occurs when students’ academic qualifications give them entry into a more selective college or university. It is based on how the college or university selection process compares to a student’s academic ability (Smith, Pender, & Howell, 2013). According to Wullur (2012), failure of students may be caused by health, finances and a discouraging learning context created by teachers. A discouraging learning environment emanates from poor teacher-student relationships and poor teacher-students (whole class) relationship. Garland (1993, p. 189 cited in Wullur, 2012) explains that “teaching-learning resources, lack of prerequisite knowledge, lack of self-discipline, decreased motivation and lack of time” contribute to student failure rates. Failure in class can generate frustrations.

Constructivism

Constructivism is defined according to an individual’s perception, interpretation and explanation of the same object and his/her position (Ültanir, 2012). It is the creation of knowledge or new understanding through the interaction of “what individuals already believe and the ideas, events and activities with which they come into contact” (p. 195). “Constructivism … is not a social or educational theory; it is both a scientific and metatheory which defines the possibility and limitations of daily life theories in the formation of humanity" (Ültanir, 2012, p. 196). Mvududu and Thiel-Burgess (2012) argue that in education constructivism is "a theory of science, educational theory or an all-encompassing world view" (p. 109). Weegar and Pacis (2012) assert that, in constructivism, knowledge is constructed through active participation in their learning. Learners possess concepts and skills with which they construct knowledge to solve environmental problems. Additionally, Brooks and Brooks (1993, p. vii cited in Ültanir, 2012) propose that constructivism is a theory that "defines knowledge as temporary, developmental, socially and culturally mediated, and thus, non-objective." It is "a synthesis of multiple behaviourists and cognitive ideas infused into one form and a process of constructing meaning and how people make sense of their experiences" (Merriam & Caffarella, 1999, p. 260 cited in Amineh & AsI, 2015). Mvududu and Thiel-Burgess (2012) suggest that teachers should put students' knowledge first and "allow them to put that knowledge into practice" since there is no universal definition of constructivism, (p. 10). Constructivism includes variations such as Piaget's cognitive development and Vygotsky's social constructivism (Weegar & Pacis, 2012). In the study, I have included radical constructivism by von Glasserdfeld (1995; 1996).

Piaget's Cognitive Development

Piaget's (1952) constructivism has to do with the individual constructing knowledge. Cognitive constructivism, the first part, is an individualistic perspective based on Piaget's theory. The theory proposes that humans construct their own knowledge and cannot be given information that they immediately understand and use. Piaget's theory consists of two parts, the age and stages, and that children understand certain concepts at different ages. According to Piaget (1952), children rely upon their perceptions during the process of cognitive development. The basis of perception are cognitive configuration and knowledge development in a person. A child's perception of the world and the decisions he/she makes are different from those of an adult (Ültanir, 2012). Piaget (1953; 1969 cited in Ültanir, 2012) listed four main stages of development of a child's mind that are the "sensorimotor stage, the pre-operational stage, the concrete operational stage and the formal operation stage" (pp. 202-203).

Cognitive development's second major part of the theory describes how children develop cognitive abilities. Piaget (1977 cited in Amineh & Asl, 2015) states that learning occurs through the active construction of meaning. A state of disequilibrium or imbalance is created whenever a learner encounters a challenging situation or task. A learner makes sense of the new information by assimilating it into the existing knowledge or schema to restore equilibrium or balance. The learner adjusts his/her schema to accommodate the new information or knowledge during the learning process. If new information fails to be assimilated, it is restructured to a higher level of thinking (Amineh & Asl, 2015).

Vygotsky's Social Constructivism

Vygotsky (1978) supported the role biological traits play in cognitive development but his focus was on social interaction. Vygotsky (1978, p. 84) contends that the process of knowing is brought about by interaction with other people and is mediated by community and culture. He further proposes that cognitive development is a product of "culture, history and social interaction rather than individual construction". He viewed cognitive "development as an historically situated and culturally determined" (Costley, 2012, p. 2). Human beings are born and immersed in an ever changing society that uses conventional tools and signs (Costley, 2012). Internalization of social interactions through language results in cognitive development. Hence, Vygotsky (1978), claims that the most important psychological tool people created to master their behaviour is language (Mvududu & Thiel-Burgess, 2012).

von Glasserdfeld's Radical Constructivism

von Glasserdfeld (1996) formulated the theory of radical constructivism that aims at proving that knowledge is not a commodity but a theory of active knowing. He further claims that knowledge is not a conventional epistemology that embodies the truth which reflects the world but that knowledge is actively built up by the cognitive objects (von Glasserdfeld, 1996). The "two basic principles" of radical constructivism, according to von Glasserdfeld (1996, p. 192) are, firstly, that "knowledge is not received through the senses or by passive communication … ". Secondly, "the function of cognition is adaptive and serves the subject's organization of the experiential world, not the discovery of an objective ontological reality" (p. 192). Adopting these two principles involves reconceptualising the idea that knowledge "to be good knowledge, would have to be a true representation of the real world" (von Glasserdfeld, 1996, p. 192). Hence, radical constructivism steps out of the conventional opinion of the world and takes a "rational view of the world" (p. 192). Contrary, the sceptics argue "that true knowledge of an objective world is impossible" (von Glasserdfeld, 2012, p. 192). Radical constructivism denies individual's experiences of the world as a possible "true representation of it" (p. 193). So, the radical, constructivist relinquishes metaphysical realism (von Glasserdfeld, 1996).

Constructivism in Teaching and Learning

The focus of constructivism is on knowing as a process and that knowledge is constructed and not found. The teacher provides opportunities and incentives to students to construct their own meaning. This leads to students directing their learning. Knowles (1975, p. 18 cited in Ültanir, 2012) determined the concept of "self-directed learning" that "takes place when individuals take the lead in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate strategies, and evaluating learning outcomes". Students' active participation, self-direction, experiences and views of the world "are critical to problem-solving education" (Dewey, 1961, p. 342 cited in Ültanir, 2012). Furthermore, students' experiences are more important than the subject matter. Dewey's stance on the student's experience is "the need to foster self-direction as a way to self-realisation of the learner, a way of recognising the voice, dignity and high self-concept of the learner" (Dewey, 1961, p. 342 cited in Ültanir, 2012,).

Additionally, in the theory of constructivism, the role of a teacher is changed to that of a facilitator who purposely and "consciously removes himself/herself from the "centre" of the classroom" by sharing the power and responsibility with the students (Ültanir, 2012 citing Montessori, 1912, p. 283). The facilitator's task is to prepare the teaching material and establish the student-teacher and student-student relationships, and an active learning context. S/he no longer has absolute authority on the course material and makes the student a centre of learning. Students are "empowered to exercise their desire and engage in learning activities" of their interest and are able to critique the education (Ultanir, 2012, p. 204). Constructivism therefore views the teacher as "a guide, facilitator, and co-explorer who encourage learners to question, challenge, and formulate their own ideas, opinions, and conclusions" (Weegar & Pacis, 2012, p. 8). Students construct new understanding using their prior knowledge. Hence, "if learning is based on prior knowledge", teachers must acknowledge that and create learning contexts that are "characterised by active engagement, inquiry, problem solving, and collaboration with others" (Weegar & Pacis, 2012, p. 8).

Constructivists stress that learners are not passive recipients of knowledge but construct their own meanings of concepts. Thus, learning, at its best, takes place in lived contexts. Knowledge is actively constructed for an extended period of time and provides opportunities for students to reflect on new experiences. Students reflect on how new experiences relate to current understanding and how different understandings create an improved view of the world (Mvududu & Thiel-Burgess, 2012).

Communities of Practice

According to Wenger (2010), the concept of community of practice (CoP) has its roots in the social nature of human learning inspired by anthropology and social learning theories of Lave (1988), Bourdieu (1977), Foucault (1980), Vygotsky (1978) Giddens (1984) (cited in Wenger, 2010). The CoP perspective locates "learning in the relationship between the person and the world, in which human beings are social persons in a social world" (Wenger, 2010, p. 1). A CoP, "from an analytical perspective, is the simplest social learning system" and, "from the instrumental perspective, may be viewed as a learning partnership" (p. 1). Learning in social systems requires making decisions "about what matters, what counts about learning, about directions and priorities" (Wenger, 2010, p. 12). Learning partnerships "may be collaborative" and harmonious" but may also be "tempestuous and full of conflict" (p. 12).

Partners work together to create high learning potential. The CoP is formed by people who share concerns or passions and build relations which enable them to interact and learn from each other. CoPs may be small or very large, they may meet face-to-face or online, they may be within an organisation, and they may be formal or informal. Some members are core and others are peripheral members of CoPs.

Research in Chemistry Education

In this section, I reviewed related literature concerning research questions of the study informed by studies in America, Canada, Japan, Mexico, the United Kingdom, Turkey, Australia, Nigeria, South Africa, Ethiopia and Zambia is presented. The purpose is to provide a contextual and conceptual basis for the study. Students' level of understanding of acids-bases is expected to increase or improve as they progress in their schooling. Teachers introduce the Arrhenius model of acids-bases chemistry to grade 9 and grade 12 level students. At university levels, students are taught Arrhenius, Bronsted-Lowry and Lewis models (Garnett, Garnett, & Hackling, 1995). Studies have revealed that at senior high school and first-year university students' different levels of understanding of Arrhenius and acids-bases reactions emerge. I have further arranged related literature cited into sub-sections to highlight its relevancy for this study. The sub-sections are studies on conceptions, misconception, interventions, open-ended problems and teaching-learning.

Teaching-learning of acids-bases. In Turkey, Ültay and Calik (2015) employed concept tests as a cognitive measure, attitude or aptitude scales and semi-structured interviews in their study that investigated the effects of different teaching designs, which were "(1) the Relating-Experiencing-Applying-Cooperating-Transferring (REACT strategy), (2) 5Es learning model and (3) traditional (existing) instruction relevant to "acids and bases" subject, on pre-service science teachers' conceptions and attitudes towards chemistry and to compare them with each other. The REACT strategy is an output of teachers' observed experiences" and is not based on theoretically designed issues (Ültay & Calik, 2011 pp. 57-58 cited in Ültay & Calik, 2015). The 5Es learning model consisted of the "Engage-Explore-Explain-Elaborate-Evaluate" stages (p. 57). A model demanded that students relate their scientific knowledge to lived life, socio-scientific or science-technology-society issues (Kurnaz & Çalik, 2008 as cited in Ültay & Calik, 2015). The third strategy was the traditional approach which used laboratory work, "talk and chalk". A total of 95 pre-service science teachers were sampled. Three groups were randomly assigned to be either experimental or controls. One sample was designed to REACT strategy, another sample to 5Es strategy and the third sample was a control group for traditional teaching design. They were all first-year students enrolled in a four-year science teacher education programme. All year one courses were compulsory included chemistry, biology and physics (Ültay & Calik, 2015).

The Acids-bases Chemistry Concept Test (ABCCT) had two-tier items divided in three sections. The section "A" of the ABCCT comprised multiple-choice tiers and "the second-tier requests indicated the reason for the first-tier response. The section "B" of "the ABCCT consisted of a multiple-choice first tier and an open-ended second tier that calls the PSTs for indicating their reasons for the first-tier response" (Ültay & Calik, 2015, p. 60).

The items of three sample are presented as follows:

"A2. HCl and NH_3 are acids. But NH_3 is a stronger acid than HCl. a) True b) False* c) No idea.

Please select your reason for choosing the option:

a) NH_3 has more hydrogen atoms.
b) The pOH value of NH_3 is greater.
c) NH_3 has hydrogen bonds.
d) NH_3, which includes hydrogen atoms, is a base. *

B4. Which of the solutions is a weak acid?

a) pH=1 b) pH=3 c) pH=7 d) pH=10 e) pH=12*

Please explain your reason for choosing the option: …………… C3. The acid strength depends on the number of H atom, whilst the base strength relies on the number of OH molecules.

a) True b) False* c) No idea.

Please explain your reason for choosing the option: ………………”

(Ültay & Calik, 2015, p. 61).

The Questionnaire for assessing attitudes and experiences (CAEQ) comprised of 69 items divided in three parts (Dalgety, Coll, & Jones, 2003 cited in Ültay & Calik, 2015) but Ültay and Calik (2015) modified it to suit the Turkish context. The modified CAEQ consisted of 14 items in three sub-groups. These are: “chemists (Items 1–6), chemistry research (Items 9–12) and chemistry jobs (Items 16–19)” (Ültay & Calik, 2015, p. 62). There were 20 questions for semi-structured interview. Interviews were conducted after the teaching intervention. The ABCCT and CAEQ were administered before the teaching intervention and after the teaching intervention. They were administered as pre-tests and as post-tests.

Analysed results revealed that post-test mean scores of REACT and CAEQ of experimental groups outperformed those in control groups while there was no significant difference in the pre-test mean scores between the groups (Ültay & Calik, 2015). There was a significant difference between the post-mean scores of REACT and control groups, and the 5Es and control groups emerged in favour of REACT and the 5Es. Results answered the first two research questions “are there any statistically significant differences between the experimental and the control groups’ conceptions of ‘acids and bases’ subject?” and “which of the teaching designs have the greatest effect on the pre-service teachers’ long-term memory of ‘acids and bases’ subject?” (Ültay & Calik, 2015, p. 65). Results for question three showed no statistically significant differences between the groups for the pre- and post-test mean scores of the CAEQ. Question three was “Which of the teaching designs positively influence the PSTs’ attitudes towards chemistry?” (Ültay & Calik, 2015, p. 67).

The results revealed that a slightly better retention of understanding of the acids-bases concepts was achieved by REACT due to connections to lived experiences. For example, a decrease or increase in the pH value of human blood may have attracted students' attention as it is important for a healthy life (Ültay & Calik, 2015). The intervention also might have influenced students' conception of acids-bases chemistry and seemed to stimulate the students' interest in the topic under investigation. Alternative conception ratio shifts were the same for the traditional and slightly increased in the 5Es models from the post-test mean scores. This may indicate that hard-core alternative conceptions that tend to cause students to be closed-minded may not be changed by teaching designs. For example, the strength of acids-bases depends on the number of H+ and OH- ions in their molecules is an alternative conception (Ültay & Calik, 2015 citing Özmen et al., 2009). The control group showed higher resistance to change than the REACT strategy and the 5Es learning model in Pre- and post-test scores. This may mean that the REACT strategy and the 5Es learning model had influenced students' retention of the strength of the acids-bases concept.

To answer research question three, the teaching interventions were found to be "ineffective in positively changing students' attitudes towards chemistry" (Ültay & Calik, 2015, p. 73). The more sensitive the structure of the CAEQ than a 4 or 5 Likert type scale could have caused the ineffectiveness (Sunger, 2007 cited in Ültay & Calik, 2015). Besides, CAEQ measures specific factors and does not measure general attitudes towards chemistry. Furthermore, school culture is that of passive recipients. On the contrary, the majority of REACT and 5Es interviewees indicated positive attitudes about the teaching interventions (Ültay & Calik, 2015).

Studies on misconceptions on acids-bases. Cooper et al. (2016) investigated students' reasoning about acids-bases reactions in America and Canada. A wide range of problems faced by students as they learn acids-bases reactions were discussed by the researchers. Students possess "misconceptions about the nature of acids-bases, have problems in the use of surface-level features to identify acids and bases and difficulties understanding how to use and move flexibly between models of acids-bases chemistry" (Cooper et. al., 2016, p. 1703). The researchers aimed at characterising ways in which students reason about acids-bases reactions and thereby develop an assessment protocol. Tasks were designed that prompted students to construct explanations about how and why reactions occur. Also, they investigated how students used to reason about Arrhenius, Bronsted-Lowry and Lewis acid-base behaviour. Similarly, Cooper et al. (2016) investigated the comparison between the ability of students' verbal mechanistic reasoning and drawing mechanistic arrows. A modified evidence-centred design (ECD) framework was used. ECD assessment development approach advocates that an assessment is an evidentially argument. There are four steps to follow when using the ECD approach which are:

1. "Define the *construct that is to be assessed or characterised* (emphasis as the original). Investigators would assess the reasoning of the student's acids-bases reaction.
2. *Decide what evidence is acceptable to support the argument that students understand the construct*. Students should be able to identify an acids-bases reaction, describe the scientific principles that support their identification, and provide reasoning about why this reaction is occurring.
3. *Design assessment tasks that would elicit the types of evidence specified in step 2.* Open-ended tasks were designed because they provide stronger evidence about student reasoning than forced-choice items.
4. *Decide how to analyse the evidence elicited in the assessment tasks*. Student's responses are compared across courses and over time to gain some measure of the

level of reasoning of the response" (Cooper et al., 2016, p. 1705).

The selected sample consisted of two groups of students. One group comprised of college students enrolled in general chemistry. The second group were enrolled in organic chemistry at two different universities. At the end of the second semester the assessment tasks were administrated. One hundred and twenty-one (121) students had enrolled in chemistry at a medium-sized public research university (university 1). The students were referred to as the SP12 group. University 2 was a large public university with one hundred and seven (107) students enrolled and were referred to as the SP15 group (Cooper et al., 2016). The groups were enrolled in transformed second-semester general chemistry curriculum which contained three models of acids-bases reactions. The assessment was "administered in the laboratory course for credit for the whole class at university 1", whereas "at university 2, it was administered as an extra credit assignment out-of-class to a representative sample of the whole class" (812) (Cooper, et al., 2016, p. 1705). Students were shown how the Bronsted-Lowry model describes all Arrhenius acids-bases reactions, but the reverse cannot. Also, how the Lewis model can describe all Arrhenius and Bronsted-Lowry acids-bases reactions but the reverse cannot.

Students were taught how to draw reaction mechanisms, simple nucleophilic substitutions, and some equilibrium reactions and biological reactions (Cooper et al., 2016). On comparing the results of the two groups of students, it was found that there was no significant difference in their final course marks. Their average ACT was different with SP12 students at 28 and SP15 students at 26. Although SP12 students had a slightly higher average ACT score, SP15 students constructed more logical explanations, therefore the groups were considered similar enough for comparison sake.

The assessment tasks were designed to prompt reasoning at the molecular mechanism level of acids-bases reactions. The tasks were designed “around simple reaction systems in which the full Lewis structures and the products were provided” (Cooper et al., 2016, p. 1706). The first iteration assessment for SP12 was administered using SurveyMonkey. The questions were on reactions of hydrochloric acid with water. Students were asked to identify the chemical reaction and explain their reasons (Cooper et al., 2016). The next step was to explain their reasoning of what they thought was happening at a molecular level. It was found that many students stated that the atoms had rearranged instead of stating why these atoms rearranged (Cooper et al., 2016). Since the three researchers wanted students to provide as much information as possible, they restructured the questions to provide relevant information to students to understand what is needed.

So, the structure of tasks was modified the next time they were administered. The same questions were administered to SP15 at the university. The iteration survey was administered using Socraticbe software. In this iteration, the explanation was separated into several prompts. Another question was added that asked students to draw mechanistic arrows for the reaction. The students were asked to describe what was happening at the molecular level of the reaction of hydrochloric acid with water and why it was happening and to draw mechanistic arrows (Cooper et al., 2016).

The analysed data revealed that, very few students in both SP12 and SP15 administrations, provided non-normative answers. In using the Bronsted-Lowry model description, students gave complete descriptions of what was happening but failed to describe how or why the reaction happened. Responses that involved the Bronsted-Lowry causal mechanism showed that some students were able to use Bronsted-Lowry model to talk about proton transfer

(Cooper et al., 2016).

The findings of the study indicated that various ways to reason about the acids-bases reactions were used by students that can be characterised using a framework. The framework allows the responses to be classified according to the model. Students who provided Lewis model responses as well as those who provided causal reasoning were more likely to construct correct mechanism arrows than students who used the same model without providing causal reasoning.

Studies on conceptions on acids-bases. Stoyanovich et al. (2015, p. A) employed an "outcome-based approach to teaching-learning" of acids-bases reactions in an introductory organic course. The approach focused on what the student is able to demonstrate after instruction and not on what the instructor teaches. According to the researchers, the first acid-base chemical reaction learned by students in organic chemistry is the Bronsted-Lowry model. Also, almost every later reaction learned demanded an acids-bases reaction step in the reaction. Organic chemistry students struggled with acids-bases reactions at the university level. Undergraduate students did not apply scientific reasoning to solve acids-bases reactions problems or incorrectly applied heuristic reasoning but did not apply mental models of organic acids-bases. Even students at graduate level, depicted poorly developed conceptions of acids-bases and analysed acids-bases chemistry using a single physical construct instead of a multivariate approach (Stoyanovich et al., 2015).

A set of learning outcomes (LOs) was developed by the researchers intended to help students to master acids-bases concepts. Students' knowledge and skills demonstrate at the end of the course are referred to as learning outcomes (Stoyanovich et al., 2015).Whilst, "intended learning outcomes (ILOs) is what the lecturer wants the students to know and do by the end of the course” (p. B).

The lecturers’ teaching and learning experiences of complex organic reactions, topics in textbooks and students’ known difficulties influenced the construction of the set of ILOs. They determined the frequency of Bronsted-Lowry acids-bases reactions occurrences in organic and biochemistry courses. Researchers examined the reactions for any presence of Bronsted-Lowry acids-bases steps in the mechanism required to generate the nucleophile or electrophile. Eighty-six percent of the 28 reactions analysed the required Bronsted-Lowry acids-bases steps in a phase of the reaction,

> “82% required an acid-base step as an integral part of the mechanism some of the time, 71% involved a Bronsted-Lowry acid-base step in the mechanism every time. In every reaction, more than 20% of reactions required an acid-base step to prepare either the nucleophile or the electrophile, and two-thirds of reactions involved proton transfers to neutralise the final product” (Stoyanovich et al., 2015, p. 8).

The analysis highlighted the need for students to master the acids-bases concept.

Next, researchers identified acids-bases related knowledge and skills required by students to analyse the mechanism of each reaction and solve problems related to acids-bases reactions. It was found that identifying or drawing a Bronsted-Lowry acids-bases, constituted 70% reactions of deprotonating or protonating a molecule, and identifying the most acidic or basic site in a molecule. Estimating the pKa of a given molecule of the reactions, predicting direction of acids-bases equilibrium and drawing a protonating base in each acid was thirty percent (Stoyanovich et al., 2015). Researchers concluded that students who have not mastered acids-bases concepts would experience challenges in 86% of the reactions at the proton transfer level.

Having identified the learning outcomes to analyse complex acids-bases reactions, researchers went on to analyse the coverage of acids-bases reactions in textbooks. Eight introductory organic and three advanced textbooks were analysed (Stoyanovich et al., 2015). They based the calculation of acids-bases coverage on subset chapters, examples and questions dedicated to acids-bases chemistry. It was found that textbooks devoted only 2% of their pages to acids-bases except for Dewick's textbook where 6% of 696 pages was devoted to acids-bases reactions. It was also found that, although there were discrepancies in the coverage of the topic, the Bronsted-Lowry and Lewis acids-bases mechanisms and pKa were sufficiently covered. This meant that the skills required for the complex organic mechanism that have acids-bases steps were covered. On the other hand, less covered concepts were determining the position of acids-bases equilibrium, pH and identifying predominant species at a given pH (Stoyanovich et al., 2015).

Following the analysis of the textbooks, the Intended Learning Outcomes (ILOs) instrument was formulated. Its purpose was by the end of the acids-bases section of the organic course, students should master the ILOs. The instructions were grounded in scaffolding theory where templates organised in a stepwise fashion were provided to the students to help them gain basic knowledge or skills (Stoyanovich et al., 2015). ILOs structure was based on the Structure of Observed Learning Outcomes (SOLO) taxonomy (Biggs & Collins, 2014) and revised Bloom's taxonomy. SOLO describes the complexity growth of a student's performance as he/she masters many academic tasks.

SOLO has five domains. SOLO 1 is a pre-structural level. At this stage, there is no evidence of learning. SOLO 2 is a uni-structural level is where the "student learns quantitative information, declarative knowledge and uses one single aspect" (Stoyanovich et al., 2015, p.

6). At SOLO 3 is a multi-scriptural level where the “student continues learning quantitative information and declaration knowledge but deals with several aspects”…. At SOLO 4 is a relational level where the student’s competence has increased, and the “student can make connections between several concepts”. At SOLO 5 is an extended abstract level where the student is able to “analyse concepts from different perspectives, generalise, create and transfer ideas to new areas” (Stoyanovich et al., 2015, p. 6).

Finally, experts and students validated the ILOs’ instrument. The ILOs list was used as a checklist for all classroom activities. The ILOs were employed to make sure that a learning opportunity had been created for every learning outcome.

Intervention studies on acids-bases and oxidation-reduction. In 2011, a study was undertaken in Australia to assess the development and implementation of a group podcasting assignment in a chemistry course in which students were all enrolled in degrees across the university faculties. The podcasting task was designed to promote deep learning for students with little prior chemistry knowledge. Three-hundred and fifty-two (352) freshmen students were participants and the programme ran for four weeks (Bartle, Longnecker & Pegrum, 2011). The tasks were prepared from the topics “acids-bases” and “oxidation-reduction” because they were major and difficult topics. Based on their assigned benches in the practical laboratory class, students were placed in groups of three. The topic of acids-bases was assigned to half the group and oxidation-reduction to the other half in each laboratory class. Students communicated with peers whilst working on the assignment through a discussion board. The groups listened to six podcasts (their own and five others) at the end of the semester. Three of these were on “acids-bases” and three on “oxidation-reduction”. Again, students assessed the podcast and 117 responses were sampled. Findings revealed that in deep learning; student engagement and improved learning were promoted. Besides pedagogical and motivational values in science were increased (Bartle, Longnecker & Pegrum, 2011).

Studies on conceptions on acids-bases. An acid is a substance that donates a hydrogen ion to a base, and a base is a substance that can accept a hydrogen ion from an acid states Bronsted-Lowry. In Japan, Munegumi (2013) drew a border line to distinguish between strong and weak acids. Acids-bases are defined differently by Arrhenius theory, Bronsted-Lowry theory and Lewis theory. However, the concept of strengths of acids-bases is understood from the proton migration of the Bronsted-Lowry theory. Using a solution's acidity of (pH), and -log of the constant (pKa or pKb), values can be compared to find strengths of acids-bases. Acids have their acid dissociation constant (Ka) and -log of the constant (pKa) values which are constant at a constant temperature. A stronger acid has a higher Ka and lower pKa. "Hydroiodic acid, hydrobromic acid, hydrochloric acid and sulphuric acid" are classified as strong acids (p. 13). The concentration of an acid influences the degree of dissociation (Munegumi, 2013). The degrees of dissociation may be a border line between strong acids and weak acids.

Munegumi (2013) did experiments to find the degree of dissociation of the acid and the pKa of hydrochloric acid, sulphuric acid, hydronium acid, nitric acid, trifluoroacetic acid and oxalic acid in different concentrations at 25^{o}C. The concentrations were 10 molarity (M), 1 M, 5 M, 0.1 M, 0.01 M, 0.001 M and 0.0001 M. To Munegumi (2013) the degree of dissociation in acid was compared at seven constant concentrations. It was found that 1 M acid had a 10% dissociation and its pKa was zero. Another acid at 1 M concentration showed 50% dissociation and its pKa was equal to negative 1.70 (-1.70). Acids that showed degrees of dissociation higher than 90% and 99% had lower pKa values of -2.91 and -4 respectively.

According to Munegumi (2013), the border line of most dissociation at different concentration levels 50%, seemed to be 90% and 99% of dissociation. At 50%, 90% and 99%, 1 M acids with a pKa of -1.70, -2.91 and -4 achieved the most dissociation. This may be a "border line between strong acids and weak acids. For example, acids having lower pKa values than -2.91 are strong and acids having pKa values higher than -2.91 are weak acids" (Munegumi, 2013, p. 14).

Munegumi (2013) further related the degree of dissociation and logarithm 10 (log10) of initial concentration (Co) for different acids. The degree of dissociation depended on the initial concentration. He compared degrees of dissociation of some acids and was able to discern strong or weak acids. For instance, hydrochloric acid with a pKa of -6 dissociated almost 100%, sulphuric acid with a pKa of -3 dissociated at 92%, hydronium ion with a pKa of -1.74 dissociated at 52%, nitric acid with a pKa of -1.45 dissociated at 41%, trifluoroacetic acid with a pKa of 0.25 dissociated at 7.2% and oxalic acid with a pKa of 1.27 dissociated at 2.3%. A virtual acid with a pKa of zero (0) and Ka 1 is the border line. Munegumi (2013) concluded that the lower the concentration influenced higher degrees of dissociation of all these acids at log 10 Co equals -3. Nevertheless, acetic acid with pKa of 4.76 did not dissociate at this point.

Text-books misconceptions. Munegumi (2013) analysed four textbooks from high schools in Japan to examine how teachers explained strong and weak acids. He analysed the following books for the description of strong acids:

- High School Chemistry 1B, published by Jikkyo Shuppan listed and described acids as "hydrochloric acid, nitric acid and sulphuric acid have a higher degree of dissociation to give many hydrogen ions. Therefore, these are strong acids showing a high acidity” (Munegumi, 2013, p. 14).

- Shintei Chemistry 1B defined an acid as “possessing a degree of dissociation near 1 (1) are strong acids” (Munegumi, 2013, p. 14). One stands for 100% dissociation, for example, “hydrochloric acid, nitric acid and sulphuric acid are strong acids” (Munegumi, 2013, p. 14). Weak acids have a degree of dissociation much lower than 1.
- Shosetu Chemistry 1B stated that strong acids show a degree of dissociation near 1 and weak acids show a low degree of dissociation.
- High School Chemistry 1 explains that a strong acid even at high concentration shows a degree of dissociation near 1 and weak acids show a lower than 1 degree of dissociation. For example, “hydrochloric acid possesses dissociation degree of 1 and acetic acid possesses an extremely lower degree of dissociation than 1” (Munegumi, 2013, p. 14). However, concentration and temperature control the degree of dissociation. A higher degree of dissociation is directly proportional to lower concentration and higher temperatures.

The findings from the first three textbooks showed that they did not consider the condition involving concentration when acids dissociate (Munegumi, 2013). Acids at infinite dilution show 100% dissociation. In this case, strong acids and weak acids cannot be distinguished. The curriculum guidelines restrict the concepts that are taught in schools. Furthermore, if pKa could be taught in school and students should distinguish strong acids from weak acids without creating gaps between high school and university.

Munegumi (2013) went on to analyse two more American textbooks that were translated into Japanese and are used in Japanese secondary schools:

- The first textbook is entitled "*Chemistry: Structure and dynamics* (5^{th} ed.)", by Spencer, Bodner, & Rickard (2012). The authors used Ka to distinguish strong acids and weak acids at 25ºC. For instance, a strong acid possesses a Ka greater than 1 and a pKa less than 0. A weak acid possesses a Ka value of less than 1 and a pKa greater than 0. Therefore, strong acids and weak acids can be classified by applying this rule. There are "shortcomings between this rule and general perception" such as trifluoroacetic which is a weak acid according to this rule but organic chemists recognise it as a strong acid (Munegumi, 2013, p. 15).
- *Organic chemistry* (5^{th} ed.) by Bruice (2006) is the second book analysed by Munegumi (2013). The author described very strong acids that have a Ka greater than 0.1 and possess a pKa greater than 1. A moderate strong acid has a Ka from 10^{-3} to 0.1 and a pKa value of 1 to 3, a weak acid has a Ka between 10-5 and 10-3 and a pKa value from 3 to 5, Ka for very weak acid is from 10^{-15} to 10^{-5} and a pKa between 5 and 15. Finally, an extremely weak acid has a Ka less than 10^{-15} and a pKa greater than 15. Bruice's (2006) reasons for the distinction between very strong, moderately strong and weak acids are not clear writes Munegumi (2013).

Munegumi (2013) notes that the effect of concentration on the degree of dissociation of acids is not mentioned in some Japanese high school textbooks. However, some university textbooks have used pKa to distinguish the strength of acids. The concept of pKa for strong and weak acids in high school textbooks must be clearly explained to students. Finally, the researcher proposed the use of pKa value to differentiate strong acids from weak acids. For example, a very strong acid would be in the lower range of pKa 1, moderately strong acid would be in the range of pKa 1 to 3, weak acid would be in the range of pKa 3 to 5 and a very weak acid would be in the higher range of pKa 5.

Teaching-learning of acids-bases. Alvarado et al. (2015) in Mexico applied Content Representation (CoRe) for teaching high school acids-bases chemistry to explore canonical

Pedagogical Content Knowledge (PCK). The research investigated how ten (10) experienced Mexican teachers designed, prepared, and organised their classes in teaching acids-bases reactions inside and outside the classroom. Alvarado et al. (2015) intended to document PCK utilising "Content Representation (CoRe), and Pedagogical and Professional experience Repertoire (PaP-eR)" that are Loughran, Mulhall and Berry methodological tools (2012, cited in Alvarado et al., 2015, p. 7). The findings were used to formulate a canonical PCK that includes the core concepts of acids-bases chemistry which was to be used in training new teachers (Alvarado et al., 2015). Researchers state that teachers, students, textbooks, syllabi, laboratories and information and communication technologies are key variables in the teaching and learning of science (Alvado et. al.,citing Mellado, 1998). Brophy (2001 cited in Alvarado et al., 2015) explains that the teacher should address the main task of supporting learning and students should learn to get understanding of central ideas. Students should have the capability to use the ideas outside of school. Brophy (2001 cited in Alvarado et al., 2015) further explains that students can make a connection with other meaningful learning if the structure and development of the content of the classroom activities is focused on the central ideas and their connections. Hence, the teacher should ensure that before starting any class or activity, "students know what they will learn and why it is important to learn it, review the subject's powerful ideas and draw attention to the objectives of the activities to be performed … and builds on prior knowledge and experiences of students" (Alvarado et al., 2015, p. 2).

PCK was proposed by Shulman (1986 cited in Alvarado et al., 2015) "as a model for understanding how novice teachers acquire a new understanding of the content and how this influences their teaching". PCK is a set of beliefs and knowledge possessed by teachers can act like a bridge between pedagogical aspects and content knowledge. Thus, PCK can be useful in training and updating of science teachers (Alvarado et al., 2015). Two methodological tools proposed by Loughran et al. (2012) were used to document PCK (cited in Alvarado et al., 2015). CoRe framework was employed in this study (PCK). According to Kind (2009 cited in Alvarado et al., 2015), CoRe is "a detailed description tabulating 'big ideas' or concepts relating to a topic being taught" (p. 18), possible difficulties with each concept, importance of the ideas and how CoRe fits in with other ideas. Ten (10) high school teachers from different schools with many years of experience of teaching acids-bases chemistry were selected. The research participants fulfilled the requirements to produce an effective PCK, which is" subject matter knowledge, classroom experience and positive emotional attributes" (Aldovarado et al., 2015, p. 10). All the teachers "were linked to the National University of Mexico" (p. 10). Questionnaires and interviews were used to collect the data. The teachers were first interviewed concerning the CoRe and the aims of the study. Next, a survey questionnaire was administered in which teachers were to define the central concepts of the subject after which they answered the eight (8) questions for each one of the central concepts. The data were analysed, and concepts were regrouped and reduced to eight central concepts. Also, comments to eight concepts were included. Alvarado et al. (2015) to analyse the responses of 10 teachers used the Magnusson, Krajcik and Borko (1999) model of five components of PCK.

At the core of understanding and teaching the subject of science are central concepts. The teacher uses central concepts to plan to teach the topic because they form disciplinary knowledge (Alvarado et al., 2015). The 10 teachers cited eight central concepts of the topic acids-bases chemistry which were "pH, the relative strength of acids and bases", "concept of acids and bases/Distinctive Properties of substances/substance/Reactivity" (p. 14). They defined the acids according to Arrhenius and Bronsted-Lowry models. The report was restricted to the core concepts that were cited more frequently and had a large amount of information in their CoRes which were pH and strength of acids-bases (Alvarado et al., 2015). The main quotes were selected to construct notes of a consensual PCK. “The first section had to do with concepts, the second with skills and the third with attitudes” (p. 17). The findings highlighted concentrations and pH relating to everyday life in section 1. Logics, mathematics, experiments and communication were listed in the second section. The third section presented teachers’ and students’ attitudes towards teaching and learning acids-bases reactions. Some teachers preferred rote learning while others paid little attention to the study of the strength of acids-bases, did not explain how different strengths of acids-bases interact and were not clear about calculations of molecules and atoms. On the other hand, students had little interest in the study of chemical concepts. They favoured rote learning without understanding the mathematical expressions. Researchers concluded that students should be involved to motivate them to learn (Alvarado et al., 2015).

Chemistry Education Research in Africa

Teaching-learning chemistry. In Ethiopia, Woldeamanuel, Atagana and Engida (2014) investigated the causes of students’ beliefs that chemistry is difficult and suggested alternative solutions to overcome these difficulties. A free-response survey was administered to one hundred (100) students and twelve (12) chemistry lecturers at the end of the semester. The responses were placed in four categories namely (i) factors that were environmentally related; (ii) factors that were course-related; (iii) factors characteristic to students; and (iv) factors that were staff related. The responses were further broken down into the most important and the most influential on success in a chemistry course by participants and three (3) teaching assistants.

The findings disclosed a lack of resources, numeracy skills and scientific language, overcrowded classrooms, student backgrounds and socio-economic conditions, staff economic conditions, teachers' ego-stocking (self-efficacy), specific feedback questions and scientific reasoning. It was proposed that all freshmen be subjected to a diagnostic test in the first week of being enrolled to identify the specific learning difficulties in which they need help.

Studies on open-ended problem-solving abilities. In 2020, Upahi and Ramnrain investigated the connection between students' working memory and their abilities to solve open-ended chemistry problems. It is believed that problem-solving provide students with opportunities to develop higher-order thinking skills (Cardellini, 2006). It is a problem because the way to the goal or answer is not yet known (Wood, 2006). Problems are either open-ended or closed-ended (Upahi & Ramnarain, 2020). Closed-ended problems consist of only one correct answer. Closed-ended problems reinforce concepts learned in the previous chapter. Whereas open-ended problems have a correct answer but are also composed of alternative possible answers. In science classrooms, teachers and students assume there is a unique answer for every problem. Hence, students may view science as a discipline to which they cannot contribute (Wood, 2006). Problem-solving in chemistry is composed of "mathematics and physics problems, stoichiometry, chemical synthesis, and chemical analysis" (Wood, 2006, p. 131). Contrary, closed-ended questions are prevalent in chemistry examinations.

Researchers (2020) employed working memory space as a theoretical framework to explore students' performance in solving open-ended chemistry problems. Working memory is thinking space. Thinking space is a psychological space with a limited capacity (Hindal et al., 2009). It is also a part of the brain where incoming information is stored temporarily. The psychological space is where “thinking, interpreting, understanding and problem-solving” takes place (Hindal et al., 2009, p. 190). Learning is influenced by fixed working memory capacity. Miller (1955) proposed that working memory can only hold seven plus two pieces of information (cited by Overton & Potter, 2011). Current information is integrated into prior knowledge thereby increasing the working capacity space.

A survey method was employed to measure students’ ability to solve open-ended problems and the influence of their working memory capacity. Six hundred and sixty-five (665) students from nineteen (19) universities in Nigeria were purposely selected based on (i) “the university must have” graduated chemistry students for at least “five years (5).” (ii) “it must be national universities commission (NUC) accredited” (Upahi & Ramnarain, 2020, p. 147). FIT instrument developed by Pascal-Leone (1970, cited in Upahi & Ramnrain, 2020)) was used to measure students’ working memory space. Chemistry open-ended problem test (ChemOPST) and FIT instruments were administered to students from selected universities. Each question was allocated ten (10) marks. Students were given one hour and thirty minutes to attempt all problems (Upahi & Ramnrain, 2020). The FIT was analysed using the Pearson product-moment coefficient. It measured the correlation between chemistry students’ scores in open-ended problems and their working memory capacity.

The findings revealed that the majority of the students scored below fifty (50) marks in the ChemOPST. The FIT ranged from seven (7) to twenty-six (26) with the majority score ranging from seventeen (17) to eighteen (18). Students who were successful in the open-ended problems scored high in FIT. Hence, a positive correlation exists between students’ working memory capacity and their ability to solve algorithmic and open-ended problems. Successful students adopted efficient retrieval systems without overloading the working memory space which reduced the influence of working memory capacity.

Studies on conceptions on chemical representation of phenomena. The study employed quantitative and qualitative methods to collect data to analyse grade 12 chemistry examination questions in South Africa (Ramnrain & Joseph, 2012). They investigated learning difficulties experienced by grade 12 students in the chemical representation of phenomena. Besides the complex and abstract nature of chemistry, multiple levels of representation to describe and explain chemical reactions pose difficulties for students (Ramnrain & Joseph, 2012). The three levels of chemical representation which are relevant to learning chemistry are described as follows: "(i) Macroscopic representation that compromises of tangible and visible phenomena. (ii) Sub-microscopic (molecular) representation such as atoms, molecules, and ions, and (iii) symbolic (ionic) representation that involves the use of "chemical symbols, formulas and equations" (Chandrasegaran, Treagust & Mocerino, 2007, p. 294). Teaching-learning requires mastering three levels of representations competence by teachers and students. Furthermore, students have to move across levels. Nevertheless, learning situations that demand transition across levels creates an overload of students' working memory space. Besides the three levels of representation, are "four bidirectional transformations. (i) Macroscopic ↔ sub-microscopic; a chemical reaction that takes place from macroscopic to sub-microscopic and vice versa" (Ramnrain & Joseph, 2021, p. 457). For instance, a macroscopic representation of the combustion reaction of magnesium ribbon burns with a brilliant light that results in ash. At the sub-microscopic level, the magnesium atoms change into magnesium ions by donating two electrons to oxygen forming magnesium oxide. (ii) Macroscopic ↔ symbolic level transformation is from tangible and visible to symbolic level and vice versa. Students may write the reaction symbolically using a chemical reaction; "2 Mg (s) + O_2 (g) → 2 MgO (s). (iii) Sub-microscopic ↔ symbolic level transformation, the transformation is from sub-microscopic to symbolic and vice versa" (Ramnrain & Joseph, 2012, p. 457). The student may explain that when sodium chloride dissolves in water, it ionises to sodium ions and chlorides ions. The reaction is represented in symbolic form: "NaCl (aq) → Na^{+} (aq) + Cl- (aq)" (p. 457). (iv) Macroscopic ↔ sub-microscopic ↔ symbolic level transformation. All three levels are involved in this transformation, for example, a description of the phenomena of the burning of magnesium ribbon in oxygen would include the "particulate nature of matter, symbols and equation, brilliant light and greyish ash" (Ramnarain & Joseph, 2012, p. 458). At the sub-microscopic level, magnesium atoms change into positively charged ions and "oxygen molecules change into negatively charged oxide ions" (p. 458). The reaction would be represented symbolically at the microscopic level as: "2 Mg (s) + O_2 (g) → 2 MgO (s)" (p. 458).

Researchers (2012) applied a classification framework for chemical representation (FCR) to assess the conceptual understanding of students in chemical representations. There were seventy-two (72) questions comprising multiple-choice, short answers, explanation type and problem-solving problems at each level. Eighty hundred (800) grade 12 scripts of 2009 which were marked were analysed and sorted according to FCR (Ranmrain & Joseph, 2012). The average performance of students provided quantitative data. The result showed that the highest performances were in the microscopic, sub-microscopic and symbolic. Students performed poorly in macroscopic ↔ sub-microscopic; macroscopic ↔ symbolic and macroscopic ↔ sub-microscopic ↔symbolic. Test items in which students performed poorly were compiled and administered to thirty (30) grade 12 students. Fifteen (15) students who performed poorly in the same questions were interviewed on their responses (Ranmrain & Joseph, 2012).

The findings revealed that students correctly connected the macroscopic and sub-microscopic levels but had difficulties in extending understanding to the symbolic levels. Interviews showed the disconnection between the levels. Students showed that they understood the half-reaction taking place. The findings also revealed that students needed to develop representational competence in chemistry learning. Additionally, teachers should engage students in the relationship between the levels (Ramnrain & Joseph, 2012).

Teaching-learning chemical structure and chemical bonding. In Zambia, a study was conducted to investigate the effectiveness of a composite use of concept maps and lecture methods on students' achievements in chemical structure and chemical bonding (Singh & Moono, 2015). Thirty-nine (39) first-year students from the Mufulira College of Education participated in the study. Participants were placed in three groups of thirteen (13) each. These were a control group, experimental group 1 and experimental group 2. Test items were used to collect data. A pre-test was given to the groups before the investigation commenced. Each group met three times per week for four weeks. Concept mapping was introduced to the experimental groups 1 and 2 but group 2 also experienced traditional methods (lecture and discussions). The traditional method was followed by the control group. After four weeks, two post-tests were administered to the groups (Singh & Moono, 2015). The results showed a significant difference in the mean scores of the groups with group 2 leading followed by experimental group 1 and lastly the control group. The results implied that combining concept mapping with the traditional strategy brings better results (Singh & Moono, 2015).

Summary of Chapter Two

In Chapter Two, threshold concepts have been described as akin to a portal, opening a new and previously inaccessible ways of thinking about ideas (Land et al., 2005). Threshold concepts are also transformed ways of understanding. The characteristics of threshold concepts, which are "transformative, irreversible, integrative, troublesome and bounded", have been presented. Liminal space as a learning space where students and lecturers negotiate learning was also discussed. I presented the limitations of threshold concepts as researchers and practitioners can be tempted to see threshold concepts as a big pattern that, if not mastered, mean that the student is doomed. University dropouts, which is at the centre of the study from different perspectives such as Spain has been presented. Constructivists' views on teaching and learning of Vygotsky's social cognitive development, Piaget's cognitive development and von Glasserdfeld's radical constructivism and their implications have been discussed. The community of practice has been described. Finally, research in science education and chemistry teaching-learning from selected countries have been discussed.

In the next chapter, I discuss theories and theoretical frameworks employed in this study.

Chapter Three

Theoretical Frameworks

Introduction

In the first part of this Chapter Three, I discuss and interrogate theories frameworks that helped me to unpack my research findings. I investigate the purpose of theories in research, the various theories used in this thesis and how I used them. I also explored how theories work like horse and its carriage in theoretical frameworks. I explore the various theories I am using; how I am using them individually and/or collectively to illuminate and unpack various aspects of the study and what is/are learned in/from the process. In the second section of the chapter, I discuss the reasons for choosing theoretical frameworks and their benefits and limitations. In the third section, I describe how the social learning theories of Piaget (1951), Vygotsky (1962; 1978), Lave and Wenger (1991), Bandura (1977), Bourdieu (1977), Kincheloe (2004) and Freire (2005) are used to explain the teaching and learning process.

Definition of Theories

According to Neuman (2014), a theory could be a logical "1) set of general propositions that establishes a connection between two or more variables; 2) an explanation of a specific social phenomenon that identifies a set of causally relevant factors or conditions; 3) provide insights into the real meaning of social phenomena by offering illuminating interpretations that tell the reader "what it is all about" ; 4) … it could be viewed as an entire worldview or ways of seeing, interpreting and understanding events in the world; 5) … it could be based on sets of belief/values from which it critiques the position and arguments of opponents; 6) it could be viewed as philosophical commentary on key questions or issues about how knowledge about the world is developed" or 7) it is a scientifically acceptable set of principles offered to explain a phenomenon" (Abend, 2008, pp. 177-181).

Characteristics of a theory. A system of concepts to be called a theory, it must demonstrate the following attributes (Madara, Namango & Katana, 2016): A theory "i) is not static; it is provisional, open to revision and grows into more accurate and comprehensive explanations about the make-up and operation of the social world; ii) stable - unchanged over a longer-cycle of time; iii) coherent - the components of the system have to be linked in a comprehensive and non-contradictory-way; and iv) consistent - it should not be possible to arrive at contradictory-claims by means of the types of derivation permitted in the theory" (Neuman, 2014, p. 57; Madara et al., 2016, p. 107). It exists at different variables and levels in social sciences. According to Trowler (2012, p. 2), "micro-level theory explains behaviour at the level of the individual or family environment". It focuses on "individuals' development such as cognition and behaviour, personality and interpersonal relationships" (Tavallaei & Talib, 2010, p. 575). Meso-level theory explains what the interactors of micro-level organisations are, for example, those in a community of practice (Lave & Wenger, 1991). It describes institutions, bureaucracies, organisational functions and structures. Macro-level theory considers behaviour at the level of large groups of people, for example, "ethnicity", "class" and "gender" (Trower, 2012, p. 3). It focuses on family issues, behaviour, teamwork and interpersonal networks (Tavallaei & Talib, 2010). These "different levels and types of theory inform decisions, processes and outcomes of research", and provide countless other theories at each level (Trower, 2012, p. 3). Yin (2008, p. 38) refers to theories at each level of research up to the "complete case study research design that embodies a theory of what is being studied drawn from the existing knowledge base" (cited in Trowler, 2012).

Purpose of theory in research. The role of theory varies as it is based on the type of research design. For example, case study research requires an "identification of theoretical perspectives at the beginning of the investigation because they affect the research questions, analysis, and interpretation of findings" (Tavallaei & Talib, 2010 citing Yin, 2008, p. 574). Abend (2008, p. 178) assert that theory "interprets", "reads" or "makes sense" of data rather than the researcher's own experiences and insights. Theories provide for "interpreting observations; they help the researcher to systematically organise research findings, "make sense of data and determine whether the data support theoretical predictions" when linked to "theories". Theories also "reflect environmental phenomena, generate new research through hypotheses or research questions and guide the research" (Trowler, 2012, p. 2). Madara et al. (2016) believe that theory and research are related as theory stimulates further research in areas in need of investigation. Theory connects "a single study" to a wide body "of knowledge to which other researchers" can "contribute" (p. 110). Researchers through theory, make connections "between the abstract and the concrete, the empirical and theoretical, and between thought statements and observational statements" (Madara et al., 2016, p. 110). Furthermore, theories explain how others see and experience the world around them; they shape how people develop "their own understanding" about the way they "work and the way the world works" (Rasmussen, 2017, p. 53). Theory is an invaluable resource in research as it makes it possible to apprehend, think and comprehend problems, formulate research questions that can interrogate these problems and offer responses that enhance the study. On the other hand, theory may cause "confusion, frustrations, discomfort, joy, shame, anxiety, stress and disorientation, as one attempts to create ideas that are new by bringing theory to a new problem" (Rasmussen, 2017, p. 57). These challenges are also encountered when different parts of existing theories are put together in order to look at a problem anew.

Researchers may experience confusion because they tend to explain issues of daily life without theories or when researchers fail to make theory clear and easy to use. Researchers may also become anxious when they encounter unfamiliar abstract ideas which are partially defined.

*Purpose of theoretical frameworks***.** Theoretical frameworks are based on existing theory in the field of studies that are related to or reflects the study. Theoretical framework is the structure which can support the theory of a research (Akintoye, 2015). Grant and Osanloo (2014, p. 12) explain "that a theoretical framework is the "foundation from which all knowledge is constructed for research and serves as a basis for rationale for the study, the problem statement, the purpose, literature review, methodology, and analysis". A theoretical framework consists of theories that undergird a researcher's view of how to conduct research. It explains why the problem is under study and the concepts that are relevant to the study (Grant & Osanloo, 2014). Theoretical frameworks consist of theoretical principles, constructs and concepts. A theory "underpins research design", by which context is investigated, evidence is gathered, "inform our understanding of the phenomenon under investigation and that which may emerge from the study" (Madara, 2016, p. 108). It provides a structure of the research, assists researchers in situating and contextualising theories, to focus on the research and make a link to the problem under study. Theoretical frameworks guide choice of research design, analysis, research approach, and make research meaningful and generalisable. Theories challenge the researcher's perspectives thereby deepening the core knowledge generated by and in the study so that it is not based on the personal instincts of the researcher but is rooted in an established theory confirmed by credible studies (Akintoye, 2015).

Importance of Cultural-Historical-Activity Theory

In this section, I discuss and interrogate theories that will helped me to unpack my research findings. Cultural-historical-activity theory (CHAT) is a practice-based approach which provides robust frameworks for analysing data (Foot, 2014 citing Julkunen, 2013). CHAT provides a “multi-dimensional systemic approach, psychological motives…, tools and dynamics of power, culture and history” (p. 320). Furthermore, researchers are enabled by CHAT to analyse “complex and evolving professional practices” so that “practitioners” can “engage in reflective research” (Foot, 2013 cited in Foot, 2014, p. 320). Therefore, analysing what people do may be viewed in the light of historical routes in which their actions take place. Activity relates to what people do individually or collectively, and is adjusted by cultural and historical patterns of interactions to convey its situatedness. Patterns generate activities; culture is the history of activities which indicates patterns of behaviours. CHAT is used as a theoretical framework “for understanding and explaining human activity” (Foot, 2014, p. 3). Core ideas of CHAT are that humans act individually and collectively and learn by being instructed and communicating through activities. “Humans” also “make, employ, and adapt tools of all kinds to learn and communicate” because “community is central to the process of making and interpreting meaning” (Vygotsky, 1978 p. 330). Individuals therefore act according to the instructions afforded them.

CHAT agrees with the dualistic views of thinking and being that are held by most theories of human action, reaction, transaction, interaction, learning and development. The agreement appears in the duality of internalisation and externalisation in dialectical relationships of the processes of socialisation. Duality states that two things can exist together and influence one another (Nunez, 2013). Activity theory is applied to study a wide range of problems to find solutions, for example, every problem is solved by activity and every solution creates another set of problems to be solved. Tools (artefacts) in activity theory aid in understanding different forms of thinking through activities. Tools are also resources that include spoken and written language through which rules and roles may be expressed. Language is both a cultural and psychological tool (Vygotsky, 1978). It is a cultural tool in the sense that it is used for the "development and sharing of knowledge" with "members of a community" (Nunez, 2013, p. 142). It is also a psychological tool "for re/structuring the processes and content of individual thought" (p. 142). Whereas other approaches concentrate on students' interactions which may not give a big picture of the ways in which students and teachers are knowing and becoming in schools (Roth, Radford, & LaCroix, 2012). Students come into the classrooms with their beings, upbringing, their knowing and knowingness. It is up to the researcher to deconstruct, construct and reconstruct it to make sense of it. These forms of sense making and the historicity of knowing influence learning.

Activity theory renders powerful tools that conceptualise individuals in their community as change agents who interact with other change agents all the time. The activity is temporal and is in a dynamic historical context. Any kind of human-human interaction is contextualised by activity (Bourdieu, 1977). CHAT is a theory for action (Engeström, 1997), set in action by action (Otulaja & Kampamba, 2020, oral communication, May 4, 2020). It is about human beings shaping their context and creating rules, roles and resources that allow them to construct, deconstruct and reconstruct activities.

Introduction to Social Learning Theories

In this process stated above, my goal is to combine appropriate teaching and learning theories within the domain of socio-cultural learning theories with CHAT or activity theory where and when appropriate. I will state the intentions of the social theories in the third section of this chapter. I interrogate the roles of social learning theories in this study accordingly.

Social Learning Theories

In this section, I interrogate the roles of social learning theories in this study. Piaget (1952, p. 7) believed that organisms fit in with their environment by adaptation through assimilation and accommodation and that this balance creates a developmental ideal that is called equilibrium that is to say, "if nothing, intervenes to modify the schemata". When the balance has been reached between a student's mental image (schemata), that was produced in response to a stimulus and the external world, the student is in a comfortable state of equilibrium. It means the student has mastered the subject matter or concepts that have been taught and are capable to perform the assigned task. When the student comes across new environmental phenomena that do not fit exactly into his/her mental schemata disequilibrium occurs. A student's curiosity draws him/her towards disequilibrium. Disequilibrium is used as a tool by the teacher to motivate students (Blake & Pope, 2008).

Vygotsky's (1978) social cognitive development theory discusses how social interaction occupies an important position in learning because it is "through social interaction that students" and "adults learn from each other" (p. 65). According to Fogarty (1999, p. 77 cited in Blake & Pope, 2008), social constructivism proposes that the learning process happens "first through person-to-person interaction "and then individually through an internalisation process that leads to deep understanding". Vygotsky (1978) explored further social, private and internal speech, for example, instructions given by adults to children are referred to as social speech. The children's processing of what the adults say and how they apply it to similar situations is known as private speech. Hence, children's self-control to keep quiet at the teacher's direction is an example of private speech. It is the teacher's and the student's responsibilities to develop students' private speech. The "internal or inner speech takes place as the student's silent, abbreviated dialogue that she carries on with self that is the essence of conscious mental activity" (Wilhelm, 2001, p. 11 cited in Blake & Pope, 2015). Blake and Pope (2008, p. 61) state that "thought is the result of social speech becoming private speech that has been internalised". Huiitt (2000 cited in Blake & Pope, 2008) explains that internalisation of the cultural signs makes humans acquire the capacity for higher-order thinking.

Piaget and Vygotsky

Piaget's (1951) cognitive theory and Vygotsky's (1978) social cognitive theory complement each other because Vygotsky added a tool of "social interaction" to Piaget's cognitive development. Piaget identified the stages of cognitive development which are "sensory-motor (infancy, 0–2 years), pre-operation (2–7 years), concrete (7–11 years) and formal (12-adult)" (cited by Blake & Pope, 2008, p. 64). Vygotsky proposed that cognitive development is as the result of social structures and social relations. He developed the concepts of Zone of Actual Development (ZAD) and the Zone of Proximal Development (ZPD) cognitive learning zones. In ZAD, "students can complete tasks on their own, there is nothing new to learn, and the students are independent" (Blake & Pope, 2008, p. 60). "ZPD is the gap between what learners can do independently and what they" cannot do without help (Vygotsky, 1978, p. 60). Students in ZPD are only successful with adults' or peers' assistance to complete the assigned task and instruction that leads to learning. Whereas, to Piaget, learning is construction, to Vygotsky, learning is appropriation (Dahl, 1996 cited in Blake & Pope, 2008). The cognitive theory of Piaget refers to stages of development and encourages hands-on-learning. Vygotsky claimed, "the activity theory calls attention to knowledge that is created in a negotiation/interaction among people and that people appropriate knowledge" (Dahl, 1996, p. 9 cited in Blake & Pope, 2008). According to Education Network (2005 cited in Blake & Pope, 2008), Vygotsky's theory gradually changes, using social contact and language, with development. Vygotsky believed that the learner, by interacting with other individuals, can connect his/her knowledge with others.

Lave and Wenger's (1991) situated learning theory suggests that newcomers or beginners should be taught in authentic contexts of daily practice by applying knowledge and making use of artefacts in low-risk ways. In situated learning, social interaction and collaboration is required within the community of practice (CoP). The notion of CoP is the simplest social learning system (Wenger, 2010) because members of the community of practice share concerns and passions for something they do and learn how to do it better as they interact regularly to learn from each other, formally and informally. However, not every group is a CoP, such as the neighbourhood.

Bandura's (1971, p. 2) vicarious or imitative learning occurs when the observers' "perception of the model's behaviour causes similar behaviour in the" observer's behaviour so that the similarity plays a role in generating the observer's behaviour. Imitation requires students to understand the goal of behaviour and that the goal can be achieved by other behaviours. It means students can achieve the same goal by employing different means. Roger and William (1996, p. x cited in Zou & Guo, 2016) further explain that imitation is

> "the ability to learn socially from others and to incorporate behaviours seen into the behavioural repertoire. It involves the connections between the behaviour we observe and the behaviour we enact ... It is how we absorb, repeat and so, become integrated with human culture".

For example, citing or incorporating other people's thoughts and information when writing a paper or a book is imitation. Imitative learning requires high-level cognitive abilities to understand the goal of observed behaviour and to select a different appropriate way to achieve the same goal (Hurtely & Chater, 2005 cited in Zou & Guo, 2016). Imitative learning requires reasoning. It is a thinking process that includes high- and low-quality argumentations. A sequence that starts in a task and ends in an answer in a form of writing and oral data is reasoning (Lithner, 2012). Memorised reasoning (MR) is found on recalling answers and writing them down, for instance, following every step of procedure or the fact that one mole of concentration equals $1000cm^3$. Algorithm reasoning (AR) involves recalling an algorithm and applying the algorithm to the task data (Lithner, 2012). All pre-specified procedures which allows one to find a definite result for a given class of problems is algorithm (Brousseau, 1997 cited in Lithner, 2012).

The general characteristics of social structure units are human beings who are connected by a complex network of social relations (Bourdieu, 1977; Radcliffe-Brown, 1940). Evans-Pritchard (1951, p. 5) refers to social structures as “persistent social groups such as nations, tribes and clans, which retain their continuity” and “their identity as individual groups, despite changes in their membership”. All social relations between persons are part of social structures such as the kinship structure of a society. Radcliffe-Brown (1940 cited in Leach, 1954, p. 4) explains that a “social structure consists of a set of ideas about the distribution of power between persons or groups of persons”. Activities are carried out by persons who comprise a social structure. The apportionment of activities is an important feature of the social structure of individuals who “seek recognition as social persons who have power or seek to gain access to office or the esteem of their fellows which may lead them to the office” (Leach, 1964, p. 28) as esteem is a cultural product. Social roles for members generate rules that govern the structure, such as who plays the roles and how they should carry out their roles. Culture and social and symbolic capitals are the products of the social structure. For Bourdieu (1984; 1989), a social space is the complex clustering of actors’ subjective positions where resources are not equally possessed and activated by actors. These inequalities of economic, cultural, social and symbolic capital determine the actors' predispositions as "distribution of potential and control is a central notion in Bourdieu's theories of social reproduction and social space" (Tzanakis, 2011, p. 3). Bourdieu argues that the dominant group control the "economic, social, and political resources whose culture" schools embrace and spills over into the classrooms (Harker, 1984, p. 118). Schools adopt the cultural capital of the dominant group and treat students as if they have equal access to it. This cultural capital is the most effective filter in the reproductive processes of all forms of capital. The adoption of the dominant cultural capital generates symbolic violence towards some students whose cultural capital differs from that of the dominant group (Harker, 1984). According to Bourdieu (1996) social formations are structured around social fields in which power structures exist. Fields are autonomous but their autonomy varies depending on the nature of the field, for example, the field of university education generates its own values and behavioural requirements in a hierarchy with agents (actors) occupying positions.

Third-generation activity theory model (Engeström, 2001) is an extension of the second-generation model. The third-generation model demonstrates how activity theory (AT) can be used in the classroom where students and teachers meet and interact to form new meanings. AT comprises interacting systems that are "mediating artefacts, subjects, rules, community, the division of labour, objects and outcomes" (Engestrom, 2001, p. 35). The subjects are designated as lecturers and students, the tools are the teaching-learning resources and the object or goal is the acids-bases reactions. The community comprises students, lecturers, the chemistry department and the school. The outcome is to ameliorate the high failure and drop-out rates of first-year chemistry students and achieve success in chemistry. The community is mediated by rules and division of labour, and the members collaborate with each other to achieve the outcome of AT (Engeström, 2001). According to Engeström (2001), the classroom is the intersection of the lecturer's and students' activity systems. The classroom has a social structure with rules, roles and resources. Students bring their background experiences to the classroom. Within the classroom, students and educators negotiate with the rules and resources collectively and individually to navigate their teaching and learning experiences.

Bricolage is a way of making what is already there both culturally and materially (Vallgårda & Fernaeus, 2015). Bricolage does not look for global optimal solutions but makes connections between the tools and materials at hand. According to Levi-Strauss (1966 cited by Kincheloe, 2001, p. 681), "the researcher bricoleurs pick up the pieces of what is left and paste them together as best as they can". Bricoleurs rectify the limitations that arise from employing a single method, the one disciplinary approach, and information missed by traditional practices of validating historical modes of knowledge production (Morawski, 1997 cited in Kincheloe, 2001). Hence bricoleurs seek new ontological insights. Levi-Strauss (1966 cited in Kincheloe, 2001) explains that, in meaning-making, bricoleurs put together artefacts of the given cultural context to construct meaning. They do not plan in advance but develop as "their processes … are flexible, fluid and open-ended" (Rogers, 2012, p. 3). They combine their imaginations with whatever knowledge tools that they have with the artefacts that are available in a given context to meet diverse knowledge production tasks (Rogers, 2012). According to Denzin and Lincoln (1999), five types of bricoleurs embrace meaning-making. These are interpretive, methodological, theoretical, political, and narrative bricoleurs. An interpretive bricoleur approaches research as an interactive process. Hence, he/she is shaped by the people in the setting. Multiple research tools are combined by a methodological bricoleur to accomplish a meaning-making task. "Theoretical bricoleurs work through, and between, multiple theoretical paradigms" (p. 6). Whilst political bricoleurs know the connections between knowledge and power and, narrative bricoleurs appreciate that reality is represented by inquiry (cited in Rogers, 2012).

Freire (2005) claims that "banking education" produces a fragmented form of knowledge that diminishes students' critical awareness and critical consciousness and causes them to adapt to the world as it is. It also minimises students' creative power and stimulates their naivety that serves the interests of the oppressors (Freire, 2005). It is often employed as a haven for most conservative and many liberal educators who hide their materialist and consumerist conception of education therefore Freire (2005) proposes critical pedagogy.

Macedo (2017) describes a practice that considers students to be undernourished with knowledge that must be filled so that they will be able to "know" and to reproduce the knowledge in the examinations and tests, while confirming the teacher's superior knowledge. In this case, it is done under the pretext that students' consciousness is spatialised. On the contrary, critical conscientisation, proposed in *The Pedagogy of the Oppressed* (Freire, 2005), is an antidote to the banking education model (Macedo, 2017). According to Freire (1970), consciousness is the ability to intervene and change but conscientisation is the process by which a person, who is a knowing subject and not a recipient, reaches a deep awareness of the socio-cultural reality on which life is built and his/her ability to transform that reality. It is a continuous process that allows a student to move towards critical consciousness (Freire, 1970) when both the teacher and students engage in dialogue and learn from each other, and the teacher learns from the students but still teaches. Freire's (2005) critical pedagogy includes collaborative learning and problem-based learning pedagogies that stimulate student engagement. The key ideas of critical pedagogy for the eradication of teacher-student contradictions are:

> “1) the teacher, teaches and the students are taught; the teacher knows everything, and the students know nothing; the teacher disciplines and the students are disciplined; the teacher acts and the students have the illusion of acting through the teacher and the teacher is the subject of the learning process and the students are mere objects. 2) Proposes problem-posing education that involves a constant unveiling of reality. 3) As students are increasingly posed with problems relating to themselves in the world and with the world, will feel increasingly challenged and obliged to respond to the challenge and 4) Education must begin with the solution of the teacher-student contradiction, by reconciling the poles of the contradiction so that both are simultaneously teachers and students” (Freire, 2005, pp. 73, 81).

Cultural-Historical-Activity Theory

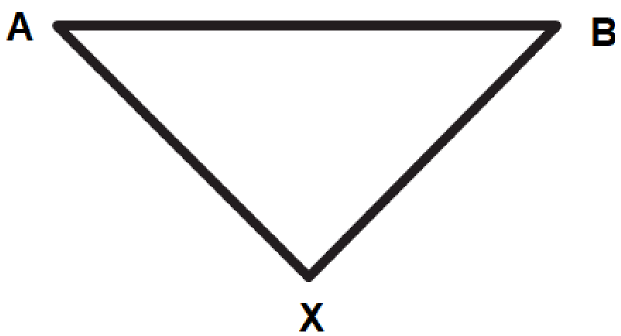
Activity Theory (AT) … is “a comprehensive model of the interrelated elements of an activity system. It provides philosophical frameworks that can facilitate the investigation, illumination, and description of a community of practice (Wenger, 1998) where people work together with shared histories of activity and discourses to achieve common goals” (Barnard, 2010, p. 26). AT has its roots in the work of Soviet Russian psychologists Vygotsky, Leont’ev and Luria (Barnard, 2010) and in Marxist theories. According to Marx, work constitutes the context for the development of human psychology. While the goal of an activity is always conscious, according to AT, the plans, motives, methods of performance and goal-directed behaviours can be formulated consciously or unconsciously (Barnard, 2010). The first generation’s conception started with Vygotsky and is characterised by the “mediated act” (Vygotsky, 1978). Activity Theory was first formulated in the 1930s by Vygotsky (1978), which was subsequently developed into a second-generation activity theory by Leont'ev (1978). Third-generation, a more elaborate model of AT (Engeström, 2001) was formulated to transform discourse communities into speech communities of practice through expansive learning. Expansive learning does not rely on acquisition or participation but on learning something which is not yet there. For example, in expansive learning, students construct their new object and concept for their new collective activity and implement this new object and concept in practice (Engeström, 2001).

First Generation Activity Theory

A dialectic relationship between the subject and society was the core of Vygotsky's theory of learning. Vygotsky (1978) formulated mediational artefacts and the genetics method to investigate mental and cultural development in order to explain interaction. Vygotsky (1978) used the term "genetic method" to describe the theory of geneticism that is the notion that the history of an individual can be used to explain the individual's form and behaviour. Subjects or individuals are social beings and the nature and possibility of "our minds depend in some deep sense on members in a community, or on our participation in culture" (Bakhurst, 2009, p. 200). Vygotsky employed the role of culturally constructed artefacts into human activity that connected the individual to the societal structure (Engeström, 2001). Individuals could be understood within their cultural means and the society could be understood within the agency of individuals who use and produce artefacts. It meant that objects were no longer raw materials for logical operations but became cultural entities and the object-orientedness of action became the key to understanding the human psyche (Engeström, 2001). Using physical and psychological tools or resources changes the environment and processes to master and transform themselves (Dang & Marginson, 2013 citing Vygotsky, 1981). According to Bakhurst (2009, p. 199), Vygotsky (1981 cited in Dang & Marginson, 2013) introduced the concept of mediation because "human behaviour is not called forth by stimuli alone but is mediated by artefacts that are created to prompt or mediate action". Vygotsky (1981 cited in Dang & Marginson, 2013) demonstrated mediation with a knot tied in a handkerchief. The knot acted "as an artificial stimulus functioning to control mental behaviour" (cited in Marginson & Dang, 2017). He showed a mediation triangle, as shown in Figure 3.0 where A and X are stimuli and B is a "point" acted upon.

Figure 3.0

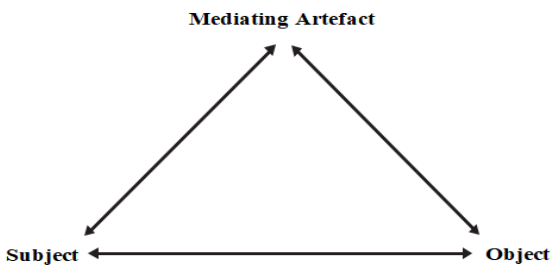
Vygotsky's Model of Mediation



Source: Sannino, 2011 citing Vygotsky, 1978, p. 40).

The first-generation models of actions were interrelated by activity theorists. Leont'ev formulated the first-generation Activity Theory model following Vygotsky's unfinished work.

Figure 3.1
First-generation activity theory's (Vygotskian) model of action



Source: Bakhurst (2009)

Vygotsky classified the artefacts into physical and psychological. The physical “tools” are those that humans used to work on nature. Psychological tools are “signs” used to transform and master themselves. For instance, a person utilises the power of the artefact or stimulus to control his/her behaviour through them, making them serve his/her purposes and give him/her the control and power that he/she wants (Engeström & Sannino, 2010). Behaviour is influenced in different ways by tools. The tool is externally oriented while the sign is internally oriented and bidirectional. On one hand, the sign is “shaping social activities, relations and the behaviour of others; and on the other hand, regulating the mental capacities and activities of the self” (Vygotsky, 1978, p. 55). The basic behaviours of the human are influenced by the environment and tools transform their relations with the environment. People have basic psychological needs that are optional for psychological development. The self-determination theory (SDT) proposes that aspects of people’s interpersonal environments and their own individual differences will affect the degree to which they are able to satisfy their basic psychological needs and sustain their growth-oriented nature (Deci & Ryan, 2012). The outcome of this ongoing interaction of people with the social context, whether supportive or thwarting, has a profound impact on their motivation, cognition, affect and wellbeing (Deci & Ryan, 2012). Vygotsky (1978) models the transformation of an individual as a continuous dialectical interaction between the biological (internal) and socio-cultural factors (external). Vygotsky (1978) explained that external artefacts are physical and psychological. The external oriented tools created changes in objects and assisted in mastering nature. Usually, tools were unidirectional and had secondary effects on the mind. Contrary, signs were “internally oriented”, “a means of internal activity aiming at mastering oneself” (Vygotsky, 1978, p. 55). A sign was bidirectional, whilst shaping the relations of social activities, and the behaviour of others, it was regulating the mental capacities of the self.

Phylogenetic domain of nature and human society in the cultural-historic domain are in a dialectical relationship. The dialectical approach explains that nature has influence on a human and, in turn, the human affects nature and “creates through his [sic] change in nature new natural conditions for his existence” (Vygotsky, 1978, p. 60 cited in Marginson & Dang, 2017). Likewise, Vygotsky states that continuing interactions between biological and socio-cultural development model the formation of the child. The relationship between nature and human is dialectical. In this case, the “individual interacted with the social domain in the dialectic of subject and society” (Marginson & Dang, 2017, p. 7). On the other hand, Vygotsky maintains that the process of the historical human behaviour and the process of evolution are not a continuation of each other.

Tools help in mastering nature. There are three kinds of artefacts: primary, secondary and tertiary artefacts. Primary artefacts are physical objects such as needles, axes, and bowls that are used to produce the means of existence and the reproduction of species. Symbols, rituals, utterances, and dances are secondary artefacts that are created for preserving and transmitting skills in the production and use of primary artefacts. “Tertiary artefacts are imaginary and relatively autonomous worlds such as works of art or the imaginative domains” (Dang & Marginson, 2013 citing Wartisky, 1979, pp. 201–209). Vygotsky proposed four general fundamental genetic domains through which behavioural development passed. These stages are “phylogenetic domain (humans undergoing natural evolution), the cultural-historical domain (the social settings of human activity), the ontogenetic domain (the individual life span) and the microgenetic domain (immediate events)” (Dang & Marginson, 2013 citing Wartisky, 1979). Activities are in constant interaction with activities in another domain which are “phylogenetic or natural domain, human society domain and cultural-historical domain” (Marginson & Dang, 2017, p. 13). The role of social experience being central in human development was emphasised by Vygotsky. His reasoning was illustrated with a child’s early speech development efforts to contact others and join in social conversations. First experiences of speech lay patterns in the child’s mentality (Dang & Marginson, 2013). In the zone of proximal development (ZPD), the child builds the capacity for more advanced activities in conjunction with another person. In this way, subject formation is shaped by forms of social organisation and relations of power around the child. A limitation is that the unit of analysis focuses on individual action.

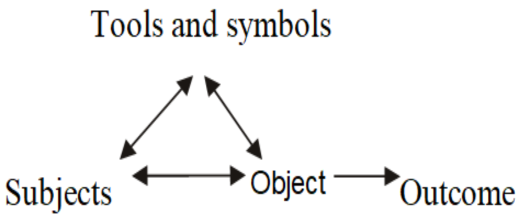
Second-Generation Activity Theory: Leont’ev

Due to untimely death of Vygotsky, Leont’ev, his student, expanded Vygotsky’s work. “Leont’ev formulated what” is … “known as the first-generation of Activity Theory” (Barnard, 2010, p. 27). He characterised activity theory by expanding the unit from individual actions to collective activities. Leont’ev used the “primeval collective hunt” to demonstrate the distinction and complex relationships between individual actions and collectively (Sannino, 2011).

> “When members of a tribe are hunting, they individually have separate goals and they are in charge of diverse actions. Some are frightening a herd of animals towards other hunters who kill the game, and other members have other tasks. These actions have immediate goals, but the real motive is beyond hunting. Together these people aim at obtaining food and clothing—at staying alive. To understand why separate actions are meaningful one needs to understand the motive behind the whole activity. Activity is guided by a motive” (Sannino, 2011, citing Leont’ev, 1978, pp. 62–63).

Figure 3.2

The Original Model: Activity Theory



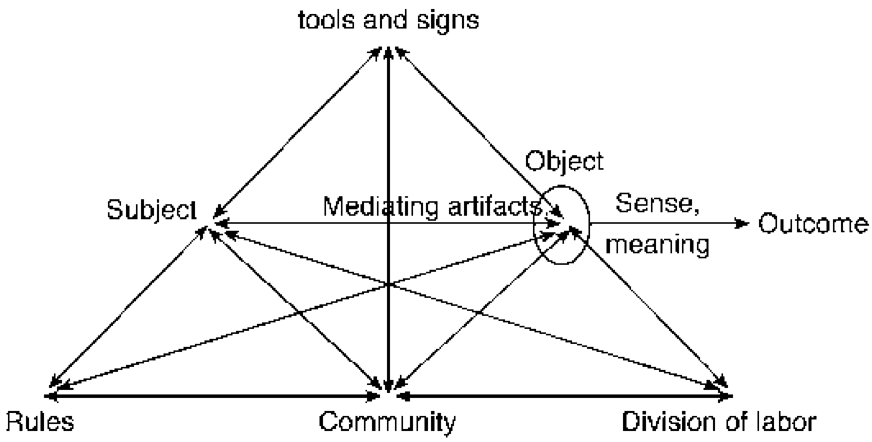
Source: Barnard (2010 citing Leont'ev, 1978)

"The subject is the individual or group engaging in the social activity chosen for investigation", such as the "hunter collaborates with others using tools (spears, knives, bush-beaters, etc.) and symbols (spoken and non-verbal language) to mediate the joint venture, the object of which is the prey". The desired outcome "is the transformation of the prey to the killed beast" (Sannino, 2011, citing Leont'ev, 1978, p. 1999). The object of other subjects would be the dead animal who would using appropriate tools and symbols skin, clean and cook the animals. The intended outcome is to provide food for community members (Barnard, 2010, citing Leont'ev, 1978). There are three notable features which are classified in the order of their functions: 1) Activity is significant, which means that it is an individual's motivation; 2) an individual's motivated activity is communal; and 3) the activity is systematically "broken down into actions, and actions into operations, all serving to achieve the overall aim/objective" (Barnard, 2010, p. 27).

Teaching activity at any level of education is systematic and socially constructed. In the classroom, the role of the teacher consists of the following: teaching; setting the rules and roles of the classroom; giving assignments; writing on the whiteboard or giving a Power Point presentation; asking and answering questions; giving feedback, etc. (Barnard, 2010). There are no teachings without students' community and communities of practice (CoP) among teachers (Wenger, 1998). In a CoP, members share and construct experiences, attitudes, knowledge, and research (Barnard, 2010). The teachers may be members of professional associations, which are also communities. They share journals, books, and conferences. All the work of these social communities hinge on the teachers and other members of the communities, such as theorists, textbook writers, publishers, and textbook users. These factors make up the teaching, learning and research activities whose goals are also socially and culturally determined and fulfilled. Since teaching, learning and research activities are universal human activities, values on the goals and the means of attainment of the intended outcomes within the contexts of the specific activity system are different due to cultural diversity (Barnard, 2010). However, Leont'ev graphically expanded Vygotsky's model into a collective activity system which he represented as follows in Figure 3.3, which the researcher believes can be expanded.

Figure 3.3

The human activity system structure



Source: Engeström (1987, p. 78).

According to Engeström (2001), Leont'ev's top sub-triangle may be the "tip of the iceberg" representing individual and collective (group) actions embedded in a collective activity system. The object indicates that object-oriented actions are either explicit or implicit and are characterised by “ambiguity, surprise, interpretation, sense-making, and potential for change” (Engeström, 2001, p. 134). However, the concept of activity turned the focus on complex interrelations between the individual and his/her community. Furthermore, societal activity systems in Soviet Union studies were largely limited to play and learning among children. Cole (1988; 1984 cited in Engeström, 2001) reveals the deep-seated insensitivity of the second-generation activity theory toward cultural diversity. Questions of diversity and dialogue between different traditions or perspectives are serious challenges, internationally. The third-generation activity theory deals with these challenges (Engeström, 2001).

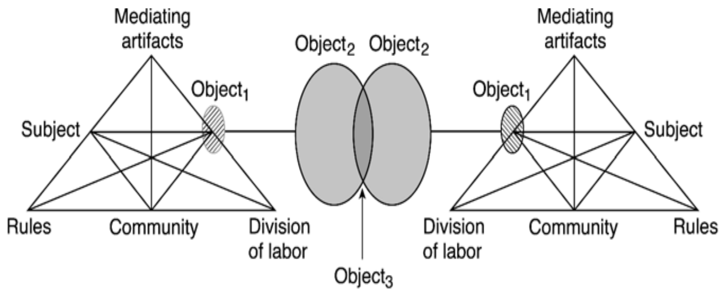
Third-Generation of Activity Theory

First-generation activity theory’s discourse was of higher psychological functions. Whereas second-generation activity theory was insensitive to cultural diversity. The third-generation activity theory must deal with these challenges (Engestrom, 2001). “Third-generation activity theory” longed “to develop conceptual tools to understand dialogue, multiple perspectives, and networks of interacting activity systems” (Engeström, 2001, p. 135). Engeström (2001) cites researchers who have attempted to develop such conceptual tools that include Bakhtin’s (1981; 1986 cited in Engeström, 2001) ideas on dialogically. Bakhtin’s ideas and Leont’ev’s concept of activity and notions of activity networks (Russell, 1997 cited in Engeström, 2001) and Lateur’s (1993 cited in Engeström, 2001) actor-network theory were put together by Engeström (1995). Engeström et al. (1995) elaborated on the concept of boundary crossing in activity theory, for instance, the concept of the “third space” to account for events in classroom discourse (Engeström, 2001 citing Gutierrez et al., 1995). The classroom is “where self-sufficient worlds and scripts of the teacher and the students meet and interact to form new meanings that go beyond the evident limits of both” (Engeström, 2001, p. 136). In this research, to include a minimum of two interacting systems the original model was expanded as in Figure 3.3 (Engeström, 2001).

Yamazumi (2007) explains the model (Figure 3.4) of how two activity systems collaborate. Yamazumi (2007) discussed an example of the collaborative project to form of a “new school” to enhance the after-school learning of young children and community organisations. The two separate activity systems work together to educate the child who undergoes a cycle of “expansive” learning (Barnard, 2010). Engeström (2001) relates this transformative process to Vygotsky’s zone of proximal development (ZPD). Transformation requires mutual collaborations between the subjects and across the two activity systems. Furthermore, the two separate communities of practice have to adjust various elements (Barnard, 2010). This results in the contact zone becoming one merger reducing the risk of working at cross-purposes rather than collisions of harmony and the dissonance of proximity rather than distance. The transformative learning is a by-product that occurs within the co-constructed activities between the two systems. The two systems, which are merged into a single community of practice, form a new transformed activity system that conjoins aspects of both. The dynamic nature of interactions between individuals and institutions is a cross-cultural contact zone that Homi Bhabha (1994) termed “third space” consisting of “hybrid” between two cultures.

Figure 3.4

Two interacting activity systems as a minimal model for the third generation of activity theory



Source: Engeström (2001)

Engeström's (1987) model of activity system is a graphic representation of the expanded unit of analysis of the second-generation activity system. Furthermore, the third-generation activity system encompasses relations between multiple activity systems (Sannino, 2011).

> "The object of activity is continuous motion and not reduced to conscious short-term goals. The object moves from an initial state of unreflected, situationally given raw material to a collectively meaningful object constructed by the activity system and to a potentially shared or jointly constructed object" (Engeström, 2001, p. 136).

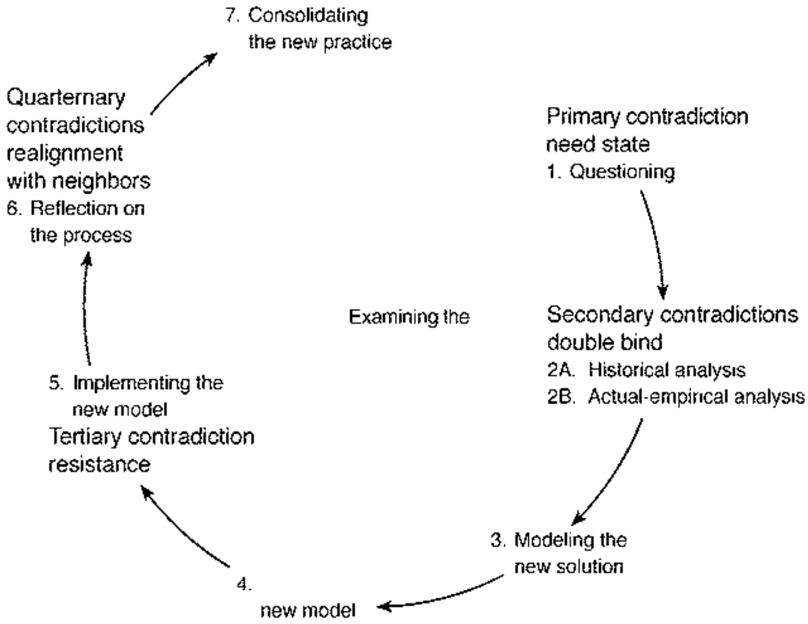
Five principles summarised the activity theory: (1) the prime unit of analysis consists of "collective, artefact-mediated and object-oriented activity systems" where goal-directed individuals, group actions and operations are relatively independent. These activity systems, by generating actions and operations, realise and reproduce themselves; (2) "the multi-voicedness of activity systems" (Engeström, 2001, p. 135). Activity system may be viewed as a community of practice unified in which the constituent elements are interconnected at all levels. According to Barnard (2010), a division of labour may exist in a CoP according to the members' respective knowledge, skills, and experiences. The division of labour refers to both the "horizontal allocation of tasks between community members" and the "vertical distribution of responsibilities, status and power" (Barnard, 2010, pp. 28-29) because "[a]n activity system is always a community of multiple points of view, traditions and interests" (Engeström, 2001, p. 136). Participants carry their own diverse histories and the activity systems are engraved in their own artefacts, rules, and conventions (Engeström, 2001). (3) Activity systems are shaped and transformed over periods of time. The local history of the activity could be studied to understand their problems and potentials. (Engeström, 2001); (4) Contradictions play a central role of promoting change and development. Contradictions are "structural tensions within and between activity systems" (Engeström, 2001, p. 137). When new elements from outside influence or are adopted in the activity systems, the old elements collide with the new ones. This generates disturbances and conflicts as well as affordances to transform the activity; (5) the possibility of expansive transformations in the activity system is proclaimed. As the tensions in an activity system aggravates, some individuals may begin to question and deviate from established norms. This may lead to collaborative envisioning of collective change efforts (Engeström, 2001). According to Engeström (2001, p. 137), "an expansive transformation is accomplished when the object and motive of the activity are reconceptualised to embrace a radically wider horizon of possibilities than in the previous model of activity". A collective journey through the zone of proximal development (ZPD) of the activity may be used to understand a full cycle of the expansive transformation. Engeström (2001;1987, p. 174), defines ZPD as "the distance between the present everyday actions of the individuals and the historically new form of the societal activity that can be collectively generated as a solution to the double-bind potentially embedded in the everyday actions".

Expansive Learning

Theories of learning are focused on the process of an individual's change in behaviour after acquiring knowledge and skills that are stable and reasonably defined. In tackling the challenges in the processes of transformations of personal lives and organisations, Gregory Bateson (1972 cited in Engeström, 2001) described his three levels of learning theory. In Learning I, through conditioning, people acquire deep-seated rules and patterns of behaviour characteristics which occur in contexts of instrumental reward and instrumental avoidance. Learning I and Learning II occur concurrently, for instance, in a classroom where students learn how to please the teacher, how to pass the examinations, how to belong to the group, how to ask questions, how to write assignments, etc. In Learning I, students learn the "hidden curriculum" (Engeström, 2001). In Learning II, pressure is generated in the process of Learning I (Bateson, 1972 cited in Engeström, 2001). Pressure creates the agency to make corrections to change the set of alternatives from which choice is made or to change how the sequence of experience is punctuated. Bateson (1972 cited in Engeström, 2001) interprets Learning II as a phase where individuals or a group begins to question the logic and meaning of the context and to construct an alternative context. Similarly, Learning III is a learning context of Learnings I and II. Bateson (1972 cited in Engeström, 2001) reveals that Learning III could be difficult and rare. It can also be dangerous and some fall by the way. The theory of expansive learning develops Learning III into a systematic framework. Engeström (2001, p. 139) states that "Learning III is seen as a learning activity which has its own actions and tools". The object of expansive learning is entire activity system in which the students are engaged in activities. "Expansive learning activity produces culturally new patterns of activity" (p. 139). Figure 3.5 depicts the expansive learning cycle.

Figure 3.5

The Expansive Learning Cycle



Source: Engeström (2001)

Reasons, why in this study activity theory is employed. Activity theory is an interdisciplinary and international activity movement, which is applied in a variety of organisations to understand human life and development and to create conditions for their improvement (Lompscher, 2006). This is because people are social beings, they exist as they create and recreate the conditions of their own lives. They do not only adapt to the world surrounding them, but they also change it through activities. Activities are how humans form relationships with the world. Their interactions are mediated by objects, methods, norms, values, or knowledge of previous generations. Vygotsky (1978, p. 141 cited in Marginson & Dang, 2017, p. 6) believes that "all phenomena are in motion and subject to change and should be investigated in terms of their origin and development". He further asserts that since cultural artefacts are "inherited from ancestors" who "inherited them from their ancestors", "behaviour can be understood as the history of behaviour". It is through these transformations that people reveal and reflect on the conditions, regularities, irregularities, and contradictions in nature and life. Activity theory may assist in understanding classroom activities such as subject to object, subject to resources, and subject to subject relationships. The subjects are students and their lecturers who are involved in teaching-learning of threshold concepts of acids-bases chemistry. Objects are the classroom and the university at large. There are computer-based software tools, videos, whiteboards and the subject of acids and bases chemistry (Plakitsi, 2013).

The third-generation of activity theory, which is concerned with understanding and modelling of networks of the activity system (Plakitsi, 2013), is being used in this study to understand the academic activities that generate high failure and drop-out rates of first-year chemistry students. The participants are members of multiple activity systems within the university's chemistry class of first-year students. Hence, for example, every participant in group A, who engaged in one activity system is also influenced by other activity systems nested within the chemistry classroom and other chemistry classes, within the university in which these students/groups participate/cultivate. The framework intends to illuminate some of the causative agents of difficulties lecturers and students experience in teaching-learning of acids- bases reactions thereby assisting in answering my research questions.

Associated Social Learning Theories

Swank, Garrison and Richardson (2009) explain that inquiry and community are at the core of Dewey's (1938) educational philosophy, which states that an individual's development is dependent on the community. Inquiry is a social activity and, through collaborations, individual learners actively construct and confirm meaning. Similarly, Campbell (1992, p. 38

citing Dewey, 1884) claims that humans are social creatures whose identities and fulfilments are rooted in communal participation. Humans are “bounded together in associations, whether domestic, economic, religious, political, artistic or education” (Campbell, 1992, p. 33). Dewey further discusses “that the education process has two sides”, the “psychological and sociological, and that neither can be subordinated to the other or neglected”. Knowledge is a social condition and it is important to help students construct their own learning. Thus, instruction must focus on the child as a whole by giving attention to the social environment of the classroom and the selections of collaborative learning activities (Swank et al., 2009) because we learn to be human by living with human beings and our cognitive development depends on motivation. This collaborative constructivist approach has been further explored in social learning theories (Swank et al., 2009). The constructivists argue that constructivist pedagogical approaches and community are essential for creating and confirming learning (Swank et al., 2009). Now, I discuss the theories of social learning by different philosophers.

Lave and Wenger’s Situated Learning Theory

According to Lave and Wenger (1991), learning is a socio-cultural phenomenon rather than just the acquisition of knowledge by individuals. Learning is a social process. Situated learning means that learning is experienced and mediated through relationships with community members. In the “community of practice”, members “interact with each, shape the ways in which work and play are produced, their meaning, and the skilled, stylised relations among old-timers to which newcomers aspire” (Lave, p. 76). Individuals learn as they participate and interact with the community, for example, “with its history, assumptions and cultural values, rules, and patterns of relationship; the tools at hand …” (Besar, 2018, p. 51 citing Haferkamp & Smelser eds., 1992; & Kozulin et al. eds., 2003). Situated learning explores the relationship between learning and social situations in which activities occur

(Lave & Wenger, 1991). Situated learning posits that students learn more by actively participating in learning experiences. It creates meaning from the real activities of everyday life, where learning occurs relative to the teaching environment. Field trips, cooperative education and internship experiences, music and sports halls for physical education and laboratories and child-care centres that are used as classrooms are examples of situated learning activities that replicate actual work settings in which students are immersed and "actively involved in addressing real-world problems" (OTEC, 2007, p. 1). Hence, the student is "situated" in the learning experience and knowledge acquisition becomes part of the learning, its context and the culture in which it is developed and used" (Oregon Technology in Education Council [OTEC], 2007, p. 1). In addition, students construct their meaning from the experiences they bring to the learning situation.

Social interactions and kinaesthetic activities are the drivers of successful situated learning experiences. It also focuses on the type of social engagements that provide an enabling context for learning to take place. For example, a newcomer is less experienced than experts in a certain field. This is referred to as "Legitimate Peripheral Participation" (LPP) and the newcomer is a Legitimate Peripheral Participant (LPP). LPP is the process by which a newcomer works her/his way towards full participation. The learner, who is entering a community of practice, is also a member of a community of other learners sharing in the process. The teacher is an expert with skills and knowledge of the field of study. Becoming a full member occurs when a newcomer participates in a community of practice, first as a legitimate peripheral participant but, as time progresses, is drawn inwards and becomes more engaged and more complex (Lave & Wenger, 1991). At first, an LPP is challenged with less demanding tasks that are productive and necessary to achieve the goals of the community of practice. Learners develop conceptual understanding by participating with experts in problems related to their real-world activities. Finally, the students' roles change from being an LPP to an expert as they become more active and immersed in the social community where learning often is "interactional rather than deliberate" (OTEC, 2007).

Possibilities of situated learning theory. Critics argue that situated learning theory ignores students' diversities such as race, social class, gender, different abilities, prior knowledge and socio-cultural contexts. These differences influence the process of learning and teaching within and outside the classroom (Besar, 2018). The interactions between students and the lecturer cause constraints and affordances for students. Students' backgrounds may conflict with the classroom culture such as the teaching approaches of the lecturer, lecturer's subject knowledge, students' knowledge levels and learning paces. During activities, students who possess much lower subject knowledge may find it difficult to contribute as fully as others who have higher subject knowledge. Fenwick (2001) suggests that learning is not a knowledge substance ingested and applied but it is the process of participation in the immediate situation. Unsupervised classroom contexts could reinforce notions of values and strategies that constrain individual and/or collective participation. For example, some students, called "target" students, could criticise other students during student-student interactions causing trauma and preventing them from active participation. Target students monopolise class discussions and receive a disproportionate amount of the teacher's attention (Martin, Milne, & Scantlebury, 2006). According to Tobin (1988) cited in (Martin et al., 2006), typical target students are high achievers who are extensively involved in classroom interactions by responding to teacher questions and providing information. Eventually, target students generate social and cultural capital and isolate themselves from their peers, which leads to the formation of cliques within the classroom that marginalise some students by minimising their access to the teacher and other students. Some clique members can be rude to other students and may make fun of them (Martin et al., 2006). The second category of target students comprises risk-takers, active participants and self-initiated interactions that attract teachers by calling out and raising their hands.

Reasons for engaging in situated cognition. The science domain comprises abstract concepts that are often difficult to comprehend and teach. Most of the teaching is done out of context, especially in a third-world context. For instance, my study of acids-bases, the theories of Arrhenius, Bronsted-Lowry and Lewis, which I term threshold concepts in chemistry, are often explained in abstract ways. I explore the learning of acids-bases reactions as it is connected to the learners' life world, local context and issues of practice that have meaning for local societies (Lotz-Sisitka, 2010). Moreover, students as LPPs, know how they construct meaning from the experiences that they bring into a CoP. Learning is teamwork that includes students' progress and growth, for example, solving problems, and students working together on tasks designed by the lecturer in the classroom. I apply the observations and interviews in interpreting activity theory regarding the rules, roles and resources available to stimulate social context in the classroom. I discuss Piaget's cognitive development as relates to cognitive constructivism below.

Cognitive Development (Constructivism)

Accommodation is part of the learning process that enables learners to change prior ideas in order to take in new ones. New schemata (cognitive structures) may develop during the process, for example, a child seeing a dog with four legs for the first time. The child assimilates this information into his/her schema for dogs. At this point, s/he might believe that all animals with four legs are dogs but later the child learns that cats also have four legs. The child then undergoes the process of accommodation in which the existing schema for dogs changes and s/he develops a new schema for cats (Piaget, 1951). Thus, accommodation involves transforming existing knowledge. Only new information that is intelligible is compatible with prior knowledge which is then integrated into the mental structure. Incompatible experiences, interactions and information result in conflict or disequilibrium in the schema that is a learning stage involving shifting new schema and adapting old schema (Piaget, 1951). For example, first-year students possess prior knowledge from home and prior disciplinary knowledge that crosses boundaries into the university experience as new information. Some of these new experiences and ideas are easily accommodated in their schemata while others are incompatible and result in disequilibrium. This is the learning stage of the student that draws new information to assimilate with existing information. Assimilation, as proposed by Piaget (1951), is when information or experiences are accommodated in the existing schemas. The process of assimilation modifies experience or information to fit within pre-existing knowledge. Assimilation and accommodation are learning processes and work simultaneously.

Affordances of Piaget's constructivist theory. Learning occurs when cognitive, conflicts exist when the students' beliefs, culture and prior knowledge do not match the observed reality and a disturbance in the student's cognitive structure is produced. How the student resolves the conflict is unpredictable (Schunk, 2012). When the cognitive conflict is too great, it triggers equilibrium. The equilibrium is triggered if current information conflicts with previously formed mental structures (schemata). If new information is incompatible with previous information and the schemata does not make sense of the incoming information, this results in a cognitive conflict. This situation leads to disequilibrium and a person becomes uncomfortable. Once the schemata adjust to integrate the new experience successfully, a cognitive equilibrium balance is achieved (Bormanaki & Khoshhal, 2017).

Learning is optional when the cognitive conflict is small because current information must be partially understood to cause cognitive changes. For example, in higher institutions of learning, first-year students come from diverse academic and socio-cultural backgrounds and they bring their diversities into the classroom. The instructor exposes all students to the same teaching method and teaches subject content at a higher level (university level) that may create too great a conflict for some students to mediate. For example, threshold concepts (key ideas) that are central to the discipline, are like doors opening up new and previously inaccessible ways of thinking but when students are struggling to master key concepts, they may not be able to proceed to learn higher concepts (Cousin, 2006). This is where some students may seem to be "stuck" and fail to proceed to the next level of learning because they were unable to resolve the conflict through assimilation and accommodation.

Rationale for engaging Piaget's constructivist theory. This theory is very applicable to my study as learning is a process of acquiring and generating new information, particularly the threshold concepts of acids-bases. Students' existing concepts and understandings may cause difficulties in learning new concepts especially if they are alternative. Nevertheless, prior knowledge is a steppingstone to complex concepts such as teaching from known to unknown and simple to complex. The approach makes accommodation and assimilation of information easier for the students. If concepts are too complex and beyond the students' cognitive abilities, they fail to integrate into the schema and may withdraw. Thus, during my data collection, in my lesson observations, I noted how the lecturer (educator) presented the threshold concepts and how the students responded because of their prior knowledge of the theories of acids-bases. I used the theory to discuss the lecturers' and students' conversations, and interactions between student-student and student-lecturer in a diverse learning context. In the next paragraphs, I discuss social cognitive development.

Social Cognitive Development

At the heart of Vygotsky's (1978) theory "lies the understanding of human cognition and learning as social and cultural, rather than an individual phenomenon" (Kozulin, Gindis, Ageyer, & Miller 2003, p. 1). Vygotsky's (1978) collective learning further stresses the importance of cultural, historical and social interaction in shaping a child's development and learning that modifies experiences or information to fit within pre-existing knowledge. Vygotsky's social cognition purports that the human child develops in the context of a culture in which s/he is immersed. The culture includes the family, society and school environment. The culture teaches the child what to think and how to behave (Vygotsky, 1962). Children succeed in applying a social attitude to themselves when they develop a method of behaviour or psychological tool for guiding themselves that had previously been used in relation to another person, and organise their own activities according to a social form of behaviour (Vygotsky, 1962). For example, a learner at school may decide whether to learn or not and when to learn in each space and time therefore the learner has been influenced by the culture of the classroom. On the other hand, the learners may collectively learn from each other and construct their own meaningful learning. The time and space structural is based on social relations between learners-teachers, learners-learners themselves, schools and their surroundings. A school cannot force a student to learn even though the structure is controlled and can accommodate them.

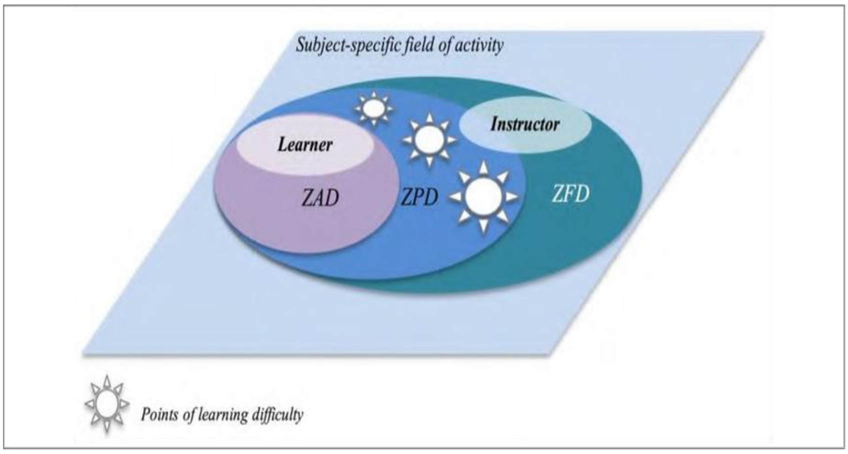
Possibilities with/of social cognitive theory. Vygotsky (1978) raises the dialectics of cognitive development and social development relationship in the zone of proximal development learning processes. He regards shared experiences as essential to implement scaffolding as a learning tool. David (2001, p. 107) states that "scaffolding is a form of adult assistance that enables a child or novice to solve a problem, carryout a task or achieve a goal which would be beyond his assisted efforts" (cited in Blake, 2008). Scaffolding simplifies the role of a learner rather than the task and serves as an instructional function through apprenticeship as the novice works closely with experts. ZPD occurs in cultural settings and can transform learners' cognitive development (cited in Schunk, 2012).

Vygotsky's (1978) Zone of Proximal Development (ZPD) posits that "any function in the child's cultural development appears twice, in two planes. First it appears between people as inter-psychological category, and then within the child as an intra-psychological category" (Kozulin et al., 2003, p. 1). Scaffolding (mediation) happens when an adult or an able peer of the learner assists the learner to overcome a difficulty in learning what s/he was not able to learn on her/his own, for instance, when a teacher verbalises her/his thinking as s/he solves a quadratic equation on the chalkboard/whiteboard. According to Vygotsky (1978), mediation may take a series of developmental events depending on the level of difficulty of a task and ability of a learner. Vygotsky (1978) differentiates between the Zone of Actual Development (ZAD) which is the actual level of development achieved independently by solving a problem and the potential level of development (ZPD) reached with the guidance of another's expertise. Productive teaching and learning can occur within these levels (Mahn, 1999).

ZPD is a stage of mastering concepts that are new and difficult. Liminal space is like ZPD. Liminality is a state of suspension in which understanding is fully grasped (Meyer & Land, 2003). It is a more of a liquid space, simultaneously transforming the learner and being transformed by the learner as he or she moves through it (Meyer & Land, 2003; 2005). Figure 3.6 depicts the various developmental events of a learner in ZPD/liminality.

Figure 3.6

Representation of the zones of development



Source: Based on Zaretskii 2009, p. 82. Taylor & Francis Ltd. ZAD: Zone of Actual Development; ZPD: Zone of Proximal Development; ZFD: Zone of Far Development (cited in Thompson, 2019).

Possibilities of social cognitive theory. Piaget (1962 cited in Subero, Llopart, Siques; & Esteban-Guitart, 2017) established " a continuity between the non-human world and the human world through assimilation and accommodation", which allows an "adaptation to the environment guided by … the equilibration of cognitive structures" (p. 2). Vygotsky (1978) differentiated between external inter-individual control and personal intra-psychic control. According to Vygotsky (1993 cited in Subero et al., 2017, p. 3), "the creation and use of signs and symbols" is a fundamental feature in regulating one's own and other people's behaviour which allows "development, transformation and integration of the lower functions into the higher psychological processes" (Subero, 2017 et al., p. 3). Piaget contends that there is no dialectic relationship between human behaviour and the environment, but it is culturally conditioned or mediated. Humans manipulate the environment "to amplify, extend and regulate their physical and psychological faculties" (p. 3). Physical objects and observable patterns of behaviour such as routines and social practices are material instruments required to manipulate the environment. Besides abstract knowledge, beliefs and values are symbolic instruments.

Despite social cognitive theory's limitations, peer-assisted learning in ZPD fits well with constructivism. Peers who display academic excellence can motivate others in the social environment (Schunk, 2012). Peer collaboration reflects collective activity or learning when students work in groups. Group-shared interactions serve as an instructional tool as shared experiences are essential to implement scaffolding as a learning tool.

Rationale for engaging social cognitive theory. The school is nested in the society and has a culture distinct from the society that is fundamental to human mental functioning. In this study, I used social cognitive theory as a lens to see the flow of information from lecturer to students, from students to lecturer (educator) and collaborative learning engaged in by both students and lecturers (Blake & Pope, 2008). These activities enabled me to observe the challenges that both students and lecturers experienced in teaching-learning threshold concepts in acids-bases reactions. As all students experience ZPD at one stage or another, mediation assists them to master difficult concepts. The theory assisted in discussing the findings and in interpreting the structure of the learning context. I discuss social learning theory of Bandura in the following section.

Vicarious (Imitative) Learning

Much human learning occurs vicariously. Imitating is the replicative modelling of others that is the simplest form of cognition and is a form of teaching-learning mechanism. All animals that visualise, vocalise, recognise and replicate actions are capable of imitating (Otulaja, 2020 – verbal communication). Chatting, listening, acting, etc. are the common media of vicarious learning. Vicarious sources accelerate learning. Vicarious learning arises from learning experiences that resulted from reacting to stimuli generated by the self or another. According to Bandura (1977), this is accelerated only if the learner must perform the behaviour in order to learn.

Social learning theory is concerned with how people learn from one another within a social context (Bethards, 2014). Learning by vicarious experience has been labelled imitation, observational learning, copying, social facilitation, vicarious learning, contagion, identification and role-playing. Vicarious-learning experiences and response-guidance procedures involve both symbolic and live models (Bandura, 1965). The diversity in constructs reflects the distinctions between descriptive terms based on certain stimuli, and mediating or terminal-response variables even though the same learning process is involved (Bandura, 1965). Hence, the terms imitative, observational and vicarious learning are employed interchangeably to describe behavioural modifications resulting from exposure to modelling stimuli. Vicarious-learning is one in which

> "new responses are acquired, or the characteristics of existing response repertoires are modified as a function of observing the behaviour of others and its reinforcing consequences, without the modelled responses being overtly performed by the viewer during the exposure period" (Bandura, 1965, p. 3).

Not all vicarious experiences are direct and not all observations are vicarious. So, the term vicarious observation learning is introduced (Hoover, Giambatista, & Belkin, 2012). Bandura and Carroll (1985, p. 269) describe "vicarious observational learning" (VOL) as "a method in which all learning phenomena result from direct experience by observing other people…". In management education, VOL is a learning process where vicarious observation is the initial component of the total learning activity followed by direct experience with the activity itself. Merriam-Webster.com defines vicarious as "experienced or realised through imaginative or sympathetic participation in the experience of another" (cited in Hoover et al., 2012, p. 594). Bandura (1962) defines observational learning as the learning that occurs simply by observing a model's behaviour.

Cognitive demands are placed on people who are directly experiencing a task, as opposed to lighter demands placed on the observers (cited in Hoover et al., 2012). Modelling observational learning is governed by attention, retention, reproductive and motivational processes. Modelling or observational learning can establish behavioural response patterns to enable the observer to reproduce the model's behaviour (Bandura, 1971). Attention processes are based on how the observer perceives and becomes aware of learning opportunities (Hoover et al., 2012). There must be the active involvement of the learners' minds with the experiences of others. This engagement process can enable the learner to identify with the experiences of others. On the other hand, retention processes do not happen when a model's behaviour cannot influence the observer unless the observer has a memory (Bandura, 1971). In this case, the response patterns must be represented in memory in symbolic form to reproduce a model's behaviour. Two representative systems, the imaginal and the verbal, are involved in observational learning. For instance, a name is always associated with a person's physical attributes. Verbal coding is the second representational system which is the long-term retention of modelled contexts by humans. Verbal coding can require a refrained and reproduced route traversed by a model through verbal coding the visual information into a sequence of right and left turns (Bandura, 1971).

Motor reproduction processes involve symbolic representations that guide overt acting. A learner puts together a given set of responses or skills according to the modelled pattern to achieve behavioural reproduction. Finally, reinforcement and motivational processes refer to the importance of reinforcement in learning which may be activated into overt performance. If negatively sanctioned or unfavourably received, these would not activate positive incentives unless learning is promptly translated into action (Bandura, 1971). Reinforcement regulates and influences the overt expression of making behaviour.

Possibilities with vicarious or imitative learning. Persons learn much by imitation or observation by paying attention and recognising the essential features of the model of action being taught that include exposing students to models or to instructors demonstrating a task. Children may not imitate actions incompatible with their schema but may imitate actions they understand (Schunk, 2012). Learners are less likely to stray from their cognitive comfort zones because they may be conservative before engaging in the task (Hoover et al., 2012). However, elements possessed by the student can easily be integrated to produce new patterns of behaviour. On the other hand, if the components of the responses, which are developed by modelling and practice, have subskills that require complex performances, faulty behaviour reproductions may be generated by observing the desired behaviour in an individual from an idea of how response components must be combined and temporarily sequenced to produce new behavioural configurations (Bandura, 1971).

Rationale for engaging in vicarious learning. The curriculum consists of many complex concepts which are key ideas that are central to a discipline and may be difficult to grasp by most students. Vicarious learning is mostly applicable in university settings with large numbers of students in lecture theatres where the most common mode of teaching is the use of PowerPoint and demonstrations. Both formal and informal interactions between the students and the lecturer could be considered as vicarious or observational learning as, individually or collectively, students observe the lecturer or fellow student explain and demonstrate how to solve chemistry problems. Later, students may retain and imitate the observed actions, with the learners motivating their own behaviour toward orientation with that of the model (Bandura 1971). Interpersonal and intrapersonal interactions occur during vicarious learning. Sharing experiences and knowledge with one another generates collective learning and enriches individual cognitive acquisition. Also, the concept of LPP is covered where the newcomers learn from the experts until they also become experts. The theory of vicarious learning was compatible with the study and helped to interpret, analyse, and explain the results of classroom video recordings and students' focus-group interviews. I discuss Bourdieu's notion of social reproduction in the following paragraph,.

Social Reproduction of Bourdieusian Concepts

Preamble of Bourdieusian concepts. Bourdieu's theory (1977) of exclusion maintains that students from the "working-class and cultural" minorities, "on average, fail in the school system" because the school system is based on social and cultural practices of the middle class (Nash, 1990, p. 436). Dominant groups "define what is taken to be legitimate meaning" (rules, language, subject matter, pedagogy, etc.) (Bredo & Feinberg, 1979, p. 316). In this way, they influence schools. "Schools reproduce the power structure indirectly by" organising "their day-to-day" activities" in a way that is consistent with" legitimate "meanings" (Bredo & Feinberg, 1979, p. 316).

The content of school culture and the curriculum may be regarded as arbitrary. Bredo and

Feinberg (1979) assert that "something is arbitrary when it cannot be deduced from any universal principle, and thus cannot be shown to be logically or physically necessary" (p. 317). In this case, the school's effectiveness to transmit culture is weakened. On the contrary, if the the school culture is middle-class, working-class students are in a culturally unfamiliar place and are unable to benefit as much as middle-class students (Nash, 1990). According to Bourdieu (1974, p. 41 cited in Nash, 1990), students from lower working-class "do not bring to school work either the keenness of lower-middle-class children or the cultural capital of upper-class children" but rather "take refuge in a kind of negative withdrawal which upsets teachers". Negative withdrawal is due to cognitive structure and behavioural inclination which are influenced by class culture. Bourdieu contends that the school's inability to respond to lower working-class students as they are considered not to be "ready" for schooling contributes to social and cultural reproduction, thus, their logical counteract to this neglect is to withdraw (Nash, 1990). Furthermore, the school's failure to develop a culturally specific pedagogy (universal) that is inclusive may have succeeded in excluding unprepared working-class pupils.

The level at which legitimate receivers learn influences teaching methods in schools. Students who possess the cultural prerequisites to successfully learn are referred to as legitimate receivers (Bredo & Feinberg, 1979). Habitus is a "theory of socialisation" but it is limited and is produced by pedagogic work. Habitus is also a "theory of practice and action" (Nash, 2012, citing Bourdieu, 1971, p. 192). Its function in social reproductions is to generate "a long-term, stable element which is passed on from generation to generation" (Bredo & Feinberg, 1979, p. 319). Hence, through pedagogic work groups reproduce themselves and the dominant group maintain its status thereby increasing moral and intellectual integration. Broader social system are maintained by pedagogic work. Simultaneously, pedagogic work creates legitimate consumers (employers) who recognise, appreciate, and utilise the product (Bredo & Feinberg, 1979). This perceives the value of the products such as a student's intelligence in so doing conceals the cultural frame that helped shape it. Thus, pedagogic work establishes that less dominant groups accept that their cultures are categorised with less legitimacy than the dominant one when different groups have been instructed to a certain degree in habitus. In so doing, "power structure is maintained through the use of internalised controls" (Bredo & Feinberg, 1979, p. 320). Pedagogic work corresponds to socialisation. Bourdieu and Passeron (1977) define pedagogic work as a process of inculcating that which lasts long enough to produce desirable training (cited in Bredo & Feinberg, 1979). In this case, "pedagogic action is objectively symbolic violence" as it involves the "inculcation of meanings that are culturally arbitrary by a group whose power is also arbitrary" (Lakomski, 1984, p. 154). Teachers teach as though students possess the same level of symbolic skills thus, do not adjust teaching methods and criteria to suit the subcultures. Consequently, teachers treat children equally thereby indirectly maintaining inequality. Hence, punishing working-class children twice since they lack the social and cultural capitals of the dominant culture" by which they are measured and evaluated (Lakomski, 1974, p. 155).

Social reproduction. Bourdieu (1977) "argues that education plays important" roles "in" perpetuating "the reproduction of social inequality and social exclusion" (Bourdieu & Pesseron, 1977, p. 110). Cultural capital is transferred from home to school and "then used to reproduce the power structure" (Bredo & Feinberg, 1979 p. 316). Teachers' pedagogical "actions promote the cultural capital of the dominant class" (middle and upper class) in the curriculum, code of conduct, language and dressing while students from the working and lower classes are at a disadvantage (Bourdieu & Pesseron, 1977, p. 110). Thus, the school social excludes and reproduces social structures as the poor and working-class students fail to adapt to the middle-class culture. However, if teachers apply culturally relevant pedagogy by not being judgmental and including the cultural backgrounds of their students in teaching and learning, this may ameliorate working-class students' failure to adapt to the middle-class culture (Brown-Jeffy & Cooper, 2011). "Bringing the relevance of the text to the child's own experience helps the child make sense of the world" and is important to students' academic success (Jordan, 1981, p. 150 cited in Brown-Jeffy & Cooper, 2011). The relationship between school and students' cultural and social capitals that they bring with them to school, demonstrates the value of individual students.

Bourdieu (1986, p. 243) suggests that cultural capital can exist "as a embodiment of the mind and body". Cultural capital embodies "external wealth converted to an integral part of the person, into a habitus," and therefore "cannot be transmitted instantaneously … by gift or bequest, purchase or exchange" (1986, p. 244). These practices and dispositions are transmitted to children through a long-life process of family socialisation. Habitus reflects a class position or the actors' location in a variety of fields and is geared to the perpetuation of structures of dominance (Bourdieu & Passeron, 1977). Bourdieu (1986) argues that knowledge and possession of "highbrow" culture is unequally distributed on the basis of social class and education. Those who possess and deploy highbrow culture has legally institutionalised it and confers distinction and privilege.

Schools also recognise the value of highbrow culture and reward it, for instance, students who are exposed to an elite culture (computer, books, private tutors, etc.) at home are advantaged in schools. This advantage is recognised and rewarded by teachers through assessment and leadership thus excluding poor and working-class learners. Poor and working-class learners are forced into a competition that rewards only the dominant cultural capital thereby subjecting them to a form of “symbolic violence”. Nonetheless, pedagogic action is accepted as meritorious and legitimate by peripheral participants. Teachers are accused of being biased in their grading of student educational performance on the basis of the culture that is related to competences rather than scholastic performance. Therefore, schools reproduce forms of intergenerational social mobility and stratified outcomes. Scholars (DiMaggio & Mohr, 1982; Mohr, 1985; Bidwell & Friedkin, 1988; Iwin, 2009; Porles, Fernadez-Kelly, & Waller, 2009 cited in Tzanakis, 2011) have proposed that Children’s educational success is influenced by parental cultural capital since the school culture is controlled by the dominant cultural capital. Whereas family legacy which is transmitted intergenerational affects students’ educational success in later life. On the contrary, Goldthorpe and Sullivan (2007 as cited in Tzanakis, 2011) argue that children’s ability and parental contribute to social class differential in educational performance. Thus, there is room for a family cultural effect to influence children’s development.

Critics have argued that parental social class and cultural capitals appear circular and that net ability does not depend on occupational reputation and cultural capital on student academic success (Tzanakis, 2011). Hence, parental cultural capital does not mediate a student’s cultural capital. Parental cultural capital varies over time that it affects the child’s transition from high secondary to college (Tzanakis, 2011). Parental cultural capital offers a partial explanation for children’s academic achievement. A father’s cultural capital cannot influence a child’s academic attainment that can also be related to subject domains such as science but his conduct can. If the student believes that the family is not good at science subjects therefore s/he will not be able to excel.

The school and teachers. The classroom has a structure (Engeström, 1994) of “tools, rules and roles". According to Cole and Engeström (1993, p. 82), the basic structure of human cognition that results from tool mediation has been depicted as a triangle. The moment the student walks into school/classroom s/he is part of the "activity system" with its standing "rules, community and division of labour". The student recognises the roles of the teacher and students. Hence, s/he learns that, when to speak, how to speak, when and how to ask questions and to get permission to leave the class, are the rules. There are also rules of participating in activities. The timetable, arrangement of the tables and chairs and subject matter are tools and the roles are their activities. The participants play according to the rules and their roles. Nolan (2011) explains that, like a game, social fields have specific structures and rules and players accept and follow these rules for the smooth running of the game. Players come to terms with the rules and do not question them as they continue to engage in the game. "Social fields are competitive, with players continually vying for better positions and more refined skills" (Nolan, p. 204). Similarly, Wenger (1990) observes that "to assess learning, we use tests with which the students struggle in one-to-one combat, where knowledge must be demonstrated out of context and where collaborating is considered cheating."

Culture also plays a role in the learning process. For instance, African culture is communal, and students learn from each other, and the Western culture is individualistic where students may work in groups but do tests individually. This Westernised kind of learning has been imposed on African culture. The study by Dill and Boykin (2000, p. 454) found that communal learning was "superior to both peer and individual criterion" learning. The results showed that "communal orientation is a valued aspect of African American culture, at least for" low-income African American children" as reported by earlier scholars (Albury, 1991; Jaynes, 1987, p. 20 cited in Dill & Boykin, 2000). Communal working provides the learners with opportunities to cultivate their own strategies and behaviour to facilitate learning. Furthermore, the students were prepared to do a group project again. This could be mean collaborative orientation and interdependence (Albury, 1991; Jaynes, 1987 cited in Dill & Boykin, 2000).

It has been proposed that African Americans have a cultural reality that is based on both African cosmology and the historical and contemporary experiences of being Black in America. African ontology is communalism in which there is a sense of belonging, hold things in common and responsibility to one's group. This orientation is contrary to Western culture which is individualistic. Individualistic defines "self as independent and autonomous of the group" and "where personal goals are given priority" (Triandis, 1996, p. 6 cited in Dill & Boykin, 2000).

The classroom environment is heterogeneous (upper, middle, working and lower classes) to which students must adapt. McKinnon (2011) explains this in terms of "natural selection" as Spencer (1897, p. 244) applied it to education. Natural selection is the way an organism adapts to its environment. Spencer wrote that "the preservation of varieties of plants or animals that succeed better than their allies in coping with surrounding conditions is the continuance of vital movement in those directions where the obstacles to it are most eluded". So, every student has a duty to adapt to a new environment (McKinnon, 2011).

Possibilities of the Bourdieusian social reproduction theory. Students' success in educational transitions has been found not to depend on parents' cultural capital. A father's social class or cultural capital effects does not mediate the children's cultural capital. Cultural capital "is a credit, it is the power granted to those who have obtained sufficient recognition to be in a position to impose recognition" (Bourdieu, 1990a, p. 138). Besides, access to capital depends on one’s position and status in the field. The school curriculum reflects the dominant cultural capital. A student who has been exposed to a dominant cultural capital at home would be in a better position to access the school cultural capital. Also, a teacher “who have a privileged position and have learned how to play school well, have an investment in perpetuating and reproducing logic and operations of the field as it is” (Nolan, 2011, p. 204). The school does not possess its own power to shape consciousness over and above the power of the family. Instead, the school is active in its legitimation of family (Lakomski, 1984). Schools “serve to reproduce social inequality as long as it performs this sorting function in society, it produces winners and losers” (Landson-Billings, 1995 citing Villegas, 1988, p. 262). However, critics argue for viewing schools as conservative rather than liberator institutions. The students are subjected to the same objective testing procedures and inequalities in educational outcomes are considered on the basis of individual differences and merit. So, failure depends on the capability of an individual and should be accepted as “fate”. Similarly, success is considered as natural for both the students with cultural capital and the subordinates (Lakomski, 1984). Bourdieu and Passeron’s (1977) social reproduction theory eliminates human agency but claims that abstract and invisible power determine reproduction. While symbolic violence assumes a melanistic and one-dimensional character. The reader is left with a theory of socialisation.

Rationale for engaging a Bourdieusian social reproduction theory. Bourdieu’s (1977) theory includes the cultural, social and symbolic capitals of students that enrol in the university. Bourdieu (1977) stated that “cultural capital is a resource” and “can be converted into economic and social capital to exclude others from advantaged social positions” (cited by Jæger & Møllegaard, 2017, p. 132). Students, unknowingly or actively knowingly, acquire cultural capital from their parents (Jæger & Breen, 2016) or from their peers and their schools where they convert it into educational performance. This affects the teacher's perceptions of the students' academic abilities that can lead him/her to improve or neglect the students (Jæger & Breen, 2016). But students "differ in their ability to convert cultural capital into educational success" (Jæger & Møllegaard, 2017, p. 132) even though they experience the same teaching style, curriculum and learning content. Bourdieu (1965) proposes that returns on cultural capital are higher for students with a high socio-economic status than for those with a low socioeconomic status. However, the cultural mobility hypothesis (DiMaggio, 1982 cited in Jæger & Møllegaard, 2017) contends that returns are higher for low socio-economic status children because they face less competition in the schooling contexts that they inhabit.

Students who enrol in the university chemistry department come from diverse social, cultural and academic backgrounds. They bring into the classroom their culture, funds of knowledge and prior knowledge of chemistry. Likewise, teachers bring into the classroom a "culture different from that of their students, resulting in cultural clashes that can potentially lead to gaps in learning" (Brown-Jeffy & Cooper, 2011, p. 68). The classroom has its own culture (norms and values) and structure that guide the teaching-learning process. The teacher navigates the classroom to meet students' learning needs. Bourdieu's (1977) cultural reproduction theory is applied in interpreting students' abilities to convert their cultural capital into academic success depending on how they play their roles (cited in Jæger & Møllegaard, 2017). The structure of education may create constraints and affordances in learning. How the structure of the classroom influences students' agency or passivity depends on either the individual's cultural capital or the lecturer's cultural capital or both. The socio-cultural reproduction theory assisted me to interpret, analyse and discuss the classroom structure, lecturers' (educators) questionnaires, students' and lecturers' interviews, and the students' roles and abilities in converting their cultural capital into success in chemistry.

Kincheloe's bricolage is presented in the following section.

Kincheloe's Bricolage

The term "bricolage" was employed by cultural anthropologist Levi-Strauss (1966) in "his search for underlying structures that govern human meaning-making" (Rogers, 2012, p. 2). Since then, the bricolage metaphor has been applied outside structuralist circles (Rogers, 2012). Denzin and Lincoln (2011, p. 4) adopted the bricolage metaphor and proposed that "methodological practices of qualitative research may be viewed as soft science, journalism, ethnography, bricolage, quilt making, or montage". Education researcher, Berry (2004) developed the concept of bricolage further. They explained it as a process of getting down to the "nuts and bolts" of multi-disciplinary research. It can also imply the fictive and imaginative elements of the presentation of all formal research (Kincheloe, MacLaren, & Steinberg, 2011). Thus, bricoleurs move beyond their disciplinary boundaries and peer through conceptual windows to new worlds of research and knowledge. A bricoleur, according to Berry (2004), is "a handyman or handywoman who makes use of the tools available to complete a task" or a carpenter who creates a masterpiece using all the available tools (Kincheloe, 2004, p. 1).

Kincheloe (2008, p. 78)) sees knowledge production through singular method and mono-disciplinary approaches that are "detached from the socio-historical" context in "which they are shaped". These mono-logical approaches put constraints on knowledge production and overlook the dynamics of power that refers to the functional roles of administrators, education policy, teachers' and students' roles. Hence, mono-logical methods are inadequate to study phenomena in education. Kincheloe (2008, p. 74) further explains that "contexts, relationships, and politics all play complex mediating roles" in education, for instance, employing standardised testing procedures before and after pedagogical interventions. Standardised testing is then used to evaluate the effectiveness of the new pedagogy. According to Kincheloe's perspective, the research treated research participants as objects of inquiry and removed them from their context which shaped them (Rogers, 2012) as Berry (2004) explains, "the empiricism of using one methodology or even one single theory presents only a partial answer to the original research question" (p. 105 cited by Rogers, 2012) because the home culture, classroom structure and social culture influence learning.

In answer to mono-logical methods, Kincheloe (2005) adopts a critical emancipative pedagogy. He proposes that bricoleurs adopt a symbiotic hermeneutic process that allows the bricoleurs to become aware of the objects of inquiry and connect to things-in-the-world. "This means that bricoleurs seek out ways that phenomena are interconnected with other phenomena, and socially constructed in a dialogue between culture, institutions, and historical contexts" (Rogers, 2012, p. 11). Similarly, Tobin (2014, p. 9) claims that "different perspectives may reflect different positions and we accept social life as polysemic, characterised by many social truths".

Possibilities of bricolage. The concept of bricolage is a multi-method mode of research, but it has not been developed in detail (Kincheloe, 2005). Bricolage is a "process of getting down to the nuts and bolts of multidisciplinary research such as ethnography, discourse analysis, theatrical and dramatic ways of observing and making meaning" (Kincheloe, 2005, p. 323). Multi-disciplinary research demands that the researcher acquires a new level of positionality and becomes aware of various social contexts in which s/he is operating. The researcher-bricoleur is focused on his/her position in the diverse community of researchers, in which they "inform, support and critique each other" based on social locations and concerns (Kincheloe, 2005, p. 4). Bricoleur moves into the domain of the complexity of the lived world. The epistemology of complexity is the ground of bricolage. “All observations of the world, either consciously or unconsciously” are shaped by social theory and “provides the framework that highlights or erases what might be observed” (Kincheloe, 2005, p. 324). The “task of the bricoleur is to” break “this complexity, uncover the invisible artefacts of power and culture, and document the nature of their influence on their scholarship as well as scholarship in general” (p. 326). The task engaged in by the bricoleur demonstrates that “theory is not an explanation of nature” but explains our relationship with nature (Kincheloe, 2005, p. 326).

Bricolage is a complex domain. Researchers actively construct their research methods from the tools at hand, rather than passively receive the correct universally applicable methodologies (Kincheloe, 2005). As an active agent, it explores findings in similar situations of other researchers. Similarly, bricolage refuses homogeneous modes of knowledge (Young & Yarbrough, 1993 cited in Kincheloe, 2005). So, researchers in active bricolage bring their “understanding of the research context together with” their “previous experience and research methods”. Using this knowledge involves “construction and reconstruction, contextual diagnosis, negotiation and readjustment” (Kincheloe, 2005, p. 325). In the light of this construction and reconstruction process, bricoleurs act as methodological negotiators in the research. Lincoln (2001 cited in Kincheloe, 2005) describes two types of bricoleurs as those who a) are involved in a wide range of research allowing circumstances to shape research methods employed; and b) engage in disciplines of genealogy or archaeology.

The rationale for engaging bricolage. Bricolage brings together different sources of data. Metaphors such as “weaving, sewing, quilting, montage and collage” can be used to describe the process of producing bricolage (Wibberley, 2012, p. 6). Levi-Strauss (1972 cited in Kincheloe, 2005) asserts that the bricolage research approach does not always follow the tradition of using only what is already in existence but utilises a diverse range of data. This makes bricolage an acceptable inclusion in my academic work. The material collected is explained, discussed and made transparent. In this case, a variety of data from lecturers’ interviews, questionnaires, students’ interviews, and classroom observations are utilised to provide an understanding of chemistry failure rates among first-year students.

Bricolage is used in qualitative research methodology to generate data (Gbadegeshin, 2018). As a bricoleur researcher, I engaged in various research strategies and research instruments to understand the causes of challenges lecturers experience in teaching threshold concepts of acids and bases reactions. Likewise, I investigated students’ experiences in learning acids and bases chemistry. The bricolage research method allows researchers “to understand in depth what [they] are seeing, hearing and experiencing, and to derive new knowledge from documents or artefacts” (Gbadegeshin, 2018, p. 104) as it is oriented towards social change. I intended to construct and reconstruct responses from the participants and develop new approach towards ameliorating of first-year chemistry students’ high failure and drop-out rates. I present critical pedagogy in the next paragraphs.

Affordances (possibilities) of Critical Pedagogy

Critical pedagogy is a philosophy of teaching-learning which was framed mainly by Freire (2005) whose work formulated a “pedagogy of the oppressed” that is “an emancipatory form of adult education that at it [sic] centre dialogue, equality and a questioning of the status quo in order to create social transformation” (Earl, 2013, p. 8). It explores the dialogue relationships between teaching-learning. It is a continuous process of traditional schooling in "learning, reflection, evaluation, and the effects that these actions have on students (Freire, 2005).

An anti-authoritarian and interactive approach that aims at examining issues of relational powers for students and educators is at the heart of Freire's pedagogy. Power is negotiated daily by teachers and students in classrooms. The curriculum is centred on social and political critiques of everyday life. Freire's goal of implementing educational practices and processes was to create a better learning environment and a better world. Critical pedagogy encourages students to think critically about their education and to recognise connections between their individual problems and experiences, and the social contexts in which they are embedded. In the light of critical pedagogy, students must question the curriculum, the resources available and the teaching-learning process. Critical pedagogy advocates that teachers learn about the students' personal and academic work lives, their authentic language and the degrees of alienation they have experienced, and base courses on students' experiences (Freire, 2005).

The relationship between banking education and oppression explores the role schools play in social reproduction. According to Freire (2005), education has become an act of depositing in which the teacher narrates and "makes deposits which the students patiently receive, memorize and repeat" (p. 72). The banking concept of education "turns students into containers or receptacles to be filled by the teacher" (Freire, p. 72). A good teacher is one who completely fills the receptacles, and good students are those who meekly permit themselves to be filled. Therefore, the pedagogy of the oppressed aims at changing the consciousness of the oppressed and not the oppressive situation. Freire (2005) proposes that the solution is not in integrating the oppressed into the oppressive structure but in transforming that structure so that they become their own beings. Freire's ideology is to transform schooling by treating classrooms as social spaces for the analysis of social life and the practice of more democratic forms of thought and action. He directed his writings to those who, knowingly or unknowingly, engaged in banking education and similar pedagogical methods (Freire, 2005).

The principles of critical pedagogy are influenced by the seminal works of Dewey's educational concepts of progressivism. Education, according to Dewey (Dewey, 1897, para. 1), is the "participation of the individual in the social consciousness of the race". Dewey (2013) feels that education should reflect the community because it is a social construct and it is a part of society. Hence, instruction must focus on the child as a whole for the teacher can never be sure where society ends or where that student will be needed or will take them. Freire (2005) refutes that it is not "about training" or teaching methods or political indoctrination" is pedagogy of the oppressed at its best that it should be imposed on students. On the contrary, it is

> "a political and moral practice that provides the knowledge, skills, and social relations that enable students to explore possibilities of what it means to be critical citizens while expanding and deepening their participation in the promise of a substantive democracy" (Giroux, 2010, p. 716 citing Freire, 1994) .

Freire (2005) further proposes that critical consciousness has the ability to intervene in a situation to change it. Freire (2005) describes critical consciousness as a socio-political tool that causes students to question the nature of their historical and social situations. It implies equity in which students and teachers "learn, question, reflect, and participate in meaning-making" (p. 81). To understand the concept of conscientisation is to see a person as a being that exists in and with the world. The agent for conscientisation is a conscious being. People, are conscious beings, are in the world and, together with other people, are active agents who transform the world. People transform the world through the creation and recreation of nature. This process leads to conscientisation which is, according to Freire (1970), the development of critical reflection or the critical insertion of a person into history and culture.

Giroux (2010) claims that, in critical pedagogy, people recognise themselves as being oppressed and are engaged in the fight for their liberation. Critical pedagogy further creates opportunities to interrogate how power works in an institution during knowledge production, distribution, and consumption and how students are equipped as "informed subjects, social agents" and cultural brokers (p. 717). A cultural broker is someone who communicates and negotiates "between different cultures, languages, social and political systems" (Wyatt et al., 2017, p. 95). An individual's role in assisting students in navigating their school experiences to close the cultural gap that exists between two worlds is referred to as cultural brokering (Wyatt et al., 2017 citing Sleeter, 2001). In this case, classrooms are grounds of debate "of how identities, values and desires are shaped" (p. 103). Thus, critical pedagogy is invested in "self-criticism about values that inform teaching and a critical self-consciousness regarding what it means to equip students with analytical skills to be self-reflective about the knowledge and values they confront in classrooms" (Giroux, 2010, p. 717).

Rationale for including Freire's pedagogy of the oppressed. Critical pedagogy is problem-posing. This means that problems faced by teachers and students in their efforts to live just and ethical lives should, in part, shape the school curriculum (Kincheloe et al., 2011). In this way, students and teachers become problem-posers who ask, "Please, support us in our explorations of the world". Teachers, as researchers, possess more reliable knowledge than experts because expert researchers are outsiders who are not familiar with the students and teachers they are studying while the teacher is both a participant and researcher. A teacher reflects on the students' needs and current understandings, studies the students and then engages in dialogue to unearth educational issues that are based on the students' socio-cultural backgrounds, their perspectives of themselves and the curriculum, interrelationships with other people and their lived worlds. Together, the teacher and students construct pedagogies that identify what students want to know and engage with them to learn it (Freire, 2000). The teacher, through dialogue with students, is himself/herself taught as "the teacher-of-the-students and students-of-the-teacher cease to exist, and a new term emerges [of] teacher-student with students-teachers" (Freire, 2005, p. 80). In this way, the students and the teacher learn from each other as the students become co-researchers. The power dynamics in the classroom are shared with the students but the teacher still maintains his/her position. This notion applied to the interviews of students and lecturers, lecturers' questionnaires and classroom observations during the collection of data. It was also a lens used in the interpreting of data, data analysis and discussion of the findings.

Chapter Three Summary

Chapter Three started by introducing the meaning of the theories and their roles in qualitative research such as providing interpretations of data, reflecting on environmental phenomena and guiding the research. Theories applied in research operate at different levels of analysis. The cultural-historical activity theory was described as a practice-based approach. It provides a robust framework for analysing complex practices in the classroom and was used together with social learning theories that included situated learning (Lave & Wenger, 1991), Bandura’s (1977) social learning theory, cognitive development by Piaget (1951) Vygotsky’s (1978) social cognitive development, education as an agent of social reproduction proposed by Bourdieu (1977) and bricolage, a multidisciplinary approach to research and teaching. It presents a bricoleur as a handyman or handywoman who uses the tools available to complete a task at hand (Berry, 2004). One of the goals of critical pedagogy (Freire, 2005) is creating opportunities for students to reflectively frame their relationship to the ongoing unfinished project of democracy. I further described the possibilities of the theoretical frameworks, social theories, and bricolage approach, and the rationale for engaging each of them in the study.

The next chapter presents research methodology employed in this study.

Chapter Four

Research Methodology

Introduction

In Chapter Four, the research paradigm and methodology used in the study of first-year students' challenges in learning threshold concepts of acids-bases reactions are discussed in the first section. Methodological approaches, research design, and research instruments used in this study are discussed in the second section. This descriptive study used a combination of research instruments which were semi-structured interviews, survey questionnaires, focus-group conversations and classroom observations. In the last section, sampling, data collection procedures used, data analysis and ethical considerations are discussed. The study aimed to reduce failure and drop-out rate of first-year students in chemistry. In the next section, I discuss the research paradigm.

Research Paradigm

The term "paradigm" originates from the work of Kuhn (1962 cited in Maxwell, 2008) that refers to a set of general philosophical assumptions about the world (ontology) and how we understand it (epistemology). In education, a "paradigm describes a researcher's worldview which is "perspective, or thinking, or school of thought, or set of shared beliefs which informs the meaning or interpretation of research data" (Kivunja & Kuyini, 2017, p. 26 citing Mackenzie, 2006). Lather and Knipe (1986 cited in Kivunga & Kuyini, 2017, p. 26) state that "a research paradigm reflects the researcher's beliefs about the world s/he lives in and wants to live in". It is a conceptual lens which the researcher uses to look at the world and examine the methodological aspects of his/her research to determine the research methods that will be used and how the data will be analysed. Denzin and Lincoln (2000) state that paradigms are human constructions which indicate where the researcher is coming from so that meaning implanted in data can be constructed. Hence, paradigms “provide beliefs and dictates, influence what should be studied, how it should be studied and how the results of the study should be interpreted” (Kivunga & Kuyini, 2017, p. 26). Furthermore, every decision made, choice of methodology and methods are defined by a paradigm. Each paradigm has its own “epistemology, ontology, methodology and axiology” (Guba & Lincoln, 1994, p. 108). “Philosophical positions such as positivism, constructivism, realism and pragmatism” are some paradigms which are at an abstract and general level (Maxwell, 2008, p. 224). Each of these paradigms represents “different ideas about reality and how to” acquire “knowledge of it” (p. 224). Interpretivism, critical theory, feminism, post-modernism and phenomenology are paradigms that are relevant to qualitative research (Maxwell, 2008).

The difference in philosophical paradigms raises issues of connections between methodology and methods. A set of beliefs and feelings about the world and how it should be understood and studied guides and interprets all research. This results in each paradigm making demands on the researcher such as questions that are asked and the interpretations of them (Guba & Lincoln, 2011).

Research Methodology

Research methodology is how the researcher proceeds with the research (Goundar, 2013). It requires a person to learn the various techniques that are necessary to conduct a research that include tests, experiments and critical studies. Hence, it provides information to solve a problem in an organised way. Research methodology is a science that studies how research is carried out. Particularly the procedures of describing, explaining and predicting phenomena by researchers. “It is the study of methods by which knowledge is gained”. Its aim is “to give the work plan for the research” (Goundar, 2013, p. 9). Research methodology includes “research design, data collection and data analysis (p. 11). It further seeks to inform the reader about the reason for undertaking the study, research problem, in what way and why the hypothesis has been formulated, data collected, the method for data collection and why a particular technique of data analysis has been used (Goundar, 2013).

Research methods include theoretical procedures, experimental studies, data collection and analysis and finally whether a solution to a problem has been found. Qualitative and quantitative methods are the two broad categories of research (Goundar, 2013).

Qualitative Method

Qualitative methodology has neither a theory nor its own paradigm neither a distinct set of methods nor practices (Denzin & Lincoln, 2011). It is a very broad area of knowledge that includes a wide range of approaches and methods. Denzin and Lincoln (2011) claim that qualitative research “is situated activity that locates the observer in the world” (Denzin & Lincoln, 2011, p. 3). A set of interpretive, material practices form qualitative research that make the world visible. These practices transform the world by turning it “into a series of representations, including field notes, interviews, conversations, photographs, recordings and memos” (p. 3). Hence, qualitative researchers attempt to interpret the phenomena by studying things in their natural settings (Denzin & Lincoln, 2011). Similarly, as a subjective research discipline, to gain an understanding of feelings, impressions, and viewpoints it looks beyond the percentages. Interpretivism and constructivism are the paradigms of qualitative (Goundar, 2013). There are multiple truths because reality is based on an individual’s experiences and views. (Berger & Luckmann, 1996 cited in Goundar, 2013). Qualitative research is concerned with social aspects of the world and seeks to answer questions about "why people behave the way they do; how opinions and attitudes are formed, how people are affected by the events that go on around them and how and why cultures and practices have developed in the way they have" (Windridge, Ockleford, & Hancock, 2009, p. 7). Cropley (2019) states that qualitative research examines the way people make sense of their own experiences in their minds and their own words. Sometimes, the information is expressed in everyday language using everyday concepts.

Qualitative researchers study the "use and collection of a variety of empirical materials" that "describe routines and problematic moments and meanings in individuals' lives". These empirical materials are "case studies, personal experiences, introspections, life stories, interviews, artefacts, and cultural texts and productions, along with observational, historical, interactional and visual tests" (Denzin & Lincoln, 2011, pp. 3-4). A wide range of interpretive practices are deployed by qualitative researchers in order to get a better understanding of the subject under study. Furthermore, qualitative research does not belong to a single discipline but has multiple uses and meanings. Nelson et al. (1992 cited in Denzin & Lincoln, 2011) define cultural qualitative studies as interdisciplinary, trans-disciplinary and sometimes counter-disciplinary fields. They cut across the humanities, the social and physical sciences. They are multi-paradigmatic in focus. There are many key elements that are commonly identified as qualitative, which are: "1) qualitative research's aims and objectives are directed at providing an in-depth and interpreted understanding of the social world of research participants by learning about how they make sense of their social and material circumstances, their experiences, perspectives and histories; 2) the use of non-standardised, adaptable methods of data generation that are sensitive to the social context of the study and can be adapted for each participant or case to allow for the exploration of emergent issues; 3) qualitative data are detailed, rich and complex but the precise depth and complexity of data may vary between studies; 4) qualitative analysis retains complexity and distinction and respects the uniqueness of each participant or cross-cutting theories; 5) it is open to emerging categories and theories at the analysis and interpretation stage; 6) outputs include detailed descriptions of the phenomena which are being researched that are grounded in the perspectives and accounts of participants; and 7) a reflexive approach, where the researcher's role and perspective in the research process is acknowledged, for example, for some researchers, reflexivity also means reporting their personal experiences of the field" (Ritchie et al., 2013, p. 4).

Affordances of the qualitative method. Qualitative methods study the meaning of people's lives in real-world conditions. Institutional, social and environmental contextual conditions influence all human activities thus they give voices to participants and probe issues that lie beneath the surface of behaviours and actions. The outcome of the events and ideas from the research represents meanings given to real lives reflected by the people who live them. Its desire to explain real-world events can be used for developing new concepts that explain social processes (Yin, 2011). Furthermore, the method cross-cuts discipline fields and subject matters, for instance, the researcher can be "a scientist, naturalist, field-worker, journalist, social critic, artist, performer, film-maker, musician, quilt maker and essayist" (Denzin & Lincoln, 2000, p. 2).

***Constraints of the qualitative method*.** Denzin and Lincoln (2011, p. 2) claim that qualitative researchers are called journalists or "soft scientists" due to their unscientific, exploratory or subjective work. Also, because qualitative research is a form of criticism and not theory, politically it is considered as a disguised version of Marxism or secular humanism. Similarly, Casey (1989 cited in Denzin & Lincoln, 2000) maintains that positivist scientists, economists and psychologists see the qualitative field as an assault on these traditional disciplines, whose adherents often retreat into a value-free objective science model to defend their position. Besides, qualitative researchers rarely make explicit or critique the moral and political devotion in their work. Positivists "allege that the new-experimental qualitative researchers writings are fiction, not science, and they cannot verify their truth statements (Denzin & Lincoln, 2000).

The rationale for using qualitative research. "Qualitative methods are used to answer questions about experience, meaning and perspectives" … "from the standpoint of the participant" (Hammarberg, Kirkman, & De Lacey, 2016, p. 499). Small-group discussions or focus-group interviews are used for investigating beliefs, attitudes, and concepts of narrative behaviour, "semi-structured interviews" are conducted to seek views on a focused topic; "in-depth interviews" are held to understand a condition; experience, or event from a personal perspective, and "texts and documents" are analysed to learn about distributed knowledge. For example, qualitative methods were used to reveal problems in teaching and learning of acids-bases reactions which may lead to better learning and teaching. The data gathered may answer personal questions or social meaning and capture real-life experiences, which are different for each person. For instance, experiences and perspectives of different classrooms (even students in the same classroom) in the same learning context will be different because meaning is culturally determined and subject to change (Hammarberg et al., 2016). When consistency is found from the research conducted in different classrooms and with different educators, it may be used to identify meaning for members of the group.

Research Design

Research design is a strategy/work plan used to solve a research problem. A work plan flow details what has to be done to complete the project from the project's research design (Dilshad & Latif, 2013). Researchers are able to answer the initial questions from the evidence obtained. A researcher asks research questions that will provide the type of evidence that is needed to answer the questions convincingly. In social research, sampling, methods of data collection and design questions are used to answer the research questions. A qualitative methodology was employed in this study for action research, case study research and phenomenology research.

Action Research

Action research, according to Bhattacherjee (2012), is an interactive design that "assumes that complex social phenomena are best understood by introducing changes, interventions, and actions into the phenomena and observing the outcomes of such actions" (p. 40). Thus, a researcher is embedded within a social context as an observer/consultant or participant to initiate "an action in response to a social problem" and examines how her/his action influences the phenomena. In this way, the researcher is also learning and generating insights into the relationship between the action and the phenomena. Theory dictates the choice of actions taken by the researcher to "explain why and how such actions may cause the desired change" (p. 40).

According to McNiff (2002 cited in Cohen et al., 2011), action research can also be called practitioner-based research. Ebbutt (1985 as cited in Cohen et al., 2011) regards action research as a systematic study that combines action and reflection intending to improve practice. Cohen and Manion (1984 as cited in Cohen et al., 2011, p. 345) define action research as "a small-scale intervention in the functioning of the real world and a close examination of the effects of such an intervention". Corey (1953 as cited in Cohen et al., 2011) argues that it is a process in which practitioners study problems scientifically so that they can evaluate, improve and steer decision making and practice.

Action research possibilities. Action research is a powerful tool for change and improvement at a local level. Hopkins (1985 as cited in Cohen et al., 2011) suggests that the combination of action and research renders action in a form of disciplined, rigorous inquiry, in which a personal attempt is made to understand and reform practice. Researchers are educating and being educated along with their students as they conduct research. Hence, it enables student-teacher and student-student relationships that reveal social interactions, more sophisticated learning activities, and more opportunities to connect academic learning with the lived experience of students and teachers. Similarly, action research "transcends the boundaries of the classroom and investigations of instructional technique and connects the school and community through the identification of common historical forces which have helped shape individuals and institutions" (Kincheloe, 1991, p. 189). According to Freire (1972), action research provides researchers with a sense of direction, an orientation that transforms the idea of research from mere data gathering into a consciousness. It promotes learning as a connection.

Limitations of action research. The most challenging limitation of applying action research is communicating and abstracting results in a way that others will understand them and will enable them to generate effective courses of action. As the knowledge is cogenerated with local knowledge, and analysed, and is built deeply into the local context therefore it is a challenge to compare results across contexts and to create generalisations (Denzin & Lincoln, 2000).

The rationale for using action research. My study requires that I engage in a critical exploration of factors that are causing high failure and drop-out rates of first-year chemistry students. It is also a professional study as it involves other educators. The educators and the students are participants as well as co-researchers because the results may enhance their teaching and learning. I embedded in the chemistry learning community as an observer because I had access as a member of the staff of the faculty. It also expanded my understanding of classroom dynamics and student interactions evaluation practices that may be causing a high failure rate of students**.** Information generated was member checked with all educators. The findings influenced me to engage educators in the design and application of findings. It assisted in translating activities to answer research questions and provided peer review leading to opportunities for critical and reflective dialogue.

Case Study Research

Nisbet and Walt (1984 cited in Cohen et al., 2011) state that a case study is a specific instance that is frequently designed to illustrate a more general principle. According to Adelman et al. (1980 as cited in Cohen et al., 2011), a case study is the study of an instance in action. Stake (1995) says that it studies of particularity and complexity of a single case within important circumstances. Merriam (2009, p. 40) presents case study research "as an in-depth description and analysis of a bounded system". Yin (2014, p. 8) defines it "as an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context when the boundaries between the phenomenon and the context are not evident". Wolcott (2005, p. 11) "sees it as a study of human beings in a social setting of field-oriented research rather than a strategy or method". Thus, the case study can be used in many situations to learn about "individuals, groups, organisations", and "social, political and related phenomena" (Yin, 2003, p. 1).

Yin (2014) classified three types of case study research which are exploratory, descriptive and explanatory. Exploratory case study research mostly is used for formulating questions or hypotheses for further inquiry in study processes in companies while descriptive case-study research describes what happens in a natural phenomenon that occurs within the data (Zainal, 2007). Descriptive cases-studies, according to Merriam (2009), may be narrative. The researcher describes the phenomena as it occur within the data.

The performance of first-year students in chemistry in different universities is a comparative case study and is an example of a descriptive case study. Data in explanatory case studies is examined closely at the surface and at deep levels to explain the phenomenon in detail. The researcher begins with data, forms "a theory" and then proceeds "to test this theory" (Zainal, 2007, p. 3). Also, explanatory case studies are employed in causal studies where comparisons are used to investigate a very complex and multi-variate phenomenon.

Possibilities of a case study. For this study, I chose to use descriptive case study research. A case study is "holistic, grounded, lifelike, exploratory and simplifies data to be considered by the reader, … illuminates meanings, and advances a field's knowledge" (Merriam 2009, pp. 30-40). This study explored and compared the experiences of five classes of students and educators in teaching-learning of acids-bases. The study provides a unique example of real people in real situations, enables readers to understand ideas more clearly than presenting them as abstract theories or principles (Zainal, 2007). Case studies penetrate susceptible situations that numerical analysis may not and can blend quantitative and qualitative data. Case-studies, according to Yin (2015, p. 4), "explain, describe, illustrate and enlighten". Since they observe effects in real contexts they can also establish the cause and effect (Cohen et al., 2011).

Case study limitations. Critics argue that the boundary line between a phenomenon and its context is blurred (Yin, 2009). Verschuren (2003 as cited in Cohen et al., 2011) argues that a case-study can be either tightly or loosely bounded. The weakness of case studies, according to Yin (2018), a researcher may not conduct the case study as a research endeavour but may be biased in reporting the findings. The researcher has to be transparent and explicit to limit biases. These challenges demand greater attention. Thus, this makes it difficult to make inferences and to draw cause and effect conclusions from case-studies. When the researcher is an observer, there is potential to be an impressionist and self-reporting (Merriam, 2009). Moreover, case studies tend to “take too long and result in massive unreadable documents” (Yin, 2018, p. 11).

The rationale for using case study research. Case study research was ideal to my study, the learning community that is interacting with each other to produce knowledge because it directs observations in natural settings, allows access to subjective factors, such as thoughts, feelings, and desires, and brings the researcher closer to the subject of interest. Case-studies are essential as the phenomenon under study is presented in detailed account (Merriam, 2009). A case study allowed the researcher to explore interactions between students and educators and the activities of acids-bases reactions. It further made me see how the classroom is structured, for instance, the roles of students and educators as they navigate the teaching-learning process. It revealed challenges and achievements within the classroom.

Possibilities of Phenomenology Research

It focuses on descriptions of what people experience, how they experience and what they experience. Therefore, a researcher can employ a general phenomenological perspective to illuminate the structure of people's experiences of their lived world (Denzin & Lincoln, 2000). Similarly, the method does not stand alone, over and above experience. Neither, more nor less perceiving and conceiving objects and actions but exists always as a constitutive part of what it is conscious of. In addition, it deals with the participants' own accounts rather than with prejudicial descriptions of experience and the underpinning structures that makes such experiences possible (Denzin & Lincoln, 2000).

Limitations of phenomenology research. Researchers have to take into consideration the participants past, present and future. S/he must temporarily live the participants' life or transpose herself/himself in an imaginary sense in the participants' situation. Hence, the experiences of the participants are described in narrative or emergent themes. The various types of phenomenology such as transcendental, existential and hermeneutic complicate the picture even more (Bhattacherjee, 2012). Understanding and developing themes requires structural analyses and sustained engagement with experiences. It also misleads to assume that hasty considerations of individual experiences can lead to deep, structural understanding of human knowing and learning. This is because it does not describe the life world as experienced at the moment of interest because the accounts of experience tend to change overtime. The change is influenced by different ways members of the culture can describe experience and the changing nature of interpretation (Roth, 2005).

***The rationale for using phenomenology research*.** Ontology is concerned with consciousness itself (Merriam, 2009). It is all about understanding the real world and its existence and action. "A phenomenological approach is well suited to studying affective, emotional, and often intense human experiences" (Merriam, 2006, p. 26). The researcher gained deeper understanding of the phenomenon of first-year chemistry students' failure and dropout rates through educators' and students' own experiences and understandings of acids-bases reactions. I now introduce the instruments I employed in the research.

Research Instruments Used in The Study

Research instruments are ways of gathering information. Different instruments used in research "can supplement each other and" increase "the validity and dependability of the data" (Zohrabi, 2013, p. 254). Qualitative data are collected through open-ended questionnaires, interviews, focus-group discussions, and classroom observations. I will discuss research instrument in the following sections.

Classroom observations. Observation, as a research instrument, reports the activities people carry out in social settings and situations (Wilkinson & Birmingham, 2003). Observation is a research tool which is carried out to answer research questions and objectives (Zohrabi, 2013). In this method, interactions and events are observed by the researcher as they occur naturally (Flick, 2006 cited in Zohrabi, 2013). According to Johnson Onwuegbuzie and Turner (2007, p. 445), "observation enables the researcher to combine" classroom observations "with questionnaires and interviews to collect relatively" objective "first-hand information" whereas Merriam (2009, p. 118) believes that "observation is a research tool when it is systematic, when it addresses a specific research question, and when it is subject to the checks and balances in producing trustworthy results". Observers study subjective factors objectively (Fraenkel, Wallen & Hyun, 2012) and Nation (1997 as cited in Zohrabi, 2013) argues that the researchers do not study the behaviour itself but its representative.

Observation can be either non-participant or participant. In non-participant observation, the observer only watches and records classroom activities without involvement. The researcher remains “aloof” and distant; they are not directly involved in the situation they are observing” (Fraenkel et al., 2012, p. 447). Furthermore, inquirers do not participate in the activity but sit and watch (Fraenkel et al., 2012). In participant observation, researchers “enter the classroom and” become part of the research participants (Zohrabi, 2013, p. 257). Burns (1999, p. 82) states “that the researcher becomes a member of the context and participates in its culture and activities” (as cited in Zohrabi, 2013). Flick (2006, p. 220 as cited in Zohrabi, 2013) emphasises that researchers “dive headlong” into the field while Merriam (1998 as cited in Zohrabi, 2013, p. 257) argues that researchers may “lose sight of the students and their activities” because they can become too involved in the classroom process.

Fraenkel and Wallen (2003) categorise observation instrument into narrow focus and broad focus. An observation which concentrates on a single element is narrow focus whereas broad focus concentrates on a “big picture” of what is happening in the classroom. According to Merriam (2009, p. 119), “research problem, research objectives, research questions, the field of study, practical issues, theoretical framework, researcher’s impressions, and understanding of the topic determine and influence observation”.

Strengths and weaknesses of observation. Data obtained from observations are first-hand pictures of events carried in “a natural field setting” that “enable the researcher to obtain contextual factors” (Zohrabi, 2013, p. 257). On the other hand, it is time-consuming to analyse data from observations, it is difficult to observe a large population, the observer can be biased, and the investigator’s presence may affect the students’ and teachers’ teaching and learning (Zohrabi, 2013).

The rationale for using classroom observation. I explored how lecturers and students, see and understand their surroundings and their interactions in activities of acids-bases reactions (Wilkerson & Birmingham, 2013) because real-world experiences influence the actors' behaviour, actions, and interactions and how other people perceive them. Classroom observations allowed me to understand more about classroom situations than from interviews and questionnaires.

Research survey. The research survey method applies standardised questions or interviews to collect data in a systematic manner about people's preferences, thoughts and behaviours (Bharttacherjee, 2012). "The method can be used for descriptive, exploratory or explanatory research" (p. 73). It is suitable to study individuals, groups, organisations or dyads as units of analysis. Descriptive and analytic statistics are the different forms of surveys. Statistical surveys describe basic characteristics or experiences of large and small populations and are quantitative summaries of observations while descriptive surveys describe the size and distributions of various characteristics of a population. Analytical statistics measure how two or more variables are related, for instance, by class size and the number of students who passed an examination (Groves et al., 2009).

Possibilities of survey research. Survey research "can generalise about an entire population by drawing inferences based on data drawn from a small portion of that population" (Rea & Parker, 2005, p. 7). It reveals the "characteristics of institutions" and "communities" that represent these entities. Survey research therefore saves the costs and time required to survey an entire population (Rea & Parker, 2005). Standardised data that are agreeable to quantification and computerisation and statistical analysis are generated by well organised surveys. Surveys are replicable; "a questionnaire that has been used in one city or community can be re-implemented in another community or administered once again in the same community at a later date in order to assess the differences attributed to location or time” (Rea & Parker, 2005, p. 8). Research questions focus on the characteristics of the selected groups or aim to provide an in-depth analysis of a small number of targeted individuals but do not require samples that are closely representative of the population at large.

Weaknesses of survey research. Much research in social sciences is based upon the use of selected and geographically homogeneous samples such as students, teachers, homeless adults, general practitioners and patients, police officers, nurses and more (Hewson, Yule, Laurent, & Vogel, 2003).

*Types of Survey Methods***.** Questionnaire and interview surveys are two categories of survey research. Questionnaire surveys tend to be mail-in, group-administered, or online surveys. Whilst interview surveys may be done in person, by telephone, or in focus groups. “Questionnaires are instruments that are completed in writing by respondents, while interviews are completed by the interviewer based on verbal responses provided by respondents” (Bhattacherjee, 2012, p. 74). In this study, I employed a questionnaire survey.

Questionnaire Surveys

As a research instrument, a questionnaire consist of a set of structured (closed-ended) or unstructured (open-ended) questions. The questions are “intended to capture responses from respondents in a standardised manner” (Bharttacherjee, 2012, p. 74). Respondents respond in their own words when answering unstructured questions. Contrary, structured questions expect respondents to select an answer from a given set of choices. Participants’ responses on a structured questionnaire may be aggregated into a composite scale or index for statistical analysis such as Likert type scale that is answered on a 5 or 7 point scale of satisfaction or agreement. Questions are designed “so that respondents are able to read, understand, and respond to them in a meaningful way" (Bhattacherjee, 2012, p. 74).

Drop off or pick up method. A drop off and pick up survey, also known as a drop and collect survey, consists of survey instruments that are hand-delivered to households or offices and are later collected or mailed after they have been completed (Trentelman, Irwin, Petersen, Ruiz, & Szalay, 2016). It is also a method where researchers interact face-to-face with the potential respondents when hand-delivering survey questionnaires and returning later for their retrieval.

Drop off and pick up method is based on three key elements of social exchange framework which are: 1) a researcher provides social rewards by giving respondents an opportunity to participate in the study; 2) social costs of participation are reduced thereby minimising or compensating social cost; and 3) trust between the researcher and the respondents is built when evidence of "legitimacy, authenticity, reassurances of confidentiality, data protection and professional communication" is provided (Trentelman et al., 2016, p. 70).

Affordances of drop off and pick up method. The respondents complete the survey at their own pace and they can provide long, narrative answers. This method was inexpensive for this study as the respondents were clustered in the same geographical area (the university campus). Hand-delivery signified the importance and legitimacy of the research. The questionnaire allowed respondents to provide open and honest feedback in a private way. The response rate was high due to face to face interactions. Personal contact allowed the researcher to explain and answer questions about the survey. It also established a relationship with the research participant before s/he had seen the questionnaire (Trentelman et al., 2016).

Weaknesses of drop off and pick up method. The drop off and pick up method could be time consuming for the researcher because sometimes the respondents are not available. Sometimes, the researcher has to make several appointments before picking-up completed questionnaires.

Rationale for using pen and paper questionnaires. This method is suitable to study small, densely settled areas, community dynamics, attitudes and behaviour towards community issues, place of attachment and to examine community members' perspectives (Trentelman et al., 2016). This study drew on lecturers' perspectives of teaching of threshold concepts of acids-bases reactions. The survey was designed to assess the lecturers' knowledge and experience of threshold concepts in acids-bases. It was suitable to reveal the lecturer's and students' group dynamics, their attitudes towards the chemistry curriculum and the learning context. It created an opportunity for me to remind the participants by phone and collect completed questionnaires. It also gave me an opportunity to review their responses and get back to respondents for validation.

Interviews. Interviews give an understanding of the world from the participants' lived experience. Research interviews are professional conversations that require conversational skills as they are based on daily life. In an interview, knowledge is constructed from the interaction between the interviewer (researcher) and the interviewee (participant/respondent). There are various forms of interviews which include computer-assisted, focus group, factual, conceptual, in-depth, intensive and narrative. The researcher may use any of these types "depending on the purpose of the inquiry, the kind of knowledge sought, the participants, personal skills and style of the interviewer" (Kvale & Brinkmann, 2009, p. 250).

Intensive or In-depth Interviews. According to Charmaz (2006), intensive interviewing, which is an interpretive inquiry method, and "allows for an in-depth exploration of a particular topic or experience" (p. 25). In this type of interview, the interviewer presents a problem statement and then with respondents who had experiences explores it (Charmaz, 2006). The questions of the researcher prompt the participant to describe and reflect on her or his experiences that occur in lived life. The role of the researcher is "to listen, to observe with sensitivity, and to encourage the" participant "to respond" (Charmaz, 2006, p. 25) . Hence, in this interaction, the participant does the talking. The researcher expresses interest and wants to know more by questioning and probing, as this helps the participants articulate their intentions and meanings. Similarly, Manen (1990 as cited in Seidman, 2006) explains that an in-depth interview's goal is to understand the lived experiences of people and meaning they make of their experiences. An intensive interview can be open-ended, semi-structured or structured.

Strengths of intensive interviews. Intensive interviews allows the interviewer to have "access to the context" of respondents' behaviour, thereby gaining "understanding of their behaviour and action" (Seidman, 2006, p. 9). For instance, to understand the concept of teaching-learning process is possible "through the experience of individuals who make up the" structure "or carry out the process" (p. 10). Furthermore, intensive interviewing transforms the researcher to think sociologically (Charmaz, 2006). By sociologically, I mean, the interviewer explains why the interviewee responded in such a way and how the questions made the interviewee to respond in that way. Besides, it draws the researcher into the following sociological ways:

> "1) the substantive area of inquiry becomes alive and meaningful; 2) the data elicited penetrate beneath the surface of ordinary conversation; 3) the discourse between the interviewer and the research participant becomes an object of study and 4) relations between ethics and research strategies become clearer" (Charmaz, 2006, p. 26)

Limitations of intensive interviews. Relative differences in power and status of the interviewer and respondent can influence the process of interviews and the results. For instance, "powerful people may take charge, turn the interview questions to address topics on their own terms, and control the timing, pacing and length of the interview" (Charmaz, 2006, p. 27). Furthermore, whether powerful or not, "individuals may distrust their interviewers or sponsoring institutions, purpose of the research" and "how the findings might be used" (p. 27). During interviews, instead of revealing personal views, professionals may recite public relations rhetoric. The participant may silently raise questions about whether the interviewer is representing the officials or is an advocate (Charmaz, 2006).

The direction and content of the interviews may be affected by gender, race, age, religion, ethnicity, social economic status and educational qualifications. These are known as "markers of difference". According to Schwalbe and Wolkomir (2002 as cited in Charmaz, 2006), since intensive interviewing occurs in one-to-one relationships and fosters self-disclosure, men may feel threatened if the interview challenges their masculinity. Hence, the findings may risk loss of public personal views (may not be free to answer questions that require personal opinion). Interviewing women depends on the topic, its meaning and circumstances of their lives as well as the researcher's skills regardless of whether the interviewer and participant are both women.

Rationale for using intensive interviews. Intensive interviews provided the researcher with individual lecturer's reflections on his/her activities of TCs of acids-bases reactions and interactions with first-year students. I collected data from each chemistry first-year class and "the nature of the introduction to the chemistry" curriculum, the context of the classroom and the pedagogies employed to present the acids-bases reactions to the students. The data explained the teaching and learning process, assisted me to answer the research questions and propose interventions that would play a role in chemistry success for both the educator and students.

Focus-group interviews. “Focus-group interview is a qualitative” strategy “for data collection” (Dilshad & Latif, 2013, p. 192). In a focus-group interview, the researcher bring together the participants to “explore attitudes, perceptions, feelings and ideas about a topic” (Yin, 2011; Dilshad & Latif, 2013, p. 192). A focus-group consists of individuals who have or previously had a common experience or share common views. The group comprises seven to 10 persons. The interviewer serves as a moderator and members of the group express their views with minimum direction. It is a way of collecting data about how the sample participant might have perceived a particular issue.

***Strengths of focus-group interviews*.** Group interviews are desirable when the participants in a group readily express themselves more than when they are alone (Yin, 2011). Focus-group discussions provide rich, detailed information about participants’ “thoughts, feelings and impressions of people in their own words” (Stewart & Shamdasani, 1990, p. 140 cited by Dilshad & Latif, 2013). They enable the researcher to find out the peoples’ understandings and experiences of the issues under study and the reasons behind their thinking, examine sensitive issues, and offer an opportunity to marginalised segments of society to expose their needs and problems (Dilshad & Latif, 2013).

*Limitations of focus-group interview*s. Some participants may dominate the discussion. This requires a skilful and experienced moderator (interviewer) to control the discussion and give all participants and opportunity to talk. The moderator has to find ways to keep the conversation going and to keep the discussion on the topic (Yin, 2011).

Rationale for using focus-group interviews. Focus-group interviews allowed me to get detailed information from the students who experienced the learning of university chemistry. I had an opportunity to ask students to explain their experiences of how their home culture, beliefs and knowledge intersect with each other and the university. It was a rich source of exploring people's feelings, attitudes, emotions, insider experiences, sensitive issues, privileged insights and experiences (Wisker, 2001 cited in Dilshad & Latif, 2013).

The data collected in focus-group interviews helped me to understand students' perspectives and experiences when learning acids-bases chemistry and how they responded to the university chemistry learning culture. Activity theory and social learning theories was used unpack data and to assist in constructing interventions. I studied the experiences and perspectives of five different groups of students studying acids-bases reactions, for example, how the contents of chemistry are presented, teaching and learning resources available and student-student and student-educator interactions. Discussing learning experiences is sensitive and was examined by focus discussion to find ways of ameliorating high failure and drop-out rates among first-year chemistry students.

Through focus-group discussions I was able to collect data related to the research question which states: "What challenges do first-year students experience in learning the threshold concepts of acids-bases reactions?" I interacted with students in the classrooms where a number of issues were revealed such as teaching approaches, learning resources, students possessing different levels of chemistry knowledge and socio-cultural backgrounds. In addition, suggestions were made regarding how challenges could be ameliorated.

Sampling of Participants

Sampling is "taking a subset from chosen sampling frame or entire population" (Taherdoost, 2016, p. 20). Social sciences study behaviours and perspectives of a particular population. Because it is not feasible to study the entire population due to time and costs (Taherdoost, 2016), a representative sample was selected for observation and analysis. The study was located in the first-year acids-bases reactions. The research strategies were action, case study and phenomenology research.

Probability or random sampling and non-probability or non-random sampling are sampling techniques. Where “every” member “of the population has an equal” opportunity “of being included in the sample is called probability sampling” (Taherdoost, 2016, p. 20). For instance, if college student population is the target, then, every college student is an element of the population (Alvi, 2016). Probability or random sampling has the least sampling biases and chances of systematic errors. Inferences drawn from representative samples are generalisable to the whole population (Alvi, 2016; Taherdoost, 2016).

Non-probability or non-random sampling focuses on small samples and its “rationale is needed for the inclusion of some cases or individuals rather than others” (Taherdoost, 2016, p. 22). For example, if the target population is college students of 2015–2016 academic year of Witwatersrand University, it means only those students who studied at that university during the mentioned period can be selected (Alvi, 2016). The non-probability technique is suitable for exploratory research which is intended to generate new ideas and to develop the understanding of a population. Its strengths are that it requires “less effort, less time to finish and is not costly” (p. 10). Contrary, “non-probability samplings are prone to encounter systematic errors and sampling biases, the sample cannot be claimed to be a good representative of the population and inferences drawn from the sample are not generalisable to the population” (Taherdoost, 2016, p. 14).

In this study, I used quota and purposeful sample techniques to identify the research context and research participants. Davies (2005 cited in Taherdoost, 2016, p. 20) defines quota sampling as “a non-random sampling technique in which participants are chosen on the basis of predetermined characteristics…”. Hence, the characteristics of the sample is the same as the population. “Purposeful sampling is a strategy in which” certain “settings or persons or events are selected deliberately to provide … information that cannot be obtained from other choices” (Maxwell, 1996 cited in Taherdoost, 2016, p. 23). In purposeful sampling, cases or participants are included in the sample because they believe that they should be there. Pseudonyms were given to research participants to protect their identities. Lecturers rescheduled their teaching of acids-bases reaction topic from the third term to the first quarter of the second term to facilitate the research.

Students. The main participants in this research were chemistry lecturers and first-year chemistry students. I present how they were selected and how data were collected. A purposive sample was chosen to reveal the challenges students/lecturers experience and how they can be ameliorated. There are about 350 students per class and six classes, giving a total of 2,100 students. The first-year chemistry students are grouped from “A” to “F”. The sample size was forty-seven (47) of first-year students who signed consent forms and participated in focus-group interviews.

Chemistry lessons are allocated six (6) hours per week, of which two (2) are for laboratory work and four (4) are for teaching. The four hours are divided into two hours of two lessons per week. Therefore, twenty (24) hours are given to six classes per week, ninety-six (96) hours per month and two hundred and eighty-eight (288) hours per term. Since there are four hours allocated to each class per week, to get the number of lessons per week, 288 hours is divided by four hours to give eighty-two (82) lessons. The 82 lessons are further divided by two hours to give forty-one (41) lessons for each class per day for a term. Thus, there are one hundred and twenty-three (123) lessons for each class per year as there are three terms in an academic year.

The students in the sample volunteered to be interviewed and signed the consent forms. Students came from different socio-cultural backgrounds, possessed different chemistry levels and different languages. A total of 47 students from the sampled classes which were taught by five lecturers who accepted to participant in the research took part in the focus-group interviews. There were thirty-three (33) males and fourteen (14) females in the sample. The participants were either repeating the first-year chemistry course or were freshmen therefore they described their experiences from different perspectives.

Educators. Six (6) chemistry educators who teach first-year students were selected. The participants were purposely sampled in conjunction with criteria and stratified by gender and years of experience of teaching first year chemistry as illustrated in Table 4.0.

Table 4

The classification: chemistry educators

Years of Experience	**Classification**
0–3	Novice or legitimate peripheral participant
4–6	Moderately experienced
7–10+	Expert

Educators' profiles. Hamoonga was a chemist researcher for 32 years and has no teaching background. He has been teaching first-year chemistry between seven and ten years.

He is currently the coordinator of general chemistry. He also teaches third and fourth-year environmental chemistry students. He is from the Southern Province of Tonga speaking people. Hamoonga was born and raised in Monze where he did his primary and secondary education. Thereafter, he qualified in chemistry at the University of Zambia.

Zulu is Ngoni from the eastern part of Zambia. He was trained as a teacher of chemistry at the University of Zambia and Virginia, USA. He has been teaching chemistry for three years. Before joining the institution, he taught at secondary school and College of Education.

Chanda is both a chemistry laboratory technician and general chemistry educator. He first worked as a teacher of chemistry at a secondary school in Copperbelt Province. He obtained a Bachelor of Science and Master’s degree chemistry education at the University of Zambia. Chanda speaks Bemba dialect. He joined the university as a laboratory technician and later began to teach chemistry 110 to first year students. He has been teaching between seven and 10 years.

Inonge has been teaching first-year chemistry part-time for four months. She has been teaching chemistry as a secondary school teacher for eight years. Her mother is from Luapula Province, her father is from Western Province and her husband is from North-Western Province of Zambia. She speaks Bemba, Lozi and Luunda Zambian languages. Inonge was born and raised in the Copperbelt Province. She obtained her Bachelor of Science degree in chemistry education at Mukuba and her Master’s degree chemistry education at Copperbelt Universities in Kitwe.

Ika is from the Western Province of Zambia and has been teaching first-year chemistry part-time for a period between seven and 10 years. He obtained his Bachelor of Science degree chemistry education and Master's degree chemistry education the University of Zambia. Ika speaks Lozi language. Currently, he is teaching at a secondary school and has taught acids-bases chemistry for some time.

Data Collection Procedure

The draft instruments were standardised and validated. Ethical clearance was sought, and permission was granted to pursue the research. On the first round of data collection, information sheets and consent forms were distributed to chemistry educators requesting for their collaboration in the research. I delivered questionnaires to the educators by hand. The responses from the questionnaires were analysed. This was followed by semi-structured interviews for first-year educators in December 2018 and January 2019. In January 2019, a workshop was organised for all chemistry educators based on the results of the questionnaires and semi-structured interviews. Second round data collection on classroom observations and student focus group interviews was in March and April 2019. Students voluntarily signed consent forms and information sheets to research with me. Also, I viewed the clips with each lecturer from their lessons and had conversations according to the research questions at times that were convenient for them.

Pen and Paper Questionnaires

A printable copy of the survey questionnaire was sent to all chemistry educators. The participants completed the unstructured question questionnaire. The researcher delivered the questionnaires by hand to the chemistry educators. I prepared the questions related to research questions to find out knowledge of undergraduate chemistry threshold concepts among chemistry educators. The survey also assessed first-year educators' experience with threshold concepts in acids-bases and first-year students' challenges in learning chemistry.

The descriptive responses determined whether the respondents would be introduced to TC theory. Before the questionnaires were handed out, the questions were validated by piloting them among chemistry educators at University of Witwatersrand, Johannesburg, South Africa. There were 25 questions formulated in line with the research questions to develop educators' questionnaires (see appendix D). The interviews related to individual educators' questionnaire responses. So, the questions were not uniform. An extract of the questionnaire is shown in Table 4.1.

Table 4.1

Extract from open-ended questions

Following questions require a "Yes" or "No" answer with some explanations. Kindly answer each question to the best of your knowledge.

2. I have the knowledge and experience of teaching threshold concepts in Chemistry.

☐ Yes ☐ No

If yes, explain.

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If no, explain.

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14. Identifying threshold concepts of acids-bases and its relationship with other chemistry topics can help improve students' performance in chemistry.

☐ Yes ☐ No

If yes, explain.

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If no, explain.

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24. If a student fails my Chemistry course, it is her/his problem (fault).

☐ Yes ☐ No

If yes, explain.

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If no, explain.
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Educators' Interviews

Each educator was interviewed twice, and the questions were not uniform. The questions were generated from completed questionnaires (see appendix E). Educators discussed students' prior knowledge of acids-bases, educators' knowledge of threshold concepts, teaching approaches, students' learning attitudes, size of the class and teaching threshold concepts as a foundation course. I had intensive video-recorded interviews with five out of six first-year chemistry educators. The first interview lasted about 45 minutes and the second one lasted about one hour. The semi-structured questions were not the same as they were based on the respondent's answers to the questionnaires. I watched selected clips of the three lessons with each educator. The questions for the post-lesson interview were also different as the lessons from each classroom were different. However, the research questions influenced the interviews. Participants spoke and, in most cases, did not show any discomfort when it came to sensitive issues that constrained teaching. I interjected into the conversation to probe further. The conversations and video viewings were video-recorded for each educator.

Educators' Workshop

The responses to the questionnaires and post-questionnaire interviews of all the chemistry educators influenced the activities of the workshop. Chemistry educators were invited to participate in a one-day workshop. In the morning, I introduced the threshold concept theory, the third space or liminal space, and getting students into and out of the liminal space.

Participants discussed challenges they experienced in teaching threshold concepts. They also discussed the challenges of identifying students who were outside the liminal space. Educators proposed various alternative means of overcoming high failure and drop-out rates of first-year students. Later, in the afternoon, lecturers identified the key ideas of acids-bases reactions in the curriculum. The proceedings of the workshop and conversations were video-recorded.

Classroom observations. Classroom observations can illuminate the most familiar events when carefully done (Wragg, 2011). Some approaches to classroom observation that concentrate on “significance, meaning, impact and individual or collective” interpretations of events are rooted in the work of cultural and social anthropologists (p. 7). This style of observation is labelled “ethnographic”. It studies what is happening in the classroom with a critical eye. “An observer may take notes about an event and then interview the participants afterward, asking questions about who did what and why” (Wragg, 2011, p. 10). I made an agreement with the lecturers before lesson observations. Educators’ class timetables were given to me. Three lessons were observed in each class and video-recorded. Lesson observations were accompanied by a post-lesson conversation to confirm the interpretations of the observations. The post-lesson conversations were also video recorded. I sat in five first-year educators’ acids-bases reactions lessons. This resulted in a total of thirty-one (31) videos. Videos captured interactions that I would have missed by writing down notes. I was also able to play the captured interactions for post-lesson conversations, data analysis and discussions. The challenge was in selecting the segments of the teaching and learning to be watched with the educator.

The classroom observations were based on the research questions; challenges first-year students experience in learning threshold concepts of acids-bases reactions; challenges educators experience in teaching threshold concepts of acids-bases concepts to first-year students and how these challenges can be ameliorated; and the causes of the high failure and drop-out rate and how they can be corrected. During the lessons, I observed the harmonious relationships between educators and students, and between students and students. Relationships are important because they alter the learning culture in the classroom. I also observed the interactions between student-educator and student-student during the activities. These included challenges and affordances experienced by the educator while presenting the chemistry content; challenges faced by students while solving problems; how the students responded to challenges; and how the lecturer responded to the whole phenomenon. I also studied individual students who interacted with the educator and with fellow students. Five educators were observed while teaching acids-bases reactions. The observation schedule was the same for all the first-year classes.

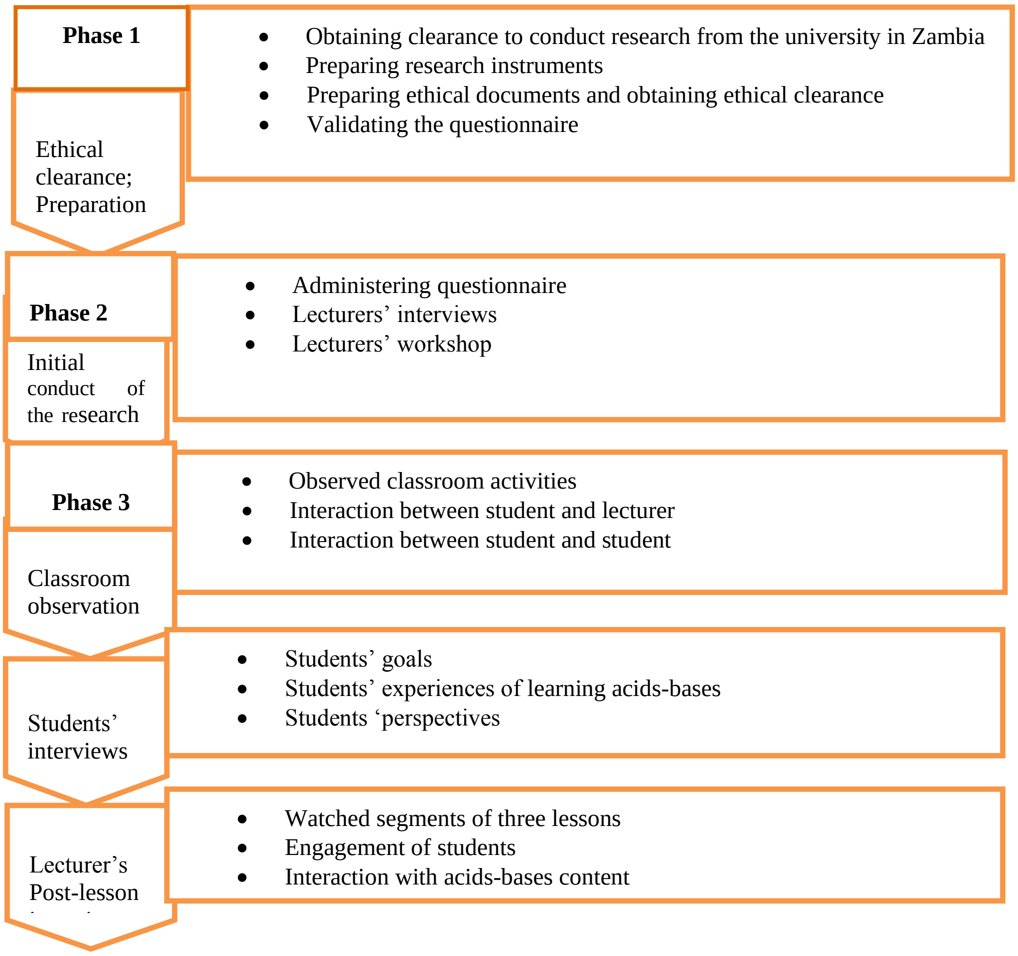
Students' Focus-group Interviews

Five groups of first-year students consented to take part in the research and be videotaped. Students were sampled from groups A, B, D, E and F. The average age of students was 19. However, the group C educator declined. Interviews were conducted in the lecture theatre after the chemistry lessons. The focus-group interview was conducted after the lesson to help them relate the questions to the previous and current classroom experiences. Before the interviews, I introduced myself, explained the data I was collecting and why I was collecting it. Students understood that the information that was being collected was purely for education purposes. The meaning of key concepts or threshold concepts was explained to them. I met groups A, B, D, E and F once. Questions were semi-structured but, at times, questions were asked based on the respondents' claims (see appendix I). Students were asked to share their aspirations for coming to the university. Because chemistry is a prerequisite for all first-year students in science and medicine programmes, the students discussed the challenges and causes of challenges they experienced in learning threshold concepts of acids-bases reactions. Students further identified what they considered to be threshold concepts of acids-bases chemistry and made proposals about what could be done to be successful in chemistry. Students felt free to talk about their experiences. The conversations were video recorded. Discussions lasted between 35 minutes and 95 minutes depending on the number of volunteered participants from each class and the contributions from members. The five focus-group interviews of the students were video-recorded. Thus, 20 videos involving students were recorded.

The summary of my data collection is illustrated in a flow chart below.

Figure 4.0

Summary of the data collection procedure



Quality Criteria

Quality criteria of qualitative research design. In this section, issues around validity and reliability of the study are discussed. Research instruments were developed according to quality criteria applicable to the research designs so that conclusive results could be found. Quality criteria are used to “establish agreement about judgments of good and poor-quality research” (Moon et al., 2016, p. 16).

Credibility. The truth value or internal validity of qualitative research is evaluated by credibility for instance, when the research is presented with an adequate description of the context and the results are recognised by the people who share the experience then the qualitative study is credible (Hammarberg et al., 2016). Lincoln and Guba (1994, p. 178) contend that “credibility refers to the degree to which the research represents the actual meanings of the research participants, or the findings sufficiently authentic”. Triangulation and substantial descriptions of the interpretation process are applied by a researcher to defend the research instrument’s credibility. Moreover, verbatim quotations from the data are supplied to illustrate and support the interpretations (Hammarberg et al., 2016 citing Sandelouski, 1986) but “where excerpts of data and interpretations are incongruent, the credibility of the study is in doubt” (p. 500).

In this study, member checking was done after the data collection by sharing the transcribed data from lecturers’ questionnaires and interviews. Member checking provided an opportunity to revise the responses that led to the arrangement of the workshop and influenced the classroom observation. The lecturers and the researcher watched the three segments of the three video-recorded lessons and had discussions about who did what, what happened, why it happened, and how the activity could have been done better. Conversations I had with the lecturers while watching the video-recorded lessons established that the findings were authentic, original and reliable (Hammarberg et al., 2016).

Applicability or Transferability. The degree to which research findings in one study can be applied or transferred to similar or related domains (Moon, et al., 2016). Similarly, when experts in the field and researchers view the findings as meaningful and applicable in their own contexts (Hammarberg et al., 2016). Furthermore, if the findings of the study are applicable or useful to theory or practice and future research (Lincoln & Guba, 1994). Then the study possess external validity. In the study, I triangulated research through several data collection methods to obtain maximum insight into sensitive topics such as issues surrounding high failure and drop-out rates of first-year chemistry students. I also purposely sampled research participants who could illuminate the phenomena being studied.

Consistency or Dependability. When other researchers are given the same data and find similar patterns, it means that the findings are dependable. In this case, researchers validate the "experience of a phenomenon to" highlight it and "discourage fulfilment of limited researchers' expectations" (Hammarberg et al., 2016, p. 500). Besides, team members verify theoretical findings by member checking and detailed procedures regarding data collection and data analysis used by the researcher to consolidate the reliability of the findings (Hammarberg et al., 2016). In the study, the researcher gave detailed coverage of "methodology and methods, research design" and "details of data collection" methods to "assess the extent to which research practices have been followed" (Moon et al., 2016, p. 2 citing Shenton, 2004).

Conformability. The report of a study should be transparent and clear. This means the reader and reviewer must follow the progression and understand their reasoning from "the purpose of the research, how it was conducted, procedural decisions, and details of data generation and management" (Moon et al., 2016, p. 500). To establish conformity, the results must be "linked to the conclusions in a way that can be followed" … and "replicated" confirms Hammarberg et al. (2016, p. 2). Results should be relevant enough to provide policy recommendations. In this study, the findings were on the basis of experiences, perspectives, feelings, attitudes or thoughts of research participants. Coding and interpretation of data was directed by the research questions, theoretical frameworks, and theories that emerged from the data. The researcher also provided a detailed methodology description (Moon et al., 2016 citing Shenton, 2004).

Ethical issues. Ethics are norms that are followed in doing a task in an acceptable manner (Bassey & Owan, 2019). The concerns in research comprise all human subject-related research. Ethics is something which is expected to be followed and ought to be maintained during the write-up and dissemination phases (Bassey & Owan, 2019). Hence, before commencing data collection, a clearance letter was issued by the institution to conduct research. It was followed by an application, research instruments, information sheets and consent forms submitted to University of the Witwatersrand ethical research committee (non-medical) for approval to carry out the research. Approval was granted (see appendix A). The information sheet informed the potential participants, who were chemistry educators and first-year chemistry students, about "the purpose of the study, study methods, time required to participate, their right to ask questions or withdraw at any time and" that there were no "potential risks or benefits" in taking part (López-Alvarado, 2017, p. 3) so that they could make informed decisions.

Potential participants were informed that interviews and classroom observations were going to be video-recorded. Their words would be used in reporting the findings and that they were free to take part in the study or not. Hence, signing consent forms meant that they agreed to take part. Participants were aware that they could withdraw from the study at any time without consequences (Abed, 2015). Signed consent forms were returned to the researcher. It was made apparent to the participants throughout the research process that they were not subjects but co-researchers. Data were shared with the lecturers and all participants received their classroom videos. This falls under respect for persons. Ethical standards demand that "participants are not" exposed to "physical or psychological harm or benefits" that can affect the individual or society (López-Alvarado, 2017, p. 3). Finally, no physical harm was experienced by participants as the collection of data happened in lecturers' offices and students' lecture halls. Confidentiality was upheld as pseudonyms were used to protect their identity. So, there was no psychological harm incurred.

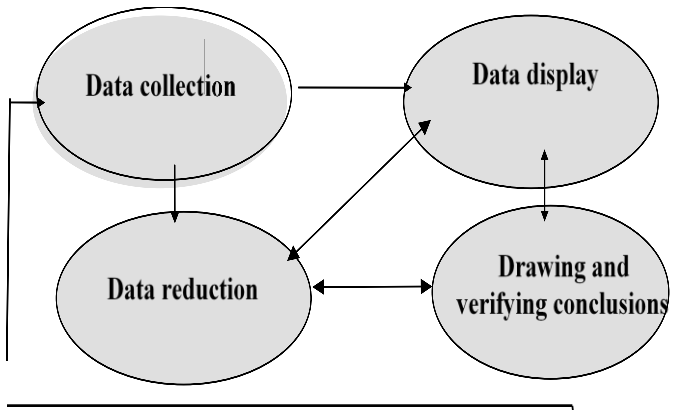
Analysis of Data

Data collected from survey questionnaires, educators' semi-structured interviews, class observations, video clips, and students' focus-group interviews are presented in this section.

Analysis of Qualitative Data

In social research, data "analysis" is breaking down data into bits, then weaving the bits together (Bohm, 1983 cited by Ahmed, 2010). It is about "making sense out of the data", which means "consolidating, reducing, interpreting what people have said and what the researcher has seen and read" (Merriam, 2009, p. 176). Hence, it is process of making meaning. According to Ahmed (2010, p. 5), "data analysis brings data together to reveal its contents" … "in an on-going process of resolving the collected research data into its constituent components". Qualitative analysis examines data from questionnaires, interviews, classroom observations and field notes. Process of qualitative analysis involves "reduction, data display, and drawing and verifying conclusions". Figure 4.1 illustrates the process of data analysis (Ahmed, 2010, p. 6).

Figure 4.1: *Components of Data Analysis: Interactive Model*



Source: Miles and Huberman, Qualitative Data Analysis (1994, p. 12 cited in Ahmed, 2010)

Analysis of educator's questionnaires. Initially, I read and reread the responses and questions to identify potential themes. I looked for patterns in the transcribed data to answer research questions. Open and selective coding was used to analyse the first key ideas of categories (Tanaka, Parkinson, Settel, & Tahiroglu, 2012). These categories were informed by the research questions. The themes that emerged were compared again with further key ideas. This resulted in subcategories. I looked for keywords and ideas used by all the respondents and used the excel sheet to note key ideas and related ideas. The recurrence of certain keywords in the answers led to the emergence of a pattern that could be categorised into the following themes: students' failure, students' responsibility, mastering of threshold concepts from a foundation, prior knowledge, lack of resources and improve learning. I linked these ideas to the experiences of the participants in the teaching of the acids-bases reactions and arranged them in groups (Tanaka et al., 2012). Putting them in groups allowed me to put them in subthemes which were: challenges experienced by lecturers in teaching threshold concepts of acids-bases and how these challenges can be ameliorated; the causes of high failure and drop-out rates and how they can be ameliorated and their capabilities and experiences of teaching threshold concepts of acids-bases reactions. The last segment of the hierarchy of the themes in which respondents expressed how they would ameliorate students' failure and drop-out rates in chemistry were: to master the threshold concept, a connection of chemistry ideas, foundation course, and adjusted teaching-learning. These responses were categorised in four areas: students' different socio-cultural and academic backgrounds, lecturer's knowledge and capability of the teaching of threshold concepts of acids-bases, limited resources; and teaching threshold concepts as a foundation course. The researcher extracted related ideas from the results of the survey with specific questions and through the lens of the main theme (Tanaka et al., 2012). This allowed me to organise responses to different questions thematically and related data that were linked to the main theme were used as points of discussion.

To verify the survey questionnaires, the researcher did member checking in some cases to clarify the responses and followed up on intensive interviews. The respondents agreed and the schedule was drawn for each respondent.

Analysis of educators' semi-structured interviews. Video and audio recorded transcribed interviews followed the coding stages (Walsh, Hayes, Freeney, & McArdle, 2019). The responses were aligned to the corresponding questionnaire questions on the spreadsheet. The researcher read and reread the transcripts to identify the categories of the concepts. I identified codes and patterns from interview scripts concerning research questions and repetition of the response generated themes (Walsh et al., 2019). Adjusting teaching and learning, connecting ideas, foundational course, prior knowledge, key ideas, resources and help were the themes that emerged. Once the themes were identified, I compared and contrasted them with the emerging key ideas across the transcriptions to review the initial codes. Subthemes emerged while I disregarded other ideas. Adjusted teaching and learning, key ideas, foundational course and related ideas emerged as subthemes. I also identified the quotes that corresponded with the themes (Walsh et al., 2019).

Interview responses were verified by comparing them with questionnaire responses and member checking. Interview themes were finalised by combining them with the questionnaires' themes.

Analysis of Classroom Observations

The researcher watched all 15 videos and transcribed them manually to get a thorough understanding of the classroom activities and classroom cultures. The observation schedule was used to code the activities (Smart & Marshall, 2012). The coding was based on the classroom context showing the educators' and students' roles in interaction, for instance, situations in which the educator lectured and solicited for students' explanations or participation in solving tasks. Students responded individually or with their peers to the educator's questions or demonstrations. The code list included the following: educator's engagement of students, the context of the lecture hall, students' interactions with each other, students' interactions with the educator, educator's interactions with students, students' interactions with acids-bases reactions tasks and the educator's response to students' questions. I watched the videos again and compared them with my field notes. Themes from classrooms were compared to develop a description of each theme (Smart & Marshall, 2012).

This resulted in subthemes which were: classroom structure, classroom culture, students' activities, nature of activities, and interactions between students and lecturer. Quotes for the themes were taken as evidence from the transcriptions.

The findings were triangulated in post-lecture video discussions with lecturers and students' focus group interviews.

Analysis of Post-lesson Video Semi-Structured Interviews

The researcher watched selected segments of the three lessons with each lecturer to provoke reflection on their practices. The post-lesson observation discussions were not feed-back but were held to understand better what happened in those lectures (Kim & Silver, 2016). Transcribed conversations created themes that were: students' participation, activities, educators' tasks, challenging concepts, prior knowledge, students' attitudes, do more examples of solving problems, keen students, fearful students, failure of students to progress to next concepts and interconnectedness of concepts. The patterns were further coded into subcategories which were: students' diversity, more examples of solving problems, students being stuck at a challenging concept and challenging concepts. Recoding data into categories was to enable a meaningful comparison of the subcategories (Kim & Silver, 2016). Furthermore, subthemes were defined and named as perspectives of educators.

Analysis of student's focus-group interviews. Transcribed information was transformed into categories and themes (Nyumba, Wilson, Derrick, & Mukherjee, 2018). Students were coded into groups A to F dynamics and individual students were given pseudonyms. Thematic analysis was guided by the research question, which challenged first-year students to experience learning threshold concepts of acids-bases reactions. Emerging themes from transcribed data were listed as follows: key ideas, lack of interaction with educators, lack of laboratory work, authoritative educators, teaching techniques, students memorising concepts, students' different academic backgrounds, different prior knowledge levels, abstract concepts, insufficient resources and pressure of work. I went through the main recurring ideas and connected them to the codes. I drew comparisons across the group dynamics and individual students' statements (Nyumba et al., 2018 citing Morgan, 1995). Subthemes emerged from this process which were: teaching strategies, students' experiences, different knowledge levels, resources and loaded chemistry content. I defined and named the themes into one main theme of students' perspectives and drew on direct quotes occurring within the group discussions.

Summary of the Chapter

In Chapter Four, detailed descriptions of the research paradigms, research design, participants and the justification for their selection, research instruments, the data collection procedures and the data analysis frameworks are given and discussed. The rationale of qualitative methodology, case-study, and action research strategies and data collection instruments employed are justified. The overview of the validity of the qualitative is presented. Ethical issues are presented and discussed in details. Chapter Five that follows presents findings and discussions of the study.

Chapter Five

Student Group Dynamics

Introduction

This chapter engages with the students' interactions in five different groups/classes. Each class was large, mixed-gendered, and had between three hundred (300) and fifty (350) students. Participants were first-year chemistry students who volunteered to be part of this study and who were learning the threshold concept of acids-bases reactions at the time. Forty-seven (47) students were interviewed and were given pseudonyms to protect their identities. My focus was on the students' perspectives. I interrogated, explained and theorised what happened in their classrooms to make meaning of their interactions with each other and with their lecturers while they were learning threshold concepts (TCs) of acids-bases reactions. I engaged activity theory (cultural-historical activity theory being a variant) being a lens in explaining dynamics of their classroom interactions and interrogated how these were impacted by the three generations of activity theories (first, second and third), where and when appropriate. I made attempts, where applicable, to link cultural-historical activity theory (CHAT) with other theories in taking multi-theoretical and multi-perspectival approaches in constructing meaning of what happened and why it happened. Furthermore, I employed narrative approach in presenting the findings.

Cultural-Historical-Activity Theory (CHAT)

The CHAT is depicted by triangular, dialectically related series of interactions (Engeström, 1987). Participants were chemistry educators and their first-year chemistry students; however, my focus is mainly on the students in this chapter. With CHAT, there are rules, which govern the activity; there are also roles or division of labour, which participants play in their classes and there are resources (tools), which were employed in mediating the teaching-learning in the classrooms. Educators and students were involved in the teaching, learning and mastering of threshold concepts (TCs) of acids-bases reactions. All students interacted face-to-face in and outside the classrooms. The community of practice (CoP) was multicultural with students from different contexts (secondary schools, families, and cultural backgrounds) in Zambia. In addition, students' prior knowledge was different (multifaceted) and included the General Certification of Education (GCE) Ordinary Level chemistry, physical sciences, combined sciences, chemistry up to GCE Advanced Level and some students who were repeating the same chemistry course. This community of practice consisted of university lecturers and their first-year chemistry students. There were resources (tools) such as computer hardware and software, whiteboards and chalkboards, projectors, smartphones of varied capacities, tablets, scientific calculators, the acids-bases curriculum, lectures, languages of instruction, assessment methods, tutorial notes, hardcopy and electronic copies of textbooks and teaching strategies, among others. The goal (object) was to enable first-year students to master TCs of acids-bases. The outcome was the students transforming their reasoning and knowledge of TCs acids-bases learned via related topics in introductory chemistry with the goals of improving students' performances in chemistry and reducing high failure and drop-out rates. Teaching and learning acids-bases required collaboration among students and with their lecturers.

Activity Theory

According to the first-generation activity theory (Vygotsky, 1978), human interactions are socially-mediated with tools (resources) such as signs (Ang, Zaphiris, & Wilson, 2010).

These activities are purposeful interactions of students-to-students and students-to-educators with TCs of acids-bases reactions as the objects of interactions. In addition, through activities that were either assigned by the educator or were generated by the students, they transformed the object of the outcome, which was to gain more knowledge of TCs of acids-bases reactions. The success of mastering the TCs of acids-bases reactions was to minimise the frustrations and tensions between the educators and students. The successful learning of threshold concepts (TCs) of acids-bases (object) was to also transform the educators and the students themselves, individually and collectively. The students were transformed in their thinking and studying of acids-bases and were able to progress to study other related concepts. When students were not transformed, they remained in the liminal space of learning the TCs and cognitively in the Zone of Proximal Development (ZPD), unable to reach the next level of learning. All activities were contextual within interdependent, interacting activity systems. Activity systems are not stagnant, nor do they come to a halt unless the objective or purpose of the activity has been achieved. Activities also do not exist in singularity rather they in waves or motion. Every activity theory has tools, rules and roles and an objective. In this case of first-year chemistry educators and students, the goal was to succeed in raising students' pass rates. While educators are thinking of how to successfully teach the TCs of acids-bases and raise students' pass rate in chemistry, students are thinking of how to master the concept in order to be successful in chemistry. In the activity theory, there is an interdependence of artefacts that are supposed to interact with educators' or students' tools or rules which may not work well, that means that there are constraints. Students may change the tools or rules to enable them to work. Then, educators and students may try to ameliorate the constraint. For instance, teaching techniques may be a form of constraint on Bwalya (group D) in understanding acids-bases reactions. Bwalya indicated that "we are exposed to this type of learning where a lecturer will just come with his slides and without getting the exact content of the concept, he moves to the next concept". Educators have their roles to play in making students learn acids-bases concepts and to succeed. Students' roles were to adjust to the new environment and also to the teaching methods and learning techniques. Njovu (group D) explained that he was "learning day-by-day how lecturers teach at the university level" and he hoped "to do much better in chemistry". So, there are roles, rules, and resources, although some resources did not work well. Educators and students adjusted the rules, roles and resources because they wanted to achieve their objectives. The objective of the educator was to teach TCs of acids-bases reactions while the students' objectives were to learn and progress by transforming intersecting activity systems.

Temwa (group E) viewed such challenges as opportunities to learn. Temwa said that she did not understand why she should fail at university if she was a good student at secondary school. She indicated that if she is not successful in learning the concepts of acids-bases reactions, she will not attribute such failure to her educator because it is her role to make her learning acids-bases reactions possible. Temwa remembered thinking that it was going to be easy when she became a university student. She intended to be successful in learning whatever concepts helped her to earn her degree. Temwa said, "We are not proton receivers. At one point we must donate protons. It is about donations in terms of learning. It is about you doing research. You are going to study. You zero in [studying late into the night]". This is because she wanted to achieve the objective of her activity system. She intended to be successful in learning the threshold concepts of acids-bases chemistry. So, she interacted with her fellow students, educators, tools and rules of the activity system. Temwa explained that some students were "geniuses" and that it could be good to interact with them. Then, students in the interacting groups could enable each other by teaching each other to succeed individually and collectively.

Multiple interdependent and interacting activity systems intersect in the classroom. According to the university schedule, students learn from 08.00 am to 4.00 pm. There are days when students have just one lesson and plan to study or are engaged in group discussions which was to enhance their studying. Then, suddenly, students receive a message that they are going to have a lesson later in the day or need to hand in their laboratory reports. The students concerned may need to transit into another activity system and back to the previous activity system because they want to accomplish their objectives. Hence, activity systems meet in one shared space or a third space, for example, listening to an educator in the classroom and then transiting back to where they were in a group discussion. Theoretically, the students did not completely come out of "studying" because studying became an epistemic object in their minds. So, the second-generation activity theory of Leont've (1978) recognises "collective mediation" in the context of the "activity system". Collective mediation enables educators and students to think together that encourages finding a solution which is the object of the collective activity system. Hence, collective mediation brings collective success. Collective success begets successes because successes motivates group members to continue working together to pursue more challenging tasks. The educator is equally encouraged because his/her objectives to teach acids-bases reactions have been achieved. On the other hand, a lack of success begets a lack of success.

Group A

Group A's dynamic. The class consisted of between 300 and 350 male and female first-year students. The group discussion took place midmorning in a lecture theatre. At this time, they were supposed to have a chemistry lecture, but the educator was absent. Therefore, I took advantage of the time to talk with the students and four (4) male students volunteered as participants. I gave these participants pseudonyms: 1) Botha; 2) Dingaani; 3) Mwansa and 4) Mwaanga. The conversations lasted 33.55 minutes and took place on 13 March 2019.

I started the conversations by trying to find out their aspirations for enrolling at the university. Like many students, they aspired to explore their potential careers. Botha chose electrical engineering; Dingaani hoped to be a neurosurgeon or cardiac surgeon; Mwansa wanted to study pure mathematics because he loves it; and Mwaanga longs to be a medical doctor and specialise in cancer treatment. Chemistry is one of the prerequisite courses for their intended programmes. Looking at the history of high failure and drop-out rates in chemistry, I decided to have a conversation with these students and the lecturer for group A.

Group A's Perspectives

When I asked the four participants about their experiences in learning chemistry and the fact that they had just had a test, Botha stated that they were not having challenges learning chemistry, but the challenge was in the writing of the test. Botha explained, "We were told two days before to study for a test and this put us under pressure". Mwansa added that the duration of the test was too short to complete answering all the questions. Furthermore, some educators marked only the final answer without marking the procedures or step-by-step calculations. Mwansa thought that these were the contributing factors to failing chemistry. Dingaani noted that the lack of practical work in chemistry is a big challenge for him because he learns better when he sees something (learning styles) therefore he had to research further on the concepts or topics on his own to fully understand them. He stated further that since the practical aspect of chemistry is lacking, he believed that "interest" is dwindling. It is memorising this constant, the equation of what happens when hydrochloric acid reacts with sodium chloride; what happens when copper sulphate reacts! We want to experience what we are learning!” He explained that, from secondary school to university level, students seldom learn to understand but only to pass the examinations. Mwaanga concurred with Dingaani that they do not practice what they learn but, if they could see what they learn, they could be able to get more information to apply in their everyday lives (lived-experience) and not just learning for the examination. Botha concluded by saying that the practical aspect was just a formality (they are discussing hands-on, mind-on activities in the classroom or laboratory).

Botha and Dingaani described how the knowledge of acids-bases (hands-on, mind-on structures in the classroom or laboratories) could be applied in manufacturing industries as part of everyday life. Botha explained that fruits contain citric acid, which is a weak acid. In the manufacturing process of beverages, chemical equilibrium, common ion effect and pH are applied. In supporting Botha, Dingaani stated, “base and its equilibrium concept are applied in soap making. Soaps are basics and our skins are acidic” and so, “the acid and base neutralise each other,” exclaimed Dingaani, “we use the soap to remove dirt on the skin”. Dingaani gave another practical aspect of acids-bases in the manufacturing of fertilisers, such as nitrates and urea, in the agricultural industry. He explained that it is in studying acids-bases reactions that students may learn how to maintain the pH of the soil.

Some students preferred a total of four (4) hours chemistry lessons instead of the two (2) hour lessons that had been split into one hour each. The lecturer shifted the lesson from two hours on a Tuesday to one hour on a Wednesday and one hour on a Thursday from 07:00 am to 08:00 am. Botha missed the introduction to chemistry and chemical equilibrium because he studied late into the night and did not wake up on time to attend the early morning one hour lecture. Botha resorted to watching electronic tutorials, reading books, consulting friends and asking the lecturer questions after the lesson. In order to download the electronic tutorials through YouTube, Botha used his personal laptop and internet data bundles. Dingaani also used his laptop, smartphone and data bundles to download YouTube videos. Before attending each lesson, he watched academic videos and asked the lecturer during the class questions about what he did not understand. Dingaani said that he learned better when he was being taught in class. Mwaanga also used his smartphone to watch videos of acids-bases reactions because the Wi-Fi was not reliable. Apart from the challenges of weak or no internet connection, there was no work done in the chemistry laboratory in the first term. However, in the second term, laboratory work was introduced for two hours per week as explained by Mwansa and Mwaanga.

Group A educator's perspective. From the educator's perspectives, the challenge in the teaching-learning of TCs revealed teacher-centred approach. The concepts were presented in much more detail than was intended for first-year students' level. According to the educator, this may have caused students to view chemistry as difficult. On the other hand, students' secondary school backgrounds can determine how they approach the course. Some students were reminded about the difficulties they experienced at secondary school level while other students come with positive attitudes because they see chemistry as interesting. As a result, these students wanted to learn more and tended to do well.

Chanda, the educator, claimed that it was easy to teach acids-bases reactions chemistry as a stand-alone topic if it is related to everyday life, but the challenge was the lack of practical work. Although hard copies of textbooks were difficult to get hold of, electronic books could be downloaded. The internet is accessible by academic staff and students. In addition, Chanda's class consisted of students at different levels of understanding. Some students talk to each other, some copy the work from the whiteboard and others listen because they learn differently, depending on their levels of understanding. Chanda kept eyes out on students to see their reactions to the learning of chemical equilibrium and calculations of pH. Chanda stated that he was sensitive to students' comments and the questions asked during the lesson. He did not expect students to experience challenges in acids-bases reaction concepts especially those who had consistently attended classes from the beginning of the year.

Researcher's perspectives. In my lesson observation, Chanda involved the students by asking them questions as the lesson progressed. Only a few students asked the educator questions but most of them were either copying the calculations, working together with friend/s or listening. Chanda had difficulties engaging the class, which may be due to the large number of students. For instance, an equilibrium reaction involving solid sodium chloride that was added to the equilibrium solution of silver chloride, which is neither acidic nor basic, the educator asked the students to identify the common ion. Students gave a correct answer "chloride" and continued to listen. According to the conversations I had with the educator, I proposed that that was the students' comfort zone. Chanda had no choice but to "talk and chalk".

From the conversation with the four members of the class, it seemed students were independent learners who learn from the YouTube tutorial lessons and more knowledgeable friends. The early morning Wednesday and Thursday's lessons did not favour some students, which caused students like Botha to miss some lectures. Although the YouTube tutorials were free to be downloaded if the internet connections were available, these required educator's recommendations. It appeared to me that the students were aloof towards the educator and the subject, as observed during the class activities. The students conversed among themselves, three students faced the back, not the educator and the board, and others were listening attentively and seemed to follow as the lecturer solved problems on the board. Students claimed that they did not have any challenges in learning acids-bases reactions except that the learning should involve chemistry practical.

Discussion of Findings

In group A, the activity system was full of activities as students were solving problems designed by the educator either in pairs or in groups while some observed the educator and were writing as he solved the tasks on the board. Generally, the context of learning was interactive and noisy (everfescent). Four male students out of about 350 students volunteered to take part in the interview. Students claimed that they had not experienced challenges in learning acids-bases chemistry but in the mode of presenting the chemistry content because the practical aspects of teaching and learning of acids-bases were missing. Dingaani complained that the teaching was "memorising this constant, this equation, what happens when hydrochloric acid reacts with sodium chloride? What happens when copper sulphate reacts? We want to experience what we are learning." Students' learning, that is, for instance, hands-on and mind-on in the reactions of acids-bases chemistry conflicted with the lecturer's teaching method as Mwaanga claimed that "some of us as he [Dingaani] said, we understand better when we see what we are taught not just to be told that this happens, but when we see that this happens …." The rules of the activity system implied that students were just expected to accept the concepts as they were presented to them by the educator without explanation or full understanding of the concepts (Bourdieu, 1977; Freire, 2005). For example, Dingaani stated that "You learn on something and then you begin to research to learn on your own without experiencing; it is very challenging".

Students interact formally and informally “inside and outside the classroom”. Interactions created affordances or constraints in the process of achieving the learning outcomes. According to Bandura (1977), the affordances include the opportunity for vicarious learning from other students within the space. Students expanded their knowledge and shaped their learning through vicarious learning. In my discussion with him, the educator indicated that university rules stated that he must teach a detailed curriculum beyond what students know. Both the affordances and constraints created by teaching a detailed curriculum make some students struggle but they also provide opportunities to challenge themselves to study more, prepare for tests and to be on the alert academically, instead of complaining, as stated by Botha and Mwaanga: “We were told two days before to study for a test and this put us under pressure … the time is too short, and you know a lot of information but the time you are trying to deal with the questions you find that the time is over [but] you didn’t finish answering all the questions and yet you knew all the questions”. Students have not reached the university level of learning, for example, learning to study for understanding chemistry content and not only to study for the examinations, for example, Mwaanga stated that “our teaching and learning from secondary school to university is different – we learn to pass the examinations and not to understand the theory aspect”.

The splitting of a two-hour class into two one-hour classes which were on Wednesday and Thursday from 07:00 am to 08:00 am became a constraint for some students even though it was a student’s responsibility to attend the class. Some students failed to wake up in time to attend early morning classes. For instance, Botha complained that “I was not there when the topic [acids-bases reactions] was introduced because our educator changed the times of meeting to one hour from 7:00 am to 8:00 am in the morning and I couldn’t make it”.

In their studies outside the classroom, students negotiated the rules, roles and even the resources they engaged in individually and collectively. For example, they mediated their own personal learning by accessing resources such as electronic tutorials (acids-bases videos), different chemistry textbooks and even consulted colleagues and friends who acted as more knowledgeable others (MKOs). Students felt empowered to construct their own learning so, when they were faced with a challenging concept, they asked the educator for clarification. This indicates that students were in the liminal space of learning (Meyer & Land, 2003) and in ZPD (Vygotsky, 1978); students seem to make efforts to cross into conceptual difficulties. Nevertheless, members of group A felt side-lined by their educator in the changes that affected them when the two-hour class was changed to an early morning one-hour class on Wednesday and Thursday. Early lessons affected their personal structures such as students had to study late into the night, regulate dinner and sleeping times.

Educator's Interaction with Students

Chanda is both a chemistry laboratory technician and a first-year chemistry educator. He had worked as a secondary school chemistry teacher. His name indicates that he is a Bemba speaking person. Chanda joined the university as a laboratory technician and later began to teaching chemistry 110 to first-year students. He has been teaching chemistry now for a period between seven and ten years.

Chanda's engagement with students during the lesson on common ions in chemical equilibrium reactions created affordances and constraints. Chemical equilibrium in acids-bases is one of the threshold concepts of acids-bases chemistry and was presented in the abstract. In a large classroom, he used "talk and chalk" which created enablement and constraints for some students. Affordances enabled students to construct their personal learning. Some were listening attentively; some were working in groups or in pairs and others were copying work from the whiteboard. Students “develop a method of behaviour for guiding themselves that had previously been used in relation to another person”, and “when they organise their own activities according to a social form of behaviour, they” seemed to have succeeded in applying a social attitude to themselves (Vygotsky, 1962, p. 104). Classroom environment was an active environment of activities. Chanda mediated and negotiated the activities by keeping eye contacts with students, asking them questions and waiting for their answers to in order to sustain the interactions between students and lecturer. Chanda used students’ answers to build on the knowledge, for instance, Chanda asked “What is the effect of common ion? In what direction will this equilibrium change when you add a drop of hydrochloric acid”? Some students responded, “to the right” while other students said, “to the left”. Chanda then expanded on the responses of what happens when a hydrogen ion is introduced and causes the equilibrium to shift to the left, which is that molecules break up in ionisation.

Chanda was sensitive to students’ reactions when he taught as they possess different levels of understanding and perceptions of concepts. He stated, “Sometimes, it will come from humming, it tells me that something is not clear to them”. His sensitivity created affordances and constraints for him and his students. For instance, an affordance assisted Chanda to notice that students were experiencing challenges in differentiating “conjugate base” from “conjugate acid” or identifying “conjugate pair” within chemical reaction. He explained, “the confusion comes in when they start viewing the reactants as primarily the conjugates”. Furthermore, Chanda and the students mediated the conjugate pair challenge by using practical examples such as the dissociations of sulphuric and phosphoric acids. Affordances also created a freer environment which caused interactions between student and lecturer as students asked questions for clarifications and contributed to the discussions. Similarly, students who mastered “conjugation” slowed down to allow other students to catch up. Hence, affordances created an agency to collective and individual interactions with weak acids-bases reactions which a lecturer claimed, “… I could observe that it was easier for them to understand; the fact that we always associate weak acids and bases with equilibrium”.

Group B

Group B’s dynamics. Group B was a large mixed-gender class of nearly 350 students. Initially, seven (7) students volunteered to have an interview or conversation with me. However, only four (4) students came (showed up) because the university was closing early that day. There were two (2) females and two (2) males. The conversation took place in the School of Mathematics and Natural Sciences Conference Room in the early afternoon. I named the participants 1) Mwenya and 2) Dumizani, who are male students and the females were 3) Mwangala and 4) Mutinta. The discussion lasted 53.25 minutes and took place on the 26th of March 2019.

I started the conversation asking about the students’ academic backgrounds and aspirations. They were hoping to improve their education in preparation for science-related careers. Dumizani hoped to do something in the field of natural sciences. Mwenya hoped to graduate and become a useful citizen so that he could participate in local affairs that include “activities like paying tax**,** participating in economic development”. Mwangala wanted to become an optomological doctor and Mutinta wanted to pursue a career in computer engineering. She hoped to create a field in which people can interact with computers. Chemistry was one of the prerequisite courses but there are high drop-out and failure rates experienced in freshman chemistry in the institution. Hence, the conversations extended to these students and their educator. The students' conversations took place after the acids-bases reaction chemistry had been taught.

Group B's Perspectives of Third Space

Students noted that in their personal experiences in learning acids-bases chemistry, it was not very difficult for them. Mutinta found the concepts "quite alright" [not difficult] "because I am able to understand the concepts and relate them to my career". I asked Mutinta to give examples of the chemical concepts, which related to her career. She responded, "Certain chemical that is made to come up with the ink that is used in the computers". Similarly, Mwangala's experience with chemistry was "quite good" [not difficult] as she was able to relate what she was studying [acids-bases chemistry] to everyday life such as "ice melting (text knowledge), boiling and cooling reactions". Mwenya echoed Mwangala that learning chemistry should related to everyday life. He claimed that chemistry is applied in everyday life without our knowledge, for instance, "… our parents use things without knowing that what they [were] applying is chemistry". I asked Mwenya to give examples where acids-bases reaction chemistry knowledge is applied. He gave an example of the preparation of traditional alcohol and a popular beverage:

> "… being in a home of an African per se. There are sometimes when it comes to making the traditional alcohol; it is chemistry … As a student who is able to learn, I am able to say no mom or dad, at this stage, you are supposed to do this so that this reaction to take place [and] there shall be no explosions that are going to occur and you are going to be safe".

I further probed him to explain traditional beer and beverages. Mwenya explained:

> "Kacasu [traditional beer] … let us talk about umukoyo [beverage]. Many people just

> prepare it as a traditional drink (beverage) … people tend to take precautions to make it [beverage] even to turn it into alcohol. Now, as a student [who] is able to learn about these things [acids-bases], if I am found where they are making, I am able to tell them that if you add these things [carbonate] you are going to turn it into alcohol".

Mwenya's description of acids-bases reactions chemistry could be more feasible if related to the preparation of traditional beer (kacasu) and beverage (mukoyo) because people apply chemistry in their everyday lives without their knowledge. Bricolage may also be applied here because it is a "positive concept for theorising experiences of learning science in schools" (Roth, 2008, p. 898). A bricoleur teacher follows the "curriculum yet" finds opportunities to hybridise "it with out-of-school, discursive resources to make school science more relevant to students' daily lives" (Sharma, 2008, p. 834). Students are "equipped with rich experiences with the material world" and "are positioned to have a dialogical engagement with school science", concrete objects and experiences (p. 898). Drawing on household knowledge, students' experiences are legitimate and "classroom practice can be built on familiar knowledge bases that students" have "to enhance learning" (Gonzalez, 2005, p. 43 cited by Sharma, 2008). Sharma's research revealed teaching to be a site of bricolage. School science is decontextualised and does not pay attention to educational concerns and is not concerned with experiences in the world. Bricolage indicates "directions for change in how science is taught in schools" (Sharma, 2008, p. 838).

Dumizani's experiences are different from the other participants, as he states, "My experiences are quite good. I have experienced a lot to do with concepts although I feel there is a lot to be done with practical aspects". He explained further that "in acids-bases we are learning the theory part but, when it comes to application, I just find it a little bit difficult to apply because it feels like there are some concepts that are missing". I asked Dumizani to shed more lights on acids-bases reactions and his difficulties applying them. He explained that he finds it difficult to apply the concepts of acids-bases in related problems such as the acids in fruits. Dumizani maintained that “it became much difficult – such as how do you measure the pH of citric acid of a lemon? How do you know that? What criterion are you going to use?” He claimed that he struggled with the lack of practical aspects but that the “theory part” [teaching and learning] was “fine”.

Despite a lack of the practical part of teaching and learning “it has been an enjoyable topic to learn” Mwenya added. He explained that “it is somehow frustrating because most of the students looked at [acids-bases] as easy since we had [acids-bases] during our secondary education. That is why, when coming to applications, like in tests, we are going to face some challenges”. Similarly, the authoritative lecturer hinders students from asking questions about things they have not understood clearly. He stated that “there are times when you may try to express your view but, if the educator is authoritative, he hinders you”. Sometimes authoritativeness causes the students to feel intimidated. In this case, authoritativeness is a form of symbolic violence which some people feel, subjugated whereas others may ignore it (Bourdieu, 1985). The authoritative lecturer, with possibly cultural capital tends to dominate the conversations in the class and does not recognise the socially imposed dominant mode as a natural norm – the participant in symbolic violence. Social capital is decomposable in the social relationships that allow individuals to claim access to resources possessed by associates and the amount and quality of those resources. Resources are obtained by virtue of membership in the group. When students do not have access to social capital it generates into social, cultural violence which generates cultural violence.

Mwangala explained that “according to my experience, this topic, acids and bases, it seems alright." She liked the theory part of acids-bases but not the calculations. Mutinta agreed that it is a "good topic but consists of certain characteristics [subtopics]" which are quite challenging, for instance, "if you are given a mixture of an acid and a base and if you are not given the information, it is [often] difficult to interpret the information especially the calculation part." As a result, "… you may not understand certain concepts by which, when you miss out on one concept within the question, then you get everything wrong". I asked the participants to give examples of concepts that were a bit challenging apart from the ones which they had mentioned. Dumizani responded that acids-bases chemistry had been "quite a challenge from the start". He claimed that the "Arrhenius definition is easy to know. The challenge is to differentiate the three definitions. Mostly, when differentiating the Bronsted-Lowry and Lewis models, the limitations are quite complicated." According to Dumizani, it "is easy to know [the] limitations" of Arrhenius's concept but "when it comes to Lewis part, the limitations are not so clear. It is the same on the Bronsted-Lowry".

I further asked the students to explain how the authoritative lecturers could have accommodated students' questions better. Mwenya claimed that when they were at secondary school, subjects were taught at a lower level than university and that educators should bear in mind that students were not at the same institution and hence, were not taught the same information. Educators should also consider that there were students who did not learn about acids-bases. Mwenya suggested that educators should try to be non-authoritative so that students could feel free to ask questions that prevent them from having "distorted information". There were also instances when a student "received an unexpected response" from the educator when the student asked a question so that the student would be unwilling to ask another question. Mwenya argued that educators must acknowledge that students "are not the same." Some students can have the capability to study on their own whereas other students need help from the educator. Mutinta added that some students went to good schools and others to average schools and that the difference may be in the type of schools attended and in the teaching and learning of chemistry that took place.

Usually, a good school may offer many chemistry lessons per week, unlike an average school as Mutinta stated, “you are having chemistry lesson just a day but there are certain people that can have chemistry class the whole day or the whole week on the time-table they are having chemistry classes”. So, the quality of the information students get would be different. Mutinta explained that, at university, the student from an average school needs input. Furthermore from the educator to understand the concepts unlike the one “from a good school who will need very little effort to understand that or a course”.

Educator’s perspective. The discussions I had with Hamoonga, the educator, were based on classroom activities. The educator claimed that neither the students nor he had experienced challenges in teaching and learning because acids-bases is an easy subject matter. He revealed that he provided notes to the students which he referred to when teaching and that the students also have textbooks. Hamoonga said that most of the problems which he solves with the students in class are from the notes. So, students try to master the concepts by solving the calculations. According to Hamoonga, students who were likely to experience challenges were the less privileged who do not have laptops and/or money to photocopy notes. He thinks the problems of the lessons were problems of poverty but nevertheless, Hamoonga holds his students to high esteem as he stated, “… these are the brightest kids that we have in the country.”

I probed Hamoonga further on the teaching-learning of weak and strong acids, dissociation, chemical equilibrium constants, concentration constants, and calculations. He retorted, “If a student cannot do concentration, they should not be here." Students understood because he had taught them in the previous lessons. He was confident that most of the students would pass general chemistry and that fewer than 10% would fail. If the failed students were to be given a chance to repeat, he believed that they would pass. In addition, he claimed that 90% of the students would complete their science-related programmes and graduate. I asked Hamoonga to elaborate on his expectation of first-year chemistry students' pass rates. He explained that usually at their first attempt, the students' failure rate is 40% and that 30% out of the 40% would pass when they repeat the examination. Hence, 10% may drop out, not because they are not intelligent but because they are not self-disciplined. I sought clarification of the lack of self-discipline from him by referring him to the video clip where he (Hamoonga) refused to answer a student's question but referred him to the notes because the student did not do his assignment. He explained that students had been told to study the notes before asking questions. Hamoonga stated, "What conversation can you have with a person who had not studied? It is pointless talking to a student who has not been reading." He illustrated his point by saying that "it is like picking somebody from the street and you start talking chemistry to them. It would not work." Furthermore, Hamoonga revealed that the majority of the students were too shy to ask questions so they came at the end of the lesson to his desk to ask him questions.

Researcher's perspectives. Students' conversations with me were a representation of intelligent students. Students were able to discuss the cultural aspects of acids-bases reactions as a way of mastering concepts. They related the concepts of chemistry to everyday life. These students saw chemistry in their environment that is relevant to their programmes. Like many students, they experienced challenges in learning key concepts of acids-bases reactions, Arrhenius, Bronsted-Lowry and Lewis definitions, chemical equilibrium equations and calculations. These students would like to participate in the lessons, but the student-educator interaction seems to be curtailed by the lecturer's authoritativeness.

Hamoonga seemed to be more of a chemist than an educator because he has no education training, but he interacted with the students very well. After demonstrating how to solve a problem on the board, he would go around the class to see how the students were doing.

Discussion of the Findings

The learning context of group B was quiet despite being a large class. The educator seemed to have control of the class so that students-to-educator and student-to-student interactions took place. Four students out of seven who volunteered attended an interview with me, two females and two males. Their conversations represented the views of the whole class. They described their experiences with acids-bases reactions to be good. Socio-cultural and prior knowledge of chemistry generated affordances and constraints as students negotiated and mediated the learning of acids-bases. For instance, there were disparities in mastering concepts of acids-bases with students who learned advanced and ordinary level chemistry and physical science students. Mwenya claimed that "for physical chemistry, [teachers] never used to go deep into these topics. So, you find that [students] find challenges in understanding the concepts of chemistry where acids and bases are concerned". Furthermore, students attended different secondary schools. Some went to schools where teaching and learning standards of natural sciences were priority but students felt that the lecturer treated them as if they were all at the same level. The learning space of group B was a hybridised space (Bhahba, 1994; Hall, 1996) that presented the participants with the cultural, social and symbolic capitals and resources to construct their own meaning (Bourdieu, 1996). This meant that they reconceptualised previous chemistry ideas and cultures, and confront new chemistry ideas, new teaching and learning, and a new culture to construct a new hybridised identity. Moreover, students reconstruct their own personal activity structures. The activity system expected students to have the capabilities to learn and to contribute to their own success by creating affordances and constraints. Students realised that they were not in the university to receive information from the educators but were co-participants in generating knowledge to achieve common goals. Hence, what seemed to be constraints created affordances to work hard, study late into the night, research, consult with friends and interact more often with the educator to reach the level at which they can learn with little mediation. Some students transformed into learners who approached learning with understanding and constructed meaning with little or no help from the educator. Students also expanded their knowledge through research and watching on-line video lessons asynchronously, individually or collectively. Mwenya explained that students consulted the educator for recommendations for a “site that contains information that is very valid and is accepted here at the university”. In negotiating and mediating with threshold concepts of acids-bases reactions, the students were making use of tutorial video sites in the absence of hands-on learning to try to enhance their successes in chemistry (Levi-Strauss, 1966; Kincheloe, 2008).

Students explained that the practical aspects of teaching acids-bases concepts were not applied. Affordances and constraints were created by students as they struggled to imagine acids-bases reactions especially calculating the chemical equilibrium of acids-bases and pH values. Individually and collectively, students negotiated with the educator to make meaning of the concepts of acids-bases reactions. For instance, Banda claimed that it is “a little bit difficult to apply because we just feel like there are some concepts that are missing. … it becomes very difficult, like how do you measure the pH of citric acid of a lemon? How do you know that? What are the criteria that you are going to use?” Students’ affordances and constraints in the classroom influenced their perspectives and learning. The constraints highlighted the nature of mediation for students which both the educator and students could engage in. The educator would have to modify activities and the structure of the classroom in order to place students in learning experiences that require community of practices (Lave & Wenger, 1991). Constraints caused students to expand their cognition of thinking “outside the box” and extend learning to what they do every day. Students claimed that connecting acids-bases concepts to brewing traditional beer and beverage situations assisted them to understand threshold concepts of acids-bases chemistry. According to Kincheloe (2008), knowledge is temporal and culturally situated. Both students and the lecturer could employ inter-, trans- and multi-disciplinary teaching and learning methodologies.

Educator’s Interaction with Students

Hamoonga, the lecturer, was a chemist researcher for 32 years and has no teacher training background. He had been teaching first-year chemistry for between seven and 10 years. He is currently coordinating general chemistry. He comes from the Southern Province of Tonga-speaking people.

Hamoonga’s lessons were a subject-centred environment. Chemistry was the convergence point at a classroom in which the educator and students were engaged in teaching and learning of acids-bases (Morrison-Saunders & Hobson, 2013). Upon realising that his students had the capability to learn, Hamoonga seemed to have created an interactive classroom context. He also exercised authority over the class. He demonstrated solving a problem on the chalkboard and the students following the procedures (Bandura, 1977). Hamoonga guided the students step-by-step to find the final and correct answer. He experienced affordances and constraints in explaining abstract concepts of acids-bases through “talk, chalk and PowerPoint slides presentation”. For him, constraints turned into affordances for students. He prepared a handbook of teaching notes and tasks for the general chemistry curriculum and often referred students to the handbook. Hamoonga expected students to study and to attempt to answer the tasks before coming to class. Only then were students able to talk to him, ask questions, and interact with him successfully, particularly using his notes, and he was able to mediate the students’ challenges. This created constraints. He refused to change the power dynamics in his class. He claimed that he could not have a conversation with a person who had not studied but he would rather have a conversation with a person who has done the assignment and is in the liminal space (Meyer & Land, 2003). However, the educator code switched to vernacular on seeing that the students did not understand the acids-bases reactions, he gave an example, “If it was a sugar solution, the sugar concentration of 6.2×10^{-8} will be weak and ‘unwa manzi’ (Chinyanja, Zambian language).” Unwa manzi means drinking this concentration of sugar solution is equivalent to drinking water. He explained that calculations of very weak concentrations were not feasible but were for learning purposes. He may have reached about 90% of students as the language is easy to understand and students drink sugar solutions in their rooms. Culturally, he linked to situational learning and created affordances to student learning.

Group D

Group D’s dynamic. I met the students in group D on 13th March 2019 in a lecture theatre at the university. I had gone there to observe a chemistry lesson on acids-bases. However, the educator was absent, so I took advantage of the time to engage with the students and explained the purpose of my research. Fifteen (15) students volunteered to participate in a discussion. Six (6) of them were females and nine (9) were males. I gave them pseudonyms. The female student participants were: 1) Witola; 2) Moomba; 3) Kaunda; 4)

Diniwe; 5) Luse; and 6) Ngoza. The male participants were: 1) Bwalya; 2) Njovu; 3) Ziki; 4) Biko; 5) Musonda; 6) Chiko; 7) Watondewa; 8) Chibwe; and 9) Walubita. The discussion took place in the afternoon but was disrupted by a class that was scheduled at 4.00 pm. The students had already been introduced to acids-bases reaction chemistry. The conversation lasted for 30 minutes. However, the conversation was rescheduled for a later date, 26th March of 2019 at mid-morning. The conversation did not take place on this date due to the university's abrupt closure.

Group D's Perspectives

All participants had one thing in common and that was to achieve their dreams. Bwalya hoped to study agriculture; Diniwe wanted to become an engineer and a researcher; Njovu hoped to become a university civil engineering lecturer; Luse wanted to become an environmental science teacher; Musonda longed to study agriculture and water engineering; Kaunda hoped to become an engineer; Chiko hoped to study environmental science engineering; Watondewa wanted to become a scientist; and Walubita, who was the first generation to be at the university, desired to study engineering.

The students and I discussed their experiences with learning acids-bases chemistry. Bwalya noted that the style of learning at university is different from secondary school. The teaching techniques make it difficult for him to understand acids-bases chemistry because "we are exposed to this type of learning where an educator will just come with his slides and without getting the exact content of that concept, he moves to the next concept without gaining the knowledge in the first concept." Bourdieu (1979) describes the social contexts and settings as a field of contention. According to Bourdieu (1983, pp. 312-13), "a field" is "a network or configuration of objective" "between" positions". These positions are "objectively defined, in their existence and in the" way "they impose upon their occupants, agents or institutions by their present and potential situation in the structure of the distribution of species of capital". The classroom is a field which has a structured space with social positions and power relations. The lecturer and students occupy the positions within the space. Structure is determined by the roles of the actors in the social place. The educator has the cultural capital and controls what happens in the lecture. The educator's cultural capital is the dominant form of capital which generates symbolic capital. Hence, the educator exercises authority over students, such as when students should ask him questions while he was teaching. The lecturer and the students interact according to the rules of the lesson. Bourdieu (1983) contended that fields are dynamic spaces of struggle and competition. Students "compete to attain the rewards offered by the field. There is opaque power relations which contribute to and sustain forms of domination" (p. 313). Social relations in classes of dominancy are forms of symbolic and physical capital or violence. They bring to light power infused behaviours of the educator. So, Bwalya explained that he had difficulties when he did not understand: "If I did not get the concept immediately someone is teaching them, then, it becomes very difficult for me to study when I did not understand in class." Bwalya enters the liminal and ZPD space because he failed to master the key concepts. Threshold concepts are fundamental understandings that are at the heart of disciplinary knowledge. Threshold concepts have discipline-specific focus on understanding of the subject and can be used to transform learners' (students') views of the content to be learned. A threshold concept represents a transformed way of understanding, interpreting, or viewing something without which the learner cannot progress (Talanquer, 2015; Cousin, 2006). Liminal space is also a space of creativity as well as a place where people get stuck when they fail to cope with the integration of the concepts. However, creativity in the liminal state does not happen in isolation but in the interplay with peers and the larger context (Lave & Wenger, 1991). Similarly, theory of Zone of Proximal Development (ZPD) (Vygotsky, 1978), as a student's potential to develop, is the space beyond her/his current capabilities and understandings (Ladson-Billings, 1995; Walqui, 1995). Students bring prior knowledge and culture to class that is waiting to be built on. Additionally, educators consider students to be on the next levels of development and capacity. It is the ZPD space in which collaborative learning occurs – the area beyond the students' levels of independent skill or knowledge. Vygotsky (1978) realised that we learn through dialogic interaction with others. Students require guidance, modelling and assistance through collaboration with educators and peers. Njovu disagreed with Bwalya over the teaching technique of using PowerPoint slides. He claimed that students "are being exposed to a new environment here in the university; that is the first thing. The second thing is that we are not used to learning using projectors; this is a new thing for all of us. It takes some time for us to adapt to this new environment [and methodology]." "Operating within a third space" brings previous "views and established ways of doing things under" scrutiny. "This" may "result in … cultural clashes and/or opportunities for transformation" (Chulach & Gagnon, 2015, p. 54). When students enter the world of science, they soon find that science is a culture that they must interact with and bring home with them to their communities and peer cultures (Aikenhead & Jegede, 2006). The pre-university teaching and learning is different from university culture and these two exit in conflicts that generates "new values, systems of meanings, philosophies, attitudes, practices and structure" (Chulach & Gagnon, 2015 citing English, 2004a). Agency enables students to transform in order to learn in the third space (Jacobs & Brandt, 2012). Students enact their agency which makes them the "actors of their own history" while generating "alternate cultural identities" (Chulach & Gagnon, 2015, p. 57). During the process of agency, people change how they respond to the teaching-learning of acids-bases reactions and how to relate to the lecturer/instructor. This alters pre-university learning and studying (Chulach & Gagnon, 2015). Njovu argued that he was "learning day-by-day how lecturers teach at the university" and he hoped to do "much better in chemistry." Similarly, Witola's major challenges in chemistry were the teaching approaches of the educator. She explained that educators take students to be at the same level of learning and require "everyone to understand at the same pace at the university, which is a bit challenging for some of us who were taking [studying] physical science."

Advanced concepts of acids-bases reactions were challenging to Walubita. Walubita declared that he studied ordinary level physical science which caused him to take more time to understand the concept than those who had studied at an advanced level or pure chemistry. Walubita believed that "physical science is basic chemistry." Witola agreed with Walubita that students who studied advanced level and ordinary level pure chemistry were at an advantage because they have prior knowledge of the acids-bases topic. She further explained that, for students who studied physical science, "when we come here, it is like it is a different level and we see certain topics to be so hard to grasp in just a short period of time." Kaunda added that students who "studied pure sciences did a lot of experiments and actually did acids-bases reactions" but students who studied physical sciences did not do many experiments.

Educator's perspectives. The conversation between Zulu, the educator and myself in group D, are presented herewith. We reviewed the teaching and learning of acids-bases chemistry. Zulu was asked to comment on students' learning of the key concepts in acids-bases chemistry – Arrhenius, Bronsted-Lowry and Lewis' definitions and acids-bases calculations (Kelly & Akaygun, 2016). According to Zulu, the definitions depend on the general way in which hydrogen ions are being released, as he explained:

> "If you are talking about hydrogen because in all those calculations [questions] have an acid in them. So, if [students] are talking about an acid like hydrochloric acid or weak acids like hydrofluoric acid, it is a weak acid, but it is contributing hydrogen ions to a solution. At the same time, water is also contributing hydrogen ions to the solution so, at the end, you look at which one is contributing more hydrogen ions concentration."

Regarding calculations, Zulu did not see any reason why students experienced challenges. I probed him on the interrelated subtopics of acids-bases reactions such as calculating percentage ionisation. Zulu explained that,

> "… percentage ionisation is when you have dropped acid in water and want to see how much of it has ionised, it should be able to help us to know concentration of the hydrogen ions. So, if we know the concentration of the hydrogen ions, it is from that concentration of hydrogen ions that we can know the pH, because you calculate the pH from the concentration of the hydrogen ions."

I further asked Zulu to review the students' learning when he solved problems on the whiteboard in terms of explaining step-by-step for those who seemed to be stuck. He confirmed that,

> "students who were stuck were asking for help, others were finding the answers without any problems. Now, this was a lesson and acid-base equilibrium is based so much on chemical equilibrium. One thing, other students were finding difficulties was because they could not relate to chemical equilibrium, for example, a weak acid equilibrium which is ionising, at the equilibrium stage, others could not take [equilibrium] that the

> weak acid has ionised and the concentration of the ions have now changed … students are making those mistakes and, also one difference was the acid-base equilibrium, the concentration of the acid after it has ionised. Students were taking [acid concentration] to almost the same, the concentration of the acid before ionisation and the concentration of the acid after it had ionised."

I asked Zulu what he would have done to help students who were stuck at chemical equilibrium and could not progress to acids-bases equilibrium. Zulu replied that the solution was "to do more examples in the textbooks and tutorial sheet." He further claimed he was not "facing any challenges teaching students these concepts of calculations but all they need is to look at more examples." When I asked him if he had challenges of teaching threshold concepts of acids-bases, he responded:

> "If we have to look at all the examples, we will take more time. That is why I give them two or three examples, other examples I ask them to look at them in the notes that I have given them to try them at their own time. If they have any challenges, I ask them to come and see me or if any challenges that are serious, they can ask in class."

Nearing the end of the topic of acids-bases, Zulu discussed metallic oxides and metals to explain the strong bases and weak bases. I brought this to his attention as some students appeared to be struggling with the interrelationship and asked him: "How could you have done better?" He replied: "What could have been done better is looking at more examples". This time, he extended the explanation:

> "Another thing is to do things in a more practical way, they see the reaction of a strong acid, the reaction of a strong base, reactions of the substances of group I elements that will give you a strong base, hydroxides of metals or substances that will give you a weak base, even differences in their reactions. In that way, they will understand differences

> between a strong base and a weak base."

Students did not experience many challenges with the definitions of acids-bases but with calculations because Zulu felt that they needed more time. I asked Zulu "How do you expect their performance to be in acids-bases?" He said:

> "They need to look at more examples because, from a class that is just a lecture and you know that the numbers are big. From a lecture, you cannot literally conclude to say that this was excellent. I would say I have taught the concepts but it is up to them to connect to you, to find more time to understand the concepts through studying on their own, solving questions."

He believed that, if the teaching was accompanied by practical, students would understand better because "there can be a practical based on that that can be more understanding. In general, I would say they have the basic concepts to genuinely answer the questions."

Researcher's perspectives. From my conversation with the students, I sensed that they were not free to express themselves which could be an indication of fear (intimidating). Acids-bases reaction chemistry had been challenging for them from the beginning. The challenges seem to be caused by their prior chemistry knowledge and the teaching methodology. On the basis of prior knowledge, some students had studied advanced level chemistry, some had studied ordinary level chemistry while others had studied ordinary level physical science. Students with advanced prior knowledge of chemistry and ordinary level chemistry had experienced laboratory work and acids-bases concepts. Those who studied physical science, had a basic knowledge of chemistry and laboratory work. Another challenge to the learning of acids-bases was the teaching approach employed by the lecturer. The educator presented the concepts using PowerPoint presentation did not give all students enough time to internalise the concepts. Students were not familiar with the lecturing method and the new environment but were confident that they were adapting to the university's way of teaching-learning.

Besides, the educator was unaware that students were experiencing difficulties in chemistry because of his method of teaching. He emphasised autonomous learning by doing calculations from his notes and textbooks. As far as he was concerned, he had done his part by teaching and the students had to do their part by studying. Zulu stated that the practical part of the teaching of acids-bases would assist students to learn.

Discussion of the Findings

Out of the 350 students in this class, nine students volunteered to represent the views of the class and were interviewed. As in other activities, in the chemistry contexts involving the Threshold Concepts (TCs) of acids-bases that were examined, the social activities in which group D was involved was guided by the dialectic interplays of rules, roles and resources within the contextual intersection of the triple dialectic relationships of agency, structure and culture (Bourdieu, 1985; Shultz, 1977; Sewel, 1992). Both students and their lecturer engaged in student-to-student and, student-to-lecturer interactions in negotiating rules, roles or resources intrinsic in activity theory (Engeström, 1987). This engagement was to achieve the objectives of learning outcomes as the result of activities conducted. The outcomes were to increase success rates in chemistry teaching and learning. The lecture hall where lecturers and students, with various levels of chemistry, meet to interact and interchange chemistry knowledge is a hybridised space or context (Bhabha, 1994; Hall, 1996) of pedagogical and knowledge interactions. A hybridised space, in this case, is the space where the intersection of activity systems, affordances and constraints occur or are generated by the triple dialectic relationship of students’ learning practices (Archer, 1996; Bhaskar, 1979). Interactions in this hybridised space are bound to generate affordances and constraints. Affordances were experienced when the lecturer created a student-centred learning context that sought prior knowledge and enabled critical pedagogy (Freire, 2000; Kincheloe, 2008), culturally relevant pedagogy (Ladson-Billings, 2014) and a dialogical instructional model (DAIM) (Ogunniyi, 2011; Diwu, Ogunniyi, & Langenhoven, 2011). Constraints were experienced when students were subjected to social, symbolic or cultural violence through the lecturer’s hegemonic, domineering method of teaching that was teacher-centred because of the use of PowerPoint slides and talk-and-chalk practices (Bourdieu, 1985). For example, Bwalya complained that the lecturer moved from one slide to the next without giving students enough time to learn the introductory concepts. As a result, Bwalya did not understand, therefore, “if I did not get the concept immediately someone is teaching, then it becomes very difficult for me to study when I did not understand in class.” Nevertheless, the constraints created affordances for the students both inside and outside the classroom as they modified their culture, structure and agency in order to learn. Inside the classroom, students interacted with the educator by asking questions for clarification and the lecturer asked the students questions as he demonstrated the steps of calculations of acids-bases reactions. The educator used PowerPoint slides to teach a large class that comprised of students from different socio-cultural and academic backgrounds. Outside the classroom, after classes, students consulted colleagues, friends and tutors to overcome collective and individual challenges. For instance, Njovu stated that he was “learning day by day how educators teach at the university”. What appeared to be a constraint became an affordance as study groups emerged with their own structures, cultures and agencies in order to succeed in chemistry and enabled students to proceed to the second year (Leonti’ve, 1978).

Students with diverse academic backgrounds and learning preferences were faced with the challenge of mastering acids-bases reactions when they entered the classroom. Affordances were created for some students to work on tasks at their own pace, while interacting with other students and the educator, as they were at different levels of chemistry knowledge. Some students mastered the concepts faster than others. The educator allowed students to work at their own pace while assisting them. Students regulated their learning strategies as they interacted with the educator while working on the activities (Carter, 2011). Hence, the structure of the dialogue and the power dynamics of the classroom shifted to motivate students to transform their practices.

Educator's Interactions with Students

Zulu is an Ngoni language speaking lecturer from the Eastern part of Zambia. He trained as a teacher chemistry at the University of Zambia and at Virginia, USA. At the time of this study, he had been teaching chemistry for three years. Before joining the institution, he was a secondary school teacher and college of education lecturer.

He experienced affordances and constraints in teaching students with different socio-cultural backgrounds, different learning preferences and different levels of chemistry. Zulu turned to PowerPoint slides and "talk and chalk", which created affordances for him to empower students to construct their own social and academic meanings. Zulu noticed that some students were stuck at the chemical equilibrium stage and could not progress to acids-bases equilibrium level (ZPD) (Vygotsky, 1978). He adjusted the culture in the classroom to give the students more tasks and one-on-one interactions in order to master chemical equilibrium. He solved a few examples of problems with students on the chalkboard in a two-hour lecture. The ZPD space created opportunities for student-lecturer interactions inside and outside the classroom. The change put the student at the centre and facilitated their learning. According to Zulu, “I would say I have taught the concepts, but it is up to them to connect to you, to find more time to understand the concepts through studying on their own, solving questions.” Teaching and learning are directly-related; to learn to teach is to teach how to learn (Scott, 2014). Zulu learned how to teach from students’ struggles with acids-bases reactions (Freire, 2000).

Group E

Group E - students’ personal goals. By the community of learning, I refer to the University Campus (School of Mathematics and Natural Sciences), chemistry educators and their students who shared the purposes of learning and teaching presented in this chapter. These students came from differing dynamic intersecting activity systems in each class and beyond. Furthermore, each student has individual goals to attain in addition to the chemistry curriculum goals. Regardless of their individual differences, students’ goals converge at the first-year chemistry class intersections to learn acids-bases reactions and how to be successful learners of that concept. My conversation with the students was held in that context at a lecture theatre at 4.00 pm after a chemistry lesson. The conversation, which took place on the 6th of March 2019 lasted 93.24 minutes.

During the co-generated dialogue (Jappinen & Sarja, 2011), students shared their goals of being at the university. Temwa wanted to be a neurosurgeon; Njavwa wanted to be a civil engineer; Nshindano aspired to be a chemical engineer; Siyomba’s goal was to become a medical doctor; Musenge longed to study medicine; Ngoniwe’s aspiration was to become a civil engineer; Salifyanji wanted to study medicine while Lungu, being the first child of his family, expected to become an engineer, but his aspirations were different. Kabungo wanted to study computer science; Chisanga came to study biochemistry; Chilala wanted to study civil engineering; Sililo longed to study cancer treatment; Kalima's goal was to study haematology; Thandiwe was aspiring to become a computer scientist and Ntalasha, who was a second-year student, was repeating chemistry in the hope of becoming an electrical engineer.

Enabling the Third Space Within (formal) and Outside (informal) the Classroom for Students

Student participants described their third space (students-to-students and students-to-lecturer interactions/interchanges) (Bhabha, 1994; Hall, 1996) experiences of learning acids-bases chemistry individually and collectively. By within the classroom, I mean within the formalised spaces for learning chemistry where students interact with each other, the educators and the curriculum within the allotted time for university teaching-learning context. By "outside the classroom", I refer to the informal spaces where students were free to engage in student-to-student interactions at their own time, space and pace, though still within the context of the university's space and time. Students moved within these embodied intersecting spaces (contexts) which they shared with each other whenever they transacted chemistry activities, thereby creating and sharing dynamic micro-, mini- or macro-spaces for individualised and/or collective interactions. These third spaces provided opportunities for students and instructors to structure their interactions, explorations, socialising, sharing knowledge, learning and teaching each other to foster individual or collective successes across constraining and enabling boundaries, hence, hybridising the space and all that took place within it. For example, Kalima described that, in the first term, "I faced a lot of challenges. I have to understand how educators prepare tests, understand how lectures progress and understand time management". Njavwa described experiences, like Kalima's.

He thought that educators were in class “to disseminate information, not to make students understand the topic but just to get over a topic”. Kalima and Njavwa stated that they felt “hurt”, because they were disappointed in the way the classroom time was utilised. The students thought they could have used that time much better by studying on their own, but they did not want to miss the opportunities to participate in the classroom discussions. Kalima indicated that he “spent a lot of time, like, two hours, and you see the results that you are getting is so hurtful; and you feel like, ‘I am better off on my own’, and, at the same time, if you miss a lecture, [you feel like] you miss a lot of things”. Njavwa’s claims were similar to those of Kalima. He also stated, “I feel hurt, because, you say, I am coming to class. I am expecting to get something; so that when I go and study, I am going to achieve something”. Njavwa explained that sometimes students miss lessons “because they think they could do better academic work on their own within the two hours [spent in the lecture hall]”. He stated that, “at the end of the day, which is when you begin to see students start missing classes because they begin to see that it is pointless to come to class, saying, ‘why I am going to class?”

Disruption in schedule. Students complained that there were many timetable changes. This, often without notice, which resulted in having lectures beyond 4:00 pm, up to 6:00 pm, when students were supposed to be at their tutorial sessions, for example, on Wednesdays, during the term. These changes often resulted in tutorials being moved to start two hours (6:00 pm) late. This then meant that students were in class for the whole day. The normal schedule was to have lectures from 8:00 am until 4:00 pm though there were days when students did not have lectures or had fewer lectures.

Chisanga explained, “normally, we are supposed to have classes from 8:00 am till 4:00 pm.

However, sometimes, an educator will cancel the lesson that we were going to have and move it at 4:00 pm to 6:00 pm. Then, afterward we are having tutorials … we cannot understand whatever we learned the whole day".

Lungu interjected,

> "We are learning from 8:00 am to 4:00 pm. There are tutorials again, which ends at 6:00 pm. Sometimes, you find that, in a day, it is continuous. So, you have been lectured to from 8:00 am to 6:00 pm, and you are tired. Even when you want to study, you cannot. You just go to sleep. So, there is too much pressure … On some days, there is just one lesson … then you hear 2:00 pm, out of the blue, you are having a class; you find laboratory books cashing [handing in laboratory reports]. By the time book cashing is finished, it is 6:00 pm. You have to cook supper. It is 9:00 pm and 10:00 pm. … students begin to zero in the night (study late into the night). When you come to class, you find people dozing and missing what is being lectured".

Sililo elaborated that students were being assessed for the whole year's work in all subjects they are studying. Temwa explained that students learned chemistry for nine months and they have many subjects, including chemistry. She claimed,

> "seven subjects and each subject is a complex organ on its own … it is not CBU (the institution) that is difficult. It is, in fact, the one who is learning (the student). I cannot grasp the concept because it is just a matter of proton donor, proton receiver [teaching and learning]. So, if you do not give me the information, I will not receive (understand) it".

Nshindano noted that "lecturers do not really tell us about the fundamental aspect of the topic. We spend two hours in a lecture, and we understand nothing". Nshindano inferred that the key concepts were not well presented in class because they were done in a rush. Students felt bombarded by the course content instead of having concepts explained to them. Temwa revealed that the content of chemistry was difficult for her, as she indicated, “I think the work is bulky. Some of the things we learned are not necessary. I have learned, for example, the structure of a grasshopper; I have never applied it in my life, but I have learned it”. Nshindano resorted to accessing on-line tutorials on YouTube, which he described as specific, short and would take only “ten minutes [then] I understand”. He also observed that tutors on YouTube “really love what they are doing. You can feel it and understand the concept. However, some lecturers do not love their work, which hinders our learning”.

Educators were not entirely responsible for the challenges the students experienced in chemistry. Temwa defended the educators and said that students should not blame the lecturers but should blame themselves for being “overconfident”, which Temwa termed, “a secondary school mentality”. Students were overconfident because they met the entry qualifications of “six points” (grade A in six core subjects). The students thought that university “it is going to be like boom (walk over)”. Chilala agreed with Temwa that he had “so much confidence that it was not so much a big deal. So, when I came here, it was like a strong acid”. I asked Chilala to elaborate on who was a “strong acid” and who was a “weak base”. Chilala explained that he was “a strong acid” when he joined university but that “the teaching was like a weak base”. He was asked to explain what he meant by “weak base” teaching, Chilala said that the lecturer did not meet his expectations because he did not “enjoy the course as usual from my background”. He claimed the teaching “was not good. It was boring … he [the lecturer] points with a pointer, he reads notes, next slide, picks other concepts”. I probed Chilala to explain whether the lecturer was talking to the students or to the board. He responded that he would read the notes and then he would say “if you come from a poor school, it is not my fault". Before a student had completed copying the notes, he "would move to the next part".

Secondary school ways of learning are different from universities. Njavwa said "at secondary school, we were given things on the silver plate [spoon-feeding]" whereas, at the university, students "study and research". Siyomba would prefer educators to teach the chemistry concepts "step by step" (known to unknown, simple to complex) because, even a "weak acid, an acid that has a lot of protons, it ionises step by step". Instead, the educator went "straight into details at a speed" so that students found themselves "left behind" and needed time to catch up. Lungu remembered learning three topics in one week and wondered how he "was going to catch up on those four hours" because he found the topics very difficult to understand. Furthermore, Chilala, likened learning in one lecture to going to a gymnasium: "You do not go to a gymnasium in one day and you come back buffed up (muscles built up)". He said that lecturers must understand that students are "from secondary school … they have to make us adapt gradually, step by step". Chilala further likened the class to a diet of "a new-born baby". A baby is first "given milk … months later porridge, semi-solid, later nshima" (maize meal-a Zambian staple food)." He went on to explain that "yes, we have come to the university, but they (educators) do not have to bombard us there and then. It has to be step-by-step".

Njavwa felt that it was too much work and he had to "sort it out to understand". Chisanga likened his chemistry learning to "a church where the Pastor just reads the scripture without interpreting it or without explaining". When it came to students asking questions, the lecturer said, "You do not understand that! Can you read? Can we move on!" The presentation of the concepts appeared to be easy and then "he asked a tough question, which people cannot answer but you are from teaching them". On the other hand, Sililo enjoyed learning acids-bases because "chemistry is involving" and when students "are involved it becomes easier". He claimed that the new educator pointed at students at random to answer and hence, he comes ready to answer. He said that "it is interesting" and he was "enjoying it".

Ntalasha, a second-year student who was repeating chemistry, described chemistry as "very difficult for me". He could not understand the educator's teaching. For instance, "you are being read to, oh, an acid is this, Bronsted-Lowry said this, and actually engaging you or interacting with you". When a student asked a question, the response was disappointing "… you have your own notes you can go and read". Ntalasha's main difficulties were adapting to university's way of teaching-learning. He came from secondary school and was "trying to understand minus [without] being engaged, minus being introduced to … I could only know about the physical part of the acid that it has a sour taste but, chemically, I was not able to understand". This applied to other topics in chemistry: "It was not just about acids but other topics, even gases". As a result, Ntalasha did not "know where to start from" when studying on his own. In contrast, Musenge remembered the Vice Chancellor's advice during orientation that "lecturers are not here to teach but to lecture". She experienced this with the chemistry educator. She did not understand but studied on her own "and I was able to understand the things (concepts) that I was studying." She also watched tutorial videos because she realised that "we should not rely on everything on the lecturers … students have potential, we need to take initiative and that is what I did". She advised her fellow students to seek help from people who understood the information. She noted that if students are passive and complain about the lecturer's teaching, "I did not get it and just sit back. Then, you will fail". Temwa echoed Musenge's suggestions because she felt that lecturers were "really good". Furthermore, there were many videos which students could use. When Temwa and

Musenge were asked how to access the online videos, Nshindano responded that videos could be downloaded from a PC (computer) or smartphone using an application or a student could search for “acids-bases” on YouTube and view the best videos depending on their rating and not the number of views. The ratings were based on the quality of the explanation of the whole concept. There are also search engines such as Google™, Yahoo™, Infomine™ and Vadlo™. Students could also ask questions, explained Nshindano. Thandiwe asked if videos were expensive. Nshindano answered “yes, video is expensive, for example, K5.00 (Kwacha-Zambian Currency), you get 750 MB”. Apart from the YouTube videos, Musenge was given data by friends “who are in the second year. That was my access for videos” she explained.

Temwa was transformed by the university teaching experiences. She learned “to zero-in in chemistry” (studying late into the night) to master what she learnt during the day. Temwa explained that the teaching method had different impacts on students. She did not see why she could fail at university if she were such a “good student at secondary school”. So, she urged fellow participants (students) to gain more from the lessons by watching videos before the beginning of the lecture. In the class “when [the educator] is teaching, he is not giving me information, but he is adding on to what I already know”. Temwa encouraged her classmates not to attend chemistry lessons with “blank minds” but to go prepared for the lesson rather than studying only after the lecture. She believed that there are “geniuses in our class” and suggested group interactions and learning with “more knowledgeable others (MKOs)”. Temwa said, “as students, we do not socialise … look for the ‘geniuses’, socialise with them. I learned electronegativity in 15 minutes just sitting with Mpundu”. However, she advised the person who needs help to approach the “geniuses” with humility. She said that students should also change their perspectives because “we are not just here to receive. We are not proton receivers. At one point, we have to donate protons. It is about donating in terms of learning.” Temwa explained further that “it is about you doing research, you are going to study, you zero-in, zero-in works”. Although she had tried to counteract the teaching and learning deficits by interacting with the “geniuses”, she had experienced criticisms from other students who said: “You talk too much; you have got ‘chikwela’ (you are troublesome)”. She encouraged participants to form study groups because it was encouraging studying at night: “If you are four and you zero, it makes a difference even if you study for four hours and you understand”. Siyomba agreed that he preferred to learn from a friend when he could not understand in class. He claimed that “for me, I find it easy to learn from a friend because he will explain it in a language that I will understand. He will use … the way we play, the way we interact with things … to explain the concepts”. There were times when students failed to ask questions in class, as Musenge stated, “… not everyone that has the courage to tell the lecturer that ‘I have not understood that part. Can you explain again?” It is easier to talk to a friend because “there is that environment [context] to say, please explain again”. Lungu agreed that “if it is a friend, he can repeat over and over again”. Kalima and Siyomba supported the idea of learning from friends. According to Kalima, “the things which are explained by the teacher may be understood by some … with a friend, I will tell him, I do not understand. He will try to give examples that will make me understand … there are a lot of ways of how things are explained”. While Siyomba claimed that

> “it saves time, it saves efforts and, at the end of the day, you get to learn, get to accommodate, adapt to how your friend is able to understand concepts [because] you ask, ‘how you are getting to understand these concepts? How do you do this? How do I go about doing this?”

I asked the participants to describe the interaction among students and the educator during acids-bases reactions lessons. It was not always easy in class as Musenge recounted what had transpired in a chemistry lesson that afternoon: “Chisanga was explaining with enthusiasm, and he knew what he was explaining; but the crowd was making noise, that noise we made intimidated him”. Sililo explained that, no sooner has your question been answered than you have another question but fear to ask again because of the class’s reactions. He stated that “sometimes when you ask a question and that question is answered, the crowd would say: ‘aha, you are just wasting our time’. That noise just intimidates”. Hence, some students do not ask questions during the lesson. Kalima said, “I will just rather die inside”. Njavwa added, “There are these things people say who are sadists. This guy talks too much.” However, Temwa shared the advice her grade 9 geography teacher told her that “it is better to ask, be laughed at and be corrected than keep inside a wrong theory.” Temwa did not care what people said about her questioning: “I want attention, others will be like, aha, it is just yap-yap (being talkative).” Besides a question, which is asked in class, may help another student in the class who has the same question. She also referred to the question, which was asked that day in class by Chisanga, and the reaction of the class. Temwa declared that she had been “thinking about that question [but] I did not have guts (courage) to ask”. She feared people’s comments “Yaa (murmur) you just want attention; but, when he asked, I was also interested to know”. However, somebody in the class said “How is this going to help you? You are just wasting our time. Do not complicate your life.” So, Temwa thought that such intimidation may make the person afraid to ask a question again. Temwa felt there was a need for students to change “their mindsets”. Students reacted indifferently because,

> “we are not interested in learning new things, as she (Inonge, the new chemistry lecturer) said, you are supposed to think outside the box. In such a situation, what comes to your mind is that the question was irrelevant. Our new lecturer would always answer your questions even when your question does not make sense”.

Finally, students identified TCs of acids-bases, as a group, as “determining the strength of an acid”. They wondered how one could determine that when they are “given a lot of names without polarisation constants”. Students did not know how bonding was taking place in the Lewis model. The Ka value of a weak acid was “confusing when the concentration of an acid is minus x … x may be ignored or negligible”. For instance, there were situations “when x was ignored or included, its [formula] gave the concentration less than 5”. Temwa had difficulties with the ICE table. She failed to transfer similar concepts of inserting values on the Initial, Change, Equilibrium (ICE) table from chemical equilibrium to acids-bases. Kabungo had not observed distinct differences between the ICE table in chemical equilibrium and acids-bases. Siyomba explained that “ICE table only works for weak acids and bases” Weak acids-bases do not ionise completely but partially ionise, hence creating an equilibrium. Temwa express her experiences as clearly as possible: “In bonding, it is not optional … if you do not put the concept where it is supposed to work and you use it because it is the ICE, it does not work”. Kabungo explained to Temwa that the problems that she was experiencing were due to not mastering concepts of how an ICE table is constructed from the beginning. According to Kabungo, the ICE table works “everywhere whether it is chemical equilibrium or acids-bases. It will still work. The best thing is to understand the concept”.

Educator’s perspectives. Inonge, the new educator of group E, said that she did not expect students to experience challenges in mastering the concepts in the conjugate of acids or bases because “we had to highlight which one is a strong acid and why it is a strong acid, and how it becomes a strong acid and that qualified them to have weak conjugate bases”. Inonge claimed that teaching first-year chemistry was interesting because students explained “concepts in their own way” and were able to ask questions. According to Inonge, the students were following the lesson. I asked her how she was able to single out one student among 350 students who was not learning. She responded that she interacts with students and it was from these interactions that she was able to see that some students "looked surprised even when they do not ask a question". She explained further that, when students understood, they would ask questions. So, she was "able to detect that part of equilibrium constant and the ionisation, dissociation constant that they have found a challenge". During the lesson, students appeared to be lost that was an indication to Inonge that she had "to go back and reteach where the gap was noticed". According to Inonge, the best way to teach equilibrium constant "could have been letting the students explore on their own" then, she would fill in the gaps. Inonge employed a "think-pair-share" approach in teaching because she hoped that thinking in pairs would make it easier for them to interact with each other. In addition, students would engage in the language they use every day, which may make students "get the concept easier, better and faster". I asked Inonge to shed more light on why students were finding the chemistry concept of equilibrium challenging. She responded that she believed that students had no confidence and that, at first "it was like Greek to them … but, with time and more examples, helping them to go to the chalkboard, [to] explain the concept, find and calculate". I pointed to a video clip where a male student was solving a question on the chalkboard and the rest of the class seemed to be following. Inonge answered that "students were able to connect to what they learned in the previous lecture and what they are about to learn". She only interpreted where she noticed a misunderstanding in calculations of the ICE table and the formulation of the ICE table data. Students were "getting initial concentration of hydrogen ions to be the concentration of the weak acid" whereas a hydrogen ion is found at the end of the reactions. She explained further that students fail chemistry due to their "lack of practice". Students failed to "iron out little problems that they face" in order to understand the current concepts such as elements, how elements combine and chemical formulae. These concepts create a "gap at the back of their minds". She claimed that "it was difficult, as a lecturer, to fill in the gap" as these are concepts that were taught at secondary school. Instead, she asked students to revisit symbols, valences and combinations which should help them to "have confidence, be able to communicate wisely and understand the concept". Inonge revealed that, despite students discussing pH, ions and dissociations in pairs, they would have done better if it was practiced in the laboratory because laboratory work enhances understanding of these concepts. I asked her whether she had challenges in teaching students with different levels of prior knowledge. Inonge agreed that it was a challenge as "about 5% [of students] have advanced level chemistry, have physical science and most of them have combined science". It was also a challenge because some students would "understand the concepts within a blink of an eye" whereas it would take her time to "actually rip the concept apart" to make other students understand. In order to overcome this challenge, Inonge created study groups in which the "gifted ones" would explain challenging questions. Each group was given a question which one member of the group would explain before the class for five minutes at the beginning of the lesson. When asked how students were learning acids-bases reactions, Inonge reported that the practical aspect was absent. Although there was not enough equipment in the laboratories, Inonge was determined to do virtual laboratory works. I probed Inonge on facial expressions of struggling students in group discussions. She responded that "in their pairs they were struggling. They do not really know what is happening; they do not know what is going on in class". So, she goes a to see students who seem lost: "I take them back to what we were doing and bring them back into the lesson and incorporate them." Despite her efforts, she was not certain whether students had mastered acids-bases concepts when she completed the topic. However, she had given each group a project to explore acids-bases reactions in everyday life which will determine whether students have mastered the concepts.

Researcher's perspective. Inonge was an energetic educator who preferred to use both the whiteboard and PowerPoint slide presentations. She had a constructivist pedagogical perspective of teaching and learning. Inonge engaged students as much as possible particularly during the lesson. She applied differentiated methods of teaching because she knew that the students were different. Inonge's greatest challenge was students' academic backgrounds. So, she seemed to apply more effort to break down the concept for students with weak prior knowledge and spent more time teaching struggling students. She was sensitive to students' learning challenges as they struggled to learn the concepts and observed their facial expressions during lectures. If needed, she intervened and mediated in students' struggles. Students were encouraged to ask questions and to "think out of the box" by Inonge. Regardless of being constructivist-oriented, she noted that class activities and laboratory works were missing that posed some challenges for her.

Students were able to express their experiences of learning chemistry with the first lecturer as well as with the second one. In the first term, students listened to the educator talk and chalk. Students responded differently to passive teaching and learning. Some students were discouraged, but the situation caused other students to find alternatives to learning such as studying at night, watching tutorial videos and learning from more knowledgeable students. Most students adapted to autonomous learning. It is an active class where students interacted with the educator by asking questions and contributing to the teaching and learning taking place. The interactions were not always welcomed by some members of the class who thought it was a waste of time which, in turn, intimidated some students who wanted some clarity from the lecturer but, nevertheless, participants continued asking questions, anyway.

Discussion of the Findings

I used activity theory as the framework for studying the high failure and drop-out rate of first-year students in chemistry highlighting the constraints and affordances, successes and failures experienced by both educators and students. The social structure of the lecture that took place in the lecture hall was guided by rules, roles and resources (tools). Students negotiated the rules, roles and resources that guided the activities in the chemistry class in order to achieve the learning outcomes that were to be successful educators and students in chemistry. The lecture hall is a place where educators and students meet to negotiate learning. Here, students' activity systems intersected with each other and with the educators. Educators and students bring to class their knowledge, culture and experiences. A classroom is a hybridised space where activities are guided by rules, roles and resources, for instance, who is to exercise power and dominion, who has access to resources and who plays what role. Individual students experienced the same teaching resources such as the human resource (educator), "chalk and talk" teaching, acids-bases chemistry content (object), learning environment, lecture hours, motives and objectives (outcomes). Additionally, students and educators experienced differences in cognitive abilities, learning styles, social-cultural backgrounds and students with Advanced Level chemistry, General Certificate of Education (GCE) Ordinary Level in chemistry, physical science and combined sciences. Interactions between student-student and student-educator generated constraints and affordances in teaching and learning.

Affordance was created when students struggled to learn acids-bases reactions as the educator struggled to teach by "talk and chalk", and the use of PowerPoint slides. Students expressed disappointment in the way the acids-bases chemistry concepts were presented in the first term by the educator. They complained that the lectures presented to them were more of disseminating information to complete the curriculum than teaching for learning. The feedback given by the educator, when asked for clarification during the activities, was discouraging as students felt “shut down”. The rules, roles and resources of the classroom implied that students were expected to research on their own to expand their knowledge. Rules, roles and resources are interdependent. This means that they are dialectically interrelated so that they influence each other. They act together to shape the outcome. They guide who should speak within the activity and when. The educator falls into power dynamics. S/he negotiates with rules, resources and roles to ensure that the curriculum is covered for the term. He/she also mediates within the activity by negotiating rules, roles and resources. In this group, the educator experienced constraints and affordances in teaching chemistry. He encountered cultural, social and symbolic capitals, and/or violence from students (Bourdieu, 1986). The students also dialectically experienced social, cultural and symbolic capitals and/or violence and constraints from the educator. Both experiences generated constraints and affordances in the teaching and learning processes of threshold concepts of acids-bases as these factors adjust the rules, roles and resources of activity theory. The constraints regulated the agency, culture and structure to organise peer learning and co-generative dialogue associated with chemistry learning. The agency was guided by the common motives, goals, conditions and tools (Leonti’ve, 1978) to succeed in chemistry and pursue their science careers.

Peer learning occurs “when students learn from and with each other in formal and informal ways” (Boud, Cohen, & Sampson, 2001, p. 2). This involved the sharing knowledge or ideas and experiences between participants. It is a collective action to overcome individual challenges. Co-generative dialogue “is applied to generate a common frame of thinking, shared meaning and a collective view in a system” (Jappinen & Sarja, 2011, p. 65). It focuses on transforming the object (constraints) of the collective activity within the hybridised space (Engeström & Blackler, 2005). The constraints open thinking and interactivities of roles, rules and tools to get results (Engeström, 1990). Students shared their knowledge of using YouTube acids-bases tutorials. Students who experienced threshold concepts, such as determining the strength of an acid, bonding in the Lewis model and chemical equilibrium in acids-bases, found themselves in the liminal space (Meyer & Land, 2003) or ZPD (Vygotsky, 1978). The activity was socially mediated by more able peers or more knowledgeable others (MKOs). Students in the liminal space or ZPD appeared to be constrained, but the constraints generated affordances by fostering peer learning. It allowed others to see that they were struggling and their peers needed assistance and that they could assist them and then, they came in to help through description and demonstration. Learning therefore became reciprocal activities. (Boud et al., 2001). The learning process provided opportunities for emotional support also. Rules, roles and resources shifted during the process of activities and students were able to make contributions to each other's learning. Hence, some students claimed that they learnt better from friends and peers than from educators because they were freer to ask friends to repeat as often as necessary and that friends used colloquial language and examples from everyday life – lived-experiences. MKOs possess "cultural, social and symbolic" capitals (Bourdieu, 1986, p. 248). According to Dill and Boykin (2000), African culture is communal and students learn from each other; therefore, it is collective while the Eurocentric cultures tend to be individualistic.

Affordances and constraints create opportunities for activities; but they tend to put pressure on students. For instance, students claimed that they were bombarded with too much information which was at a higher level and that they were unable to fully appropriate the learning that was taking place. For example, an unusual/unexpected call to hand in laboratory reports and disruptions in the timetable schedule that extended lectures up to 6.00 pm or later that affected individual students or study group programmes. Students claimed that by the time they were free to study, it was 09.00 pm or 10.00 pm and that caused them to study late into the night.

Educator’s Interactions with Students

Inonge, the new educator, taught chemistry as a secondary school teacher for eight years. Her father was from the Western Province of Lozi-speaking people and her mother was a Bemba from Luapula Province. She spoke both Bemba and Lozi. When I met Inonge, she had been teaching first-year chemistry, part-time, for four months. She took over from the previous educator in the second term.

Students were shy, fearful, intimidated and seemed to lack confidence when Inonge first interacted with them. She experienced an affordance as she struggled to negotiate learning. She created rapport with the class that generated mutual respect that enabled learning environments. The roles, rules and resources, which were usually shared in the third space environment, generated agency, culture and structure that also generated learning opportunities as students and lecturers negotiated practices for individual and collective teaching and learning to take place. Interactions in this third space generated affordances and constraints. The context created opportunities for dialectic interactions of agency, culture and structure. Inonge employed a constructivist approach to teaching and learning. In constructivism, a teacher is “a guide, a facilitator and co-explorer who encourages students to question, challenge and formulate their own meaning” from the concepts being taught (Ültanir, 2012, p. 195). Participants had access to resources which led to the adjustment of the rules and roles. In this activity system, students expressed their views and constructed their own learning. The affordance caused students to interact more with each other and with the educator. It was during these interactions that she was able to identify struggling and capable students and created ways to connect them so they could help each other to improve. According to Inonge, capable students were able to understand in a "blink of an eye" (MKO). She proceeded to form study groups and ignited the MKO in each group. Each study group was given tasks to work on and to present to the class in the next lesson for 15 minutes. The learning environment immersed students within the context that challenged their experiences, knowledge of acids-bases reactions and expanded their knowledge and understanding. The roles, rules and resources of Inonge shifted from telling students the correct answers to guiding student activities to achieve the "right answer" generating collective effervescence (Shamberger & Friend, 2013). Hence, students were co-teaching with the educator and the educator became a facilitator. Co-generative dialogue was used as a pedagogical tool to ameliorate students' diversity academic differences (Emdin, 2007). Lessons showed that the conversations during co-generative meetings became resources to draw on in changing knowledge gap levels. Co-teaching and distributed leadership are reasonable responses to the increasing challenges of a single lecturer or teacher coping with the knowledge and skill to meet students' diverse instructional needs and complex problems they bring to class. Team teaching was the kind of co-teaching and distributed leadership that were employed. Team teaching is where teachers and co-teachers lead the class activities by illustrating multiple ways to solve a problem (Friend, Cook, Hurley-Chamberlain, & Shamberger, 2010).

While students were engaged in using their cultural, social and symbolic capitals to expand their agency to teach and learn chemistry, the class became very noisy. Some students dominated the conversations which infuriated fellow students. Collaborative learning caused constraints that Inonge struggled to manage. She and other students experienced cultural and symbolic violence (Bourdieu, 1986) in the process.

Group F

Group F's dynamics. The participants in this group were nine mixed-gender students who volunteered to take part in the conversation regarding teaching-learning of acids-bases chemistry from a class of nearly three hundred and fifty (350) students. In the previous five years, there had been high failure and drop-out rates of first-year students in chemistry in such a class. At the time of the conversation, the students were already learning acids-bases reactions chemistry. The conversation took place on the 5th March 2019 in a lecture theatre at about 15.00 pm. I named the female participants: 1) Natasha; and 2) Chama. I named the male participants: 1) Goma; 2) Chiti; 3) Moono; 4) Kafwimbi; 5) Mutale; 6) Maongo; and 7) Tafuna. Participants are given pseudonyms to hide their identity. The conversation lasted about 42.34 minutes.

Group F's Perspectives

The conversation began by participants sharing their aspirations. Natasha longed to study electro-mechanical engineering; Chama hoped to become a chemical engineer; Goma hoped to study civil engineering; Chiti wanted to become a neurosurgeon; Moono desired to become a power electrical engineer; Kafwimbi hoped to study chemical engineering; Mutale wanted to study ophthalmology; Maongo longed to become a computer scientist; and Tafuna hoped to study computer science.

Students described their experiences with teaching and learning of chemistry. Tafuna explained that "sometimes it was challenging and sometimes it was fine". To illustrate his point, Tafuna referred to the test they had just written and said that "… our study criterion was not that good". The students were tested on the topics which they had learned. According to Tafuna, chemistry is not difficult but "it is just the way that we study chemistry that makes a lot of people not to do well in chemistry". Moono added that "people fail chemistry because it is abstract but, if students were given an opportunity to see the abstract concepts, they will perform better … People do not know what an atom is because we have not seen it". He argued that all students required was to view just "a general structure" and that would be enough to reduce the abstraction of chemistry concepts. Goma concurred with Moono that students are dealing with molecules which they were "not able to see". Students were unable to picture structures of molecules formed from the reactions of acids-bases, including the reactants. Goma explained that "it is difficult to imagine how an octahedral structure looks. If only the students were exposed to visualise. As we are learning chemistry, it will be very helpful to students". Chiti would not be surprised if many first-year students failed chemistry because, in the first term, students had no hands-on experience. He said that "we have been lectured to ever since we have been in the university". Hence, Chiti did not see any reasons why students were failing chemistry. He said that universities should reinforce hands-on learning in practical subjects then "student failure will be a thing of the past … chemistry will be a walkover for the students because nothing is impossible. If we do well in these other subjects, even in chemistry, we can do well, as well". Maongo resented the fact that chemistry was taught theoretically rather than practically and, as a result, he found chemistry to be challenging.

Natasha compared the teaching methods which she experienced at secondary school to the university methods of teaching. She said teachers in secondary school used "methods to try and teach us but here [at university] … if you do not understand, you have to go and research

… They do not really put in all the different techniques because not everyone will understand things just by teaching”. Natasha explained that some students need to “visualise, go through it and experience it”. Kafwimbi brought up the problem of missing the introduction to chemistry which is fundamental. Students who miss the introduction to chemistry may “encounter problems in all topics in chemistry”. He cautioned his fellow students that they could expect to “understand what acid is. You do not know what molecules are, what an atom is. It will be very difficult to understand these complex topics”. Moono further explained that the fundamental part of the introduction to chemistry was “chemistry in society … where matter comes from”. Since the students wished for practical work and activities, I asked them how many times they would prefer to have laboratory work per week. Tafuna responded that students were told that they will be having laboratory work but were not specifically told how many times per week. He further explained that topics were not arranged in the order of their difficulties. He claimed that “chemical equilibrium” was taught before the “mole concept”. The arrangement of topics caused “a lot of challenges in chemistry”.

I probed the students to elaborate on the teaching approaches of secondary school teachers. Chiti explained Natasha’s comparison of secondary school and university as follows: “In high schools, it was like a personal relationship with the teacher. Teachers tried to make students learn when they were not able to”. Chiti claimed that lecturers feel that, as long as they have done their part, if students do not understand, “it is none of their [lecturers’] business”. So, he felt that Natasha was trying to say that “the approach as well matters despite not having laboratory work”. He declared that “there must be a better way of teaching us or lecturing us; it will also make a difference”. I discussed making the lessons more visual and lecturers becoming more sensitive to students’ learning. Goma revealed that there are projectors in each lecture room and that the lecturer should make use of the projector to show them clips or slides which could help students to "visualise atoms and structures that they form". In addition, Moono gave an example of his chemistry teacher at secondary school who utilised projectors and videos to show what was happening during a chemical reaction. "If we are talking about chemical reactions, we will see what was happening in the interactions of those atoms and that created an impact on us that, even when he is lecturing there, we were capable of picturing what was actually taking place". Moono thought this methodology could be applied by educators so that students could "get the basic concepts of chemistry and understand and apply it in everyday life". Kafwimbi agreed with Moono that lecturers could employ models in teaching. He also cited his former teacher who used teaching aids when teaching chemical bonding. The teacher illustrated the concept of bonding by using the bond stick model in organic chemistry. The teacher employed the same teaching aids "to show us structures such as how carbon atoms are bonded to hydrogen". Kafwimbi also thought educators could use such teaching aids "to show how an octahedral or tetrahedral is. It is very easy for someone to remember".

In the conversation, students identified challenging concepts of acids-bases. Chiti had challenges in naming acids because it was difficult to explain without naming acids and that "we need basics in order to do well in these other topics that are hard for us". Tafuna experienced hardships in the reactions of different acids-bases because "each acid reacts differently with a base". He also found difficulties in naming acids. He explained that "when it comes to weak acids, those are difficult to name and you find that it is having a structural formula which is something else and you are supposed to name it". Furthermore, the products which are formed after the reaction are more challenging to name as Tafuna explained "… this time you have three products after they (acids-bases) react; the other time, you have two products or sometimes one product so [naming] becomes confusing". Maongo explained that another aspect of acids-bases reactions are the chemical formulae that were "quite challenging to master and … to know [from] the chemical formulae which [product] will be formed". Students to master chemical formulae, "have to know at least reactivity series of metals as the acid and base react. At the end, which metal will displace another metal". Goma claimed that the concepts of base and alkali are difficult to differentiate.

Participants elaborated on the interaction with the lecturer in terms of asking questions where students do not understand. The participants settled for a "number of questions per lecture" to enable the lecturer to complete the work. Chiti disagreed with the proposal that "the main reason for us to learn in class is for us to understand". Lecturers should "allow as many questions as possible" which are asked by students during the class. He explained that "it is better to do one topic in a week and we understand than do two topics in a week and then we do not understand … leading to failure".

Educator's perspectives. Ika, the educator, claimed that learning is ineffective because the class is so big. In order to overcome ineffective learning, effective tutorials and lecturing should be employed. He acknowledged teaching chemistry topics in one lesson incoherently. This was because the curriculum was not systematically arranged such as "acids-bases reactions and then redox". According to Ika, students faced very few challenges in learning acids-bases "because they had learned these when they were at secondary school". Arrhenius, Bronsted-Lowry and Lewis's definitions of acids-bases were other concepts in which students experienced difficulties the "only when it came to auto-ionisation of water and writing of formulae for hydroxide ions". Students had few problems in the three definitions because "water comes as acid and again as a base" depending on the prevailing factors. When it came to calculations of pH and strong acids, students also had few problems as he described: “It was a little confusing to them, but for pH and strong acid, was okay, just the formula [pOH = 14].”

Teaching weak acids-bases reactions had also been a challenge for Ika because the students had no prior knowledge of the concepts of weak acids-bases as it was “the first time they are learning it”. Ika cited a student who had asked him why the conjugate acid had a negative charge in this reaction: $CO_2^{2-} + H_2O \leftrightarrow HCO^{3-} + OH^-$. Ika explained that “some students were failing to understand that we are using mathematics, simple mathematics”. On the other hand, Ika considered his students as “a good class” despite it being large and the students having “no prior knowledge in calculations of acids-bases reactions”. This was evident in the type of questions which were asked during the lesson and the discussions that went on among the students. Aka claimed students were discussing “how they can understand”.

Researcher’s perspectives. Based on the conversations I had with the educator and the students, and my classroom observations, group F is a good class, as the educator claimed. Students expressed their experiences as honestly as possible. From the lesson observation and students’ description of the learning environment; indeed, there was little interaction between the educator and the students. On the other hand, there was more interaction amongst students. Students felt that the educator had no relationship and emotional attachment with their learning. They claimed that he taught students out of obligation. It was up to individual students to learn. Instead of one teaching approach, students wanted different teaching techniques such as acids-bases reaction activities and laboratory work. Projectors that are in the classroom could be utilised to make students visualise how acids-bases molecules react as this would form a mental picture in students’ minds of chemical reactions. Despite the absence of laboratory works, a variety of teaching techniques would help them to learn and master key concepts. Students experienced challenges in understanding Arrhenius, Bronsted-Lowry and Lewis definitions, weak acids-bases reactions, formulae, chemical equations, naming of acids and structural formulae.

Aka's perspectives corresponded with the students' perspectives. He admitted that he experienced challenges in teaching acids-bases to students especially the calculations, definitions of acids-bases, auto-ionisation of water and chemical formulae. However, the lecturer was not aware of the degree of the challenges. Ika also admitted to ineffective teaching and learning and the use of a monotonous lecturing method. He expected that effective tutorial lessons would compensate for his methods of teaching. He did not make use of any teaching aid. This was due to too many students and new concepts of acids-bases.

Discussion of the Findings

Group F was the most active and noisy class. There were more activities and discussions among students than with the educator. Some students worked alone as the lecturer was teaching. Every member of this group seemed to be doing something, such as engaging in solving problems, copying work from the board and discussing with friends and peers, while listening to the lecturer. The educator presented his lectures by "talk-chalk" method and was often interrupted by students' questions. In this group, nine out of about 350 students volunteered to be interviewed. The views presented in this discussion represent those of the class. Within the context of the class, students were free to express themselves as they interacted with the lecturer. The classroom context was student-centred. Students engaged in solving problems as they observed the educator's demonstrations on the board (Bandura, 1977). The educator and students mediated the structure and culture of the learning space. The adjusted structure empowered students to exercise agency to construct their own meanings and transformed the oppressive traditional learning context (Freire, 2005; Kincheloe, 2008). Both lecturer and students possessed cultural, social and symbolic capitals (Bourdieu, 1986). In group F activity system, power dimensions and roles were shared between students and educator. However, the educator still maintained his position as a lecturer and directed the lecture. This empowered students to mediate and negotiate to learn inside and outside the classroom. The educator collapsed power dynamics of traditional roles of teachers. Traditional roles regard the teacher as an authoritative and narrative figure and the students as passive recipients of knowledge (Feire, 2005). Additionally, within this learning context, the educator and students negotiated the learning procedures, acids-bases content, structure, culture, agency and their own roles (Engeström, 1987). Activities in this student-centred learning space generated affordances and constraints.

Students described their experiences of learning threshold concepts of acids-bases as "sometimes it was challenging and sometimes it was fine". According to Tafuna, chemistry is not difficult "it is just the way that we study chemistry that makes a lot of people not to do well in chemistry". The study of chemistry was abstract as Mono stated that "it is difficult to imagine how an octahedral structure looks like." This abstract interaction with chemistry concepts created affordances and constraints for most of the students. Most of the students modified their study culture and exercised agency to engage in collaborative learning, peer teaching and individualised learning. Students further expressed disappointment at lack of hands-on activities when learning chemistry as Chiti stated, "We have been lectured to ever since we have been in the university …". A lack of hands-on and use of one teaching technique generated affordances to some students. Some students negotiated their roles in the activity system. The teacher modified his role from a narrator to a facilitator. Students adjusted their roles from passive recipients of knowledge to active and responsible learners.

In this class, students learned from each other as well as from the educator. The educator also learned from the students because they shared the same goal that is to succeed in raising the pass rate in chemistry.

Educator's Interaction with Students

Ika's classroom was filled with activities from the beginning of the lecture to the end to which I, as an outsider, could not fit in. By this I mean that I did not know the rules that guided the teaching and learning. Everyone was busy solving problems while listening to the educator. As the activities progressed, the educator would pause to ask questions and the students would also at some point ask questions. A large class of students with diverse learning preferences created affordances and constraints for Ika. The constraints were that he could not form a lecturer-student relationship as Chiti claimed that lecturers feel that, as long as they have done their part, if students do not understand, "it is none of their business". This generated cultural, social and symbolic violence (Bourdieu, 1986). Nonetheless, Ika transformed the constraints into affordances by creating an active and supportive environment in which students constructed their own understanding and probably received emotional support. He adjusted his position to a shared responsibility with his students. He exercised his agency to mediate the culture of the class to be a facilitator.

Ika claimed that the students were a good class despite being a large class and having no prior knowledge of calculations of acids-bases reactions. This class rejected authoritative learning. Ika had to modify the roles of engagement which generated independent learning among students. The affordance created by the educator empowered the students to choose their personal strategies of learning, the pace of learning and who they should engage with in collaborative learning which went beyond answering students' questions for clarifications.

Power relations in the activity system were reduced to sustain a supportive learning environment while maintaining his position as an educator. Ika redefined the rules of engagement and adjusted the distribution of labour between student-educator and student-student in the activity system (Bourdieu, 1986; Engeström, 1987). He adopted the role of a co-participant and co-constructor of understanding as he actively assisted students with cognitive understanding of the content (Butler & Cowan, 2013).

Chapter Six

Conclusions and Recommendations

Introduction

The drop-out and failure rates among first-year students in Zambia, particularly in my institution, is alarming. Failure and drop-out rates are much higher in chemistry than in any other subject matter. In my institution, chemistry subject is a core prerequisite for all first-year students studying science programmes, medicine and science and, mathematics education. Thus, it is one of the “gate keepers” through which students must pass before enrolling in advanced science courses (Cooper & Pearson, 2012). The high failure and drop-out rates in chemistry seem to be focused on the teaching-learning of acids-bases reactions. Scholars of chemistry have identified acids-bases reactions as one of chemistry’s TCs (Timofte, 2015; Furió-Más et al., 2012). The theories of acids-bases reactions are a challenge for students from secondary school through graduate school (Bretz & McClary, 2015). For students to make connections between acids-bases reactions requires understanding the limitations of “Arrhenius, Bronsted-Lowry and Lewis’s theories and choosing appropriate theory” that “can predict and explain” acids-bases reactions (Bretz & McClary, 2015, p. 2). Furthermore, Marais (2011) in South Africa revealed that less than 50% of first-year students pass chemistry at their first attempt. In 2010, studies in Germany revealed that 45% of chemistry students quit university, while 55% changed studies (Intorp & Waitz, 2013).

The study investigates the causes of first-year chemistry students’ high failure and drop-out rates in Zambia and how to ameliorate this problem. This study explores teaching-learning of acids-bases as TCs by chemistry educators and students. I investigate how and where educators of first-year students were experiencing challenges in teaching TCs in the curriculum. Likewise, in the study, I investigated how and where first-year chemistry students were experiencing challenges in learning TCs of acids-bases reactions. The classroom context was chosen because it shows how educators interact with students and with the acids-bases chemistry, students' interactions with the educator and the curriculum, and students' interactions among themselves. Three research questions guided this study which were:

Research question 1: What challenges do first-year students experience in learning threshold concepts of acids-bases reactions?

Research question 2: What are the challenges that educators experience in teaching the threshold concepts of acids-bases reactions to first-year students and how can these challenges be ameliorated?

Research question 3: What are the causes of the high failure and drop-out rates in first-year chemistry and how can they be ameliorated?

The study discusses relevant literature under the following sub-headings: threshold concepts, liminal space, constructivism, failure and drop-out rates and global research in science education. I briefly present them in the following paragraphs.

Threshold Concepts

Threshold concepts are key ideas that are at the heart of the disciplinary knowledge. Failure to internalise them may prevent a student from making sense of the concepts that tend to exist in unstable conditions of teaching and learning. Baillie, Bowden and Meyer (2013) summarise key characteristics of threshold concepts as, firstly, transformative shifts on the perception of a subject. Secondly, when a student makes sense of them, they are integrative because TCs are interconnected with other concepts. Thirdly, once they are learned, it is difficult to unlearn them. They are irreversible. Fourthly, TCs are troublesome in nature due to the discarding of previous wrong ideas or thinking and the integration of current ideas. Fifthly, TCs are bounded within the disciplinary system.

Liminal Space

A Liminal space is the "transition period between moments in which students did not grasp a threshold concept and the moment of grasping the TC" (Timofte, 2015, p. 85). In the liminal space is where educators and students negotiate. Educators bring students to the point where they must cross the liminal space. It is a space of creativity in which activities does not happen in isolation but in consortia with one's peers and other members that inhabits. As students negotiate and navigate this space, they may experience challenges in mastering threshold concepts of chemistry and require assistance from the lecturer or more knowledgeable others. Vygotsky (1978) calls this state ZPD and Meyer and Land (2003) refer to it as liminality. This is a conceptual state. The "ZPD presupposes an interaction between a more competent" students "and a less competent" student "on a task" (Chaiklin, 2003, p. 2). Lecturers provide tasks as well as strategic advice to students and the students work to possess the potentialities and readiness to learn. Then, the student can master the concept. In the ZPD/liminality, a student imitates "only what lies within the zone of" her/his "intellectual potential" (Vygotsky, 1978, p. 202 as cited in Chaiklin, 2003). Vygotsky (1998, p. 202 as cited in Chaiklin, 2003), explains that imitation refers to,

> "all kinds of activity of a certain type carried out by the child … in cooperation with adults or with another child and includes everything that the child cannot do

independently, but which he can be taught or which he can do with direction or cooperation or with the help of leading questions".

Constructivism in Education

Vygotsky (1978) and Piaget (1951) are introduced as key educational cognitive key theorists. Vygotsky believes that the social context is central to learning. A child's ability to learn depends on "first the social level and later on the individual level; between two people (interpsychological) and then inside the child (intrapsychological)" (Vygotsky, 1978, p. 57). On examining processes of analysing and integrating of threshold concepts and transformation in liminal space, it appears that the transformation that comes from grasping a threshold concept may be equivalent to Vygotsky's theory of mediation of the learner's intrapsychological development from the ZPD to the ZAD, with the creation of a new ZPD from the learner's zone of far development (ZFD) (cited in Thomson, 2019).

In contrast, Piaget (1951 cited in Thompson, 2019) believes that there are specific cognitive developmental stages to reach the level of abstract reasoning. He sees the learner as central to learning but does not consider the culture and the social environment. Piaget further believes that change and transformation produce knowledge. "The developmental ideal is balance between assimilation and accommodation which is … known as equilibrium" (Blake & Pope, 2008, p. 61). Assimilation is the transformation of the environment so that it is "integrated into pre-existing cognitive structures" while accommodation is when cognitive structures accept something from the environment (Blake & Pope, 2008). Assimilation and accommodation change schemata.

Failure and Dropout Rates

Student withdrawals and failure in chemistry, as discussed in Chapters One and Two, are concern of any university and government. They have a negative impact on government resources and on the individual's emotions. Chemistry, as one of the "gate keepers", is a barrier to achieving students' goals in science programmes. The difference between success and failure depends on the students' choice to seek help from MKOs and align their "cultural capital" to the patterns and interactions of the "dominant cultural capital" (Bourdieu, 1996).

Theoretical Frameworks

In this study, the theoretical frameworks explain the challenges that students and educators experience in teaching and learning of threshold concepts. The activity theory helped to formulate conclusions arising from the results. The learning theories further provided a profound understanding of the process of teaching and learning in the classroom. For example, a bricoleur can make use of available resources and apply various strategies in teaching. In critical pedagogy, power relations between the educator and the students are shared but the educator still maintains her/his dialectical position as a teacher/learner. I see the educator as a broker who is trying to close the culture gap between school and home. S/he is giving up "banking" education and adopting dialogic education so that students can question the curriculum, teaching methods, education policy, and community/home beliefs to generate a beneficial change. Bourdieu (1977) discusses the classroom as having structure, culture and agency that can be different from the home dynamics. A feature of social space and fields of social practice make a hierarchical structure where the teacher occupies the dominant position that is related to the disposition of social, cultural, and symbolic capitals. Studying the classroom activities "revealed conflicts, antagonisms, and forms of resistance to the ideology of the school" in terms of production of knowledge, reproduction of social structures and negotiations of meanings, and the culture of the schools (Xu & Hampden-Thompson, 2012, p. 99).

Research Methodology

In this study, qualitative research methodology was employed. Qualitative research draws on direct experiences and meanings (Cohen et al., 2011). Action research, case-study and phenomenology methods are the types of qualitative methods that enabled me to study these types of research in a natural environment. Action research is a practitioner-based research (McNiff, 2002, cited in Cohen et al., 2011). It is also a powerful tool for change and improvement at a local level. Action research involves other participants as co-researchers. It immersed the researcher in such learning environment. According to Adelman et al. (1990, p. 75) cited in Cohen et al., (2011), “a case-study is the study of an instance in action”. Merriam (2009, p. 40) defines a case-study “as an in-depth description and analysis of a bounded system”. My preference to use a case-study is because it is holistic, lifelike, grounded and explanatory. On the other hand, phenomenology deals with participants’ lived experiences than with detrimental descriptions of experience and the structures that generate such experiences (Denzin & Lincoln, 2000).

The educators first completed a questionnaire, were interviewed, attended a workshop based on TCs and had their lessons observed. The responses from the questionnaires were analysed and the results influenced the activities of the workshop. The lessons, interviews, workshop proceedings and post-classroom observation and conversations were video-recorded. To answer research questions 1 and 2, the “what” challenges students and educators’ experiences, the “how” shows how challenges could be ameliorated. Participants were purposely sampled. The participants were all given pseudonyms. Five first-year chemistry educators and 47 students volunteered to take part in the research. There were between 300 and 350 students per class of six classes giving a total of 2,100 students. The students were from the classes of the sampled five chemistry educators. Gender was also considered. There were 33 male and 14 female students. Focus-group interviews were administered and video-recorded. A total of 41 videos were recorded.

I transcribed the survey questionnaires, classroom observations and interviews with educators and students. Coding highlighted the similarities and differences that occurred and enabled me to recognise those similarities and differences. The patterns that emerged after coding assisted me in answering my research questions. In this study, thematic analysis was employed. I present the main findings of students' group dynamics from the five classes and their educators, in the following section.

Main Findings of My Research

CHAT was engaged to other theories to construct relevant meaning. Cole and Engeström (1993, p. 7) illustrated a triangle containing "six elements: subject, object, tools, rules, community, and division of labour (roles) as" structure of activity theory. The community consisted of culturally diversified students from different schools, families and provinces (social culturalities) in/of Zambia indicating students were at different chemistry knowledge levels. Students possessed ordinary level chemistry and majored in chemistry, physical science and combined science, advanced level chemistry or were second-year students repeating general chemistry. The culture of the classroom and university community was influenced by the social, symbolic and cultural capitals of the social class (upper, middle, working class and poor statuses) (Bourdieur, 1986). The dominant (middle/working) cultural capital dictates what should be taught and the rules of engagement. Educators' and students' activity systems intersected, and the point of intersection was referred to as the "third space" (Engeström, 2001; Bhabha, 1994). It is a shared space and a learning space. Students bring to the class (shared space) their diverse cultural, symbolic and social capitals thereby creating a hybridized space (Bhabha, 1994; Hall, 2002). It is perceived that “students who possess the habitus of the dominant classes” are ready for new knowledge and those students who do not demonstrate the habitus of dominant classes are deficient (Nash, 1990, p. 436). So, the cultural, symbolic and social capitals of the classroom are resources and could generate tensions (affordances and contradictions). As a result, the hybridised nature of the classroom generates constraints and affordances for some students and educators. The teaching-learning of acids-bases reactions therefore require collaboration between educators and students (teaching-learning).

Teaching and learning was experienced differently by students and educators. Hence, their experiences in the third space are described individually and collectively. For students, university teaching approach was different from secondary school. It was characterised by teaching using PowerPoint slides and, before some students could understand the current concept, some educators have moved to the next slide/topic/concept. Lungu remembered learning three topics in one week and wondered how he “was going to catch up on those four hours” because he found the topics very hard and difficult to understand. According to Bourdieu and Passeron (1977, p. 195), “schools transmit knowledge in codes that are easily accessible to” students … “who possess a high level of linguistic and cultural capital”. Some students experienced symbolic violence. The educator possessed cultural capital in the form of chemistry content and was familiar with university culture. S/he exercised symbolic capital (Bourdieu, 1994). Furthermore, since students entered the university, they had been lectured to and bombarded with information instead of being taught step-by-step (claimed by Siyomba). Educators who were aware of disciplinary TCs provided roadmaps to students on how to utilise TCs and integrate them across topics. They also prioritised what to “teach and how” they c/would “teach it” (Land et al., 2010). On the other hand, constraints generated enablement to/for some students who sought academic assistance from the more knowledgeable others (MKOs) (Vygotsky, 1978).

The second key experience was the unexpected rescheduling of timetables (schedules) during the day; for example, shifting lectures that started at 08.00 am meant to end at 04.00 pm to end at 06.00 am on a day that was supposed to be a free day for some students without prior notice to students. This disturbed students' academic programmes. Experiences created constraints but the constraints transformed the students in some ways. Students learned from each other and studied until late at night to master what they had learned. Furthermore, students compensated their learning with YouTube lessons and additional tools/resources. Students adjusted the rules, roles and resources of their activity systems (Engeström, 2001). They (students) participated in the activities that help them in achieving the objective, which was to master the TCs and to produce the outcome, which was to attain success in chemistry (Leont've, 1978). Simultaneously, in the same process, students produced, reproduced and transformed themselves as members of the community of practice (Roth, 2004). For instance, students whose aspirations were aligned with the objective, which is to master TCs of acids-bases chemistry, and whose "means of achievement, social interactions and patterns of interactions (rules and division of labour)" correlate "with the dominant culture of schooling" that led "to" the "reproduction of bourgeois society" (Bourdieu & Passeron, 1990, p. 82). On the contrary, students with low prior knowledge who resisted alignment of their goals to the "means of" learning "and patterns of interaction with the dominant culture" failed or did poorly (p. 82). In this way, students reproduced the same dominant class structure that they were supposed to overcome (transform) (Roth, 2004 citing Bourdieu & Passeron, 1990). Musenge explained socio-cultural reproduction in this way: "If students are passive and are complaining about the lecturer's teaching that I did not get it and just sit back. Then, you will fail”. In this case, the culture of the university expects students to research and expand on the knowledge attained in class.

On the other hand, educators experienced challenges in teaching students who are at different knowledge levels. Some students possessed advanced level chemistry, others possessed ordinary level chemistry and good or poor prior knowledge of acids-bases. Students also brought their culture to class as fund knowledge (Hogg, 2011). As a result, lecturers could not get all students into, out of or through the liminal space (Chanda, first-year chemistry educator). These educators should have applied culturally relevant pedagogy that understands that students must learn to navigate between home and school (Ladson-Billings, 2006). In this case, chemistry educators must find ways to equip students with the knowledge needed to succeed in a system that oppresses them. Another key challenge was lack of hands-on and/or mind-on activities due to inadequate resources. Nevertheless, constraints created affordances for some educators and affordances became driving force of change/transformation in terms of teaching and learning. Educators modified their resources, roles and rules to engage students collectively and individually in navigating learning (Engeström, 2001). Students were able to learn from each other, learn at their own pace and work together to construct meaning within the lesson. Sharing knowledge and learning from each other promoted individual and collective successes. Lecturers collapsed their power structure to maximise students’ engagement to actively participate at their own pace according to their knowledge levels, while maintaining their roles as educators (Freire, 2005; Kincheloe, 2008). To overcome the lack of hands-on and mind-on activities, educators prepared problem-solving tasks in a handbook aimed at aiding students with their studies.

Conclusions of Each Research Question Finding

Research Question #1. What challenges do first-year students experience in learning the threshold concepts of acids-bases reactions?

The research question 1 identified the following challenges experienced by students: a lack of chemistry laboratory work, teaching approach (lecture, memorise chemical equations and constant), students studied to pass the examination and not to understand, students underrated the difficulty level of acids-bases reactions, detailed information was presented instead of key ideas, authoritative lecturers, students were at different chemistry levels and spent long hours in lectures. There was evidence of social and cultural reproduction (Bourdieu, 1977). The social disparity manifested itself in pedagogical difficulties and the knowledge levels of students. Students possessing diverse socio-cultural enter the school with different levels of cultural capital. This cultural capital includes “linguistic, knowledge aptitudes, dispositions toward schooling and interpersonal skills” (Xu & Hampden-Thompson, 2012, p. 99). Bourdieu (1973 as cited in Xu & Hampden-Thompson, 2012) suggests that schools reproduce and legitimized class structures by the culture of dominant groups that influence the curriculum, language and pedagogy. Since teaching in schools is linked with the dominant (middle-class) culture that is easily accessible to students who possess dominant “linguistic and cultural capital, schooling” favours middle-class students (p. 99). These cultural capital inequalities were manifested in “social and cultural exclusion in educational institutions” (Bourdieu, 1973, p. 99 cited in Xu & Hampden-Thompson, 2012). For instance, these students suggested that educators should bear in mind that students were not at the same institution and hence were not taught the same information. Mutinta added that some students went to good schools while others went to average schools and that, that could explain the differences between these schools in regard to teaching and learning of chemistry before entering university. It could have resulted in students who possessed “dominant cultural capital” being “perceived as more academically gifted than” students who do not (Bourdieu, 1986). Mutinta further explained that, “you need more effort from the lecturer to understand a concept than someone from a good school who will need very little effort to understand that concept or course”.

Students study chemistry for passing examinations and not to master the threshold concepts, and the overconfidence of students’ knowledge of acids-bases reactions was a common response in all the five groups. The findings revealed that students brought their fund knowledge (Hogg, 2011) and secondary school culture (prior knowledge) into their university classrooms. Tendency was that the home chemistry knowledge and culture conflicted with the university chemistry and culture. The university culture expects students to be responsible for their learning through expanded research or managing study times. Findings also revealed that challenges transformed students to study late into the night, watch academic videos and learn from more knowledgeable others and use (bricolaging) other available resources to learn.

Research Question #2: What are the challenges that educators experience in teaching the threshold concepts of acids-bases reactions to first-year students and how can these challenges be ameliorated?

The second question explored the challenges that lecturers experienced in the teaching of threshold concepts of acids-bases. The discussions of Chapter Two linked to the ways of how these challenges could be ameliorated. Information from the questionnaires, educators’ interviews, and classroom observations were bricolage. Challenges included students’ prior knowledge which positioned students at different knowledge levels and students’ positive and negative attitudes towards chemistry. A critical challenge was a lack of hands-on, mind-on teaching due to the refurbishing of chemistry laboratories at data collection stage of this study. Students bring into a classroom different knowledge levels, such as, advanced and ordinary chemistry levels. According to the educators, it was not easy to teach students possessing different levels of knowledge to get them all into the liminal space. Although students have the same hours of learning, at the university level, some required more time to grasp the concepts because students learned at their own pace. Additionally, students possess additional/alternative knowledge of Arrhenius, Bronsted-Lowry definitions, and some had not heard of Lewis's acids-bases definition before. Inonge, the educator, explained that "Arrhenius base is defined in a secondary school grade 12 textbook as a substance that ionises to form hydroxide ions as the only negative ions", but there are also oxides ions. Some students understood the concepts easily while others with less knowledge of chemistry found these difficult to understand. The knowledge gap between pre-university schools and university acids-bases reactions provided a challenge for educators to fill because they wanted to build on students' previous knowledge.

Another challenge was that there were many students in each class (large classes). Hamoonga, the educator, stated that it was like having two classes together in the same space. Student-centred pedagogies could not be employed in teaching; for example, computer simulations to illustrate the neutralisation reactions could not be used because there were not enough computers for every student in the class. Besides, hands-on, mind-on activities could not be done because of the lack of resources. Educators did not know how many students were actively following/participating in the lesson. The general chemistry curriculum was overloaded and there was not enough time to complete it as there were many disruptions, such as, attending Vice Chancellor's meetings with first-year students; and students' demands for more books and food allowances, etc.

On the one hand were the challenges that constrain teaching, on the other hand, are constraints generating affordances for educators to ameliorate. To ameliorate these different knowledge levels of students, knowledge gaps, and large numbers of students, educators encouraged students to form study groups in which students learn from each other. Educators constructed tasks to study for each topic in general chemistry which students can work on in their private study time. Also, one-on-one tutorials were held with students who sought conceptual assistance to mediate transitions to higher knowledge. During the lessons, educators allowed students to construct their own learning. I saw students working in groups or pairs while the educators negotiated the learning with others. This created relaxed and flexible learning contexts where students interacted with the educator and each other. In this way, educators collapsed relational powers by adjusting the culture, rules, resources and roles of the learning context to promote learning (Engeström, 1997; Freire, 2005). It further created an agency to scaffold students who seemed to be stuck (ZPD/liminality) as educators demonstrated more examples on the chalkboard. They asked students to do more tasks from the handbooks and to attend tutorials in which tutors helped students in much smaller groups.

Research Question #3: What are the causes of the high failure and drop-out rates in first-year chemistry and how can they be ameliorated?

The causes of high failure and drop-out rates were found to be influenced by educators, students and the university policies. The data from the study revealed the gap in knowledge between secondary school and university. Students did not know how to study the chemistry curriculum; students did not socialise with other students and students were timid, fearful and shy to interact with educators. Also, students did not utilise the handbook, missed lectures and tutorials, some thought chemistry was difficult and came into the chemistry lessons with negative attitudes. The chemistry contents were more than what first year students could handle. There were different learning cultures where students were examined in six courses at the end of the academic year, 50% pass mark and students settling down in a new place were apparent contra-indicators noted.

The findings revealed that lecturers presented chemistry content that was too detailed for first-year students. Most of the educators did not have educational (teaching and learning) backgrounds and were unfamiliar with pedagogy and learning theories. Hamoonga believed that untrained educators must be taught how to teach because “teaching is a skill” that could/should be taught. The counselling of educators to the students that chemistry is “difficult, and [that] a few of you may not make it” created intimidation and doubt in students. The learning culture in the university was different from their secondary school culture. Students’ culture and that of the university tend to conflict (Bhabha, 1994; Bourdieu, 1996; Wyatt et al., 2017). Experiences such as studying six courses and getting a 50% pass mark can cause pressure for students. This study suggests that students’ success is influenced by the social structures of the schools (Ladson-Billings, 1995). Hence, “the goal of education” is “to fit students … into a hierarchical structure” and to be culturally responsive to a more dynamic “relationship between home” or” community culture” and the “school culture” (Ladson-Billings, 1995, p. 467). Similarly, Brown-Jeffy and Cooper (2011) assert that the intersection between school and home/community cultures plays a role in the teaching strategies in schools. Bourdieu (1977) believes that the school culture is influenced by the middle-class culture that discriminates against working-class students. The schools’ cultural capital generates symbolic violence for working-class students. Furthermore, some students are shy, timid, and lack the confidence needed to ask for clarification during the classroom because of fear of exposing their lack of knowledge in the presence of their fellow students (symbolic violence). They also do not consult the lecturer or fellow students outside the classroom for fear. The lecturers explained that “keen students have an interest and, when they do not understand, they try to get clarification. Being afraid to approach the lecturer … not mixing with others, there will be no ZPD” (Hamoonga & Inonge). Students acknowledged that they did not consult friends outside the classroom as Temwa stated: “As students, we do not socialise with others … look for the ‘geniuses’, socialise with them”. Students in ZPD can be successful with instructional help from fellow students or lecturers.

Students also did not do assignments from the handbooks prepared by educators. Data revealed that students did not attend lessons and tutorials regularly. Educators claimed that if students were to attend all lectures and read and solve tasks in the handbooks, they would have no challenges in chemistry. Instead of attending lectures and tutorials, students watch electronic tutorials. Another cause for “high failure and drop-out rates” was students’ prior knowledge. Students with good educational foundations do better at university. Additionally, students struggle to master threshold concepts of acids-bases because they had not mastered the basic concepts that include chemical bonding, chemical equations, atomic structure and stoichiometry. In addition, educators also failed to activate and fill these knowledge gaps.

Research question number three (3) also asks, “How can the causes be ameliorated?” Usually, students with bad chemistry backgrounds were asked to go back and learn the basics of chemical reactions in the tutorial groups where there were fewer students and there were more interaction between the students and the tutors. In these tutorial groups, struggling students can be identified. Failure to attend lectures, do the assignments, study, and manage the pressure of the work could be addressed by counselling, too. Students can learn to be more responsible and disciplined in their studies.

The three research questions have provided findings enabling the formulation of a response to the “goal of the research” that “was to investigate” first-year students’ challenges in chemistry teaching and learning that resulted in high failure and drop-out rates and efforts to ameliorate these challenges and to increase students’ successes in chemistry.

Recommendations as per the findings of each research question

Research Question #1: What challenges do first-year students experience in learning threshold concepts of acids-bases reactions?

The use of PowerPoint slides is a common teaching strategy at universities to present concepts. However, more often, before the students could understand what was being presented, the educator has moved on to the next slide. Students were being lectured on and tutored for long hours that generated pressure that some students failed to manage well. First-year courses must be reduced from six to four courses and the chemistry curriculum should also be trimmed. Educators must use learner-centred methods that relate concepts to everyday life, such as, investigating the pH of garden soil (project approach), collaborative learning, hand-on and mind-on activities. Learner-centred approaches give opportunities for students to take control of their learning and construct (generate) their own meaning (knowledge). Students may realise that they are not only recipients of knowledge but also producers. Students were often spoon-fed at secondary school level and prepared for passing the examinations but were not prepared for the transformation of knowledge to other domains. As students interact with their colleagues, MKOs, and educators inside and outside the classrooms, they learn the university culture and can overcome challenging concepts. Thus, during induction, students should be advised that they must expand and research the knowledge given by the lecturers. Students must always attend lectures and tutorials, work hard, solve the tasks in handbooks in groups and create extra time by studying late into the night as needed.

Research Question #2: What are the challenges that educators experience in teaching the threshold concepts of acids-bases reactions to first-year students and how can these challenges be ameliorated?

Educators must find out the students' prior knowledge and understand that students possess diverse cultures, knowledge levels and possibly alternative knowledge. Instead of building on the alternative knowledge, educators must go back and teach the basics of chemistry contents to bring students up to the university chemistry level. Study handbooks should include atomic structure, chemical bonding, chemical equations, and stoichiometry (basics), as well as the tasks for each topic for individual and collective study. Collectively, students can explore the questions in the study guides and present them to the whole class where the educator can elaborate on (facilitate) them. Because most of the students do not exhibit confidence, are so shy and easily intimidated and do not interact with educators, educators should, therefore, create a friendly and flexible learning context in which the educator adjusts the roles and rules of the classroom to collectively negotiate to learn (Bourdieu, 1997). The learning context in which the power relations were shared with the students enables students to interact with lecturers, question the curriculum, question the culture of the university and adapt to the new culture (Freire, 2005). The adjusted structure of the classroom may generate opportunities for increased interactions between student-educator and collectively they can negotiate ZPD/liminal space. Educators redefined the rules of engagement and adjusted the distribution of labour between student-educator and student-student in the activity system (Bourdieu, 1997; Engeström, 2001). The educator collapsed the power dynamics of the traditional roles of teachers. Traditional roles regard the teacher as an authoritative and narrative figure and the students as passive recipients of knowledge (Feire, 2005).

Research Question number 3: What are the causes of the high failure and drop-out rates in first-year chemistry and how can they be ameliorated?

Much has been discussed earlier about promoting hands-on and mind-on activities as acids-bases reactions are abstract. Students want to experience what they are learning. I, therefore, recommend the threshold concepts approach which draws on active interactions in a specific subject area be implemented. Learning in the threshold concept approach claims that;

> “knowing is seen not simply as ‘‘retaining and applying knowledge consistently,’’ and not only as ‘‘one’s ability and capacity to use it in a personal way in a variety of situations,’’ but more profoundly, as ‘ applying knowledge actively, creatively and imaginatively [in varieties of ways] and where it forms the basis for further inquiry” (Bradbeer, 2006, p. 16).

Despite insufficient equipment in the chemistry laboratory, virtual laboratory work can help. Students need to see what is happening in the acids-bases reactions to be able to transfer this knowledge to real-life situations. The first-year general chemistry course is a foundation for higher chemistry courses and other science programmes that consist of chemistry, for example, biochemistry and pharmacy. Acids-bases reactions are one of the threshold concepts in chemistry. Preparing acids-bases threshold concepts as the foundation course may help students to master chemistry content. If students think beyond what they have learned, they could apply a concept, build on first-year acids-bases and relate it to new ideas. Cousin (2006) claims that the threshold concept approach seeks to identify key concepts and mastering them would open students “to new ways of thinking” that lead to transformative, irreversible and integrative knowledge. Also, mastering threshold concepts exposes previously hidden interrelated concepts (Carstensen & Bernhard, 2008). Educators stated that a student who has mastered “a concept finds new ways of approaching a problem. Mastery means to love threshold concepts, go beyond living it, use extended memory of treating acids-bases”. Educators further stated that making threshold concepts of chemistry a first-year foundation course is advised as students possess different levels of chemistry knowledge. Chanda explained that teaching threshold concepts would strengthen students’ foundation in terms of their understanding of the course at that higher level. Threshold concepts are key to shifting students from ordinary level to advanced level chemistry.

Due to the experiential nature of threshold concepts, students and educators identified five key concepts that are fundamental. They include the definitions of acids-bases reactions (Arrhenius, Bronsted-Lowry and Lewis), calculating of pH, buffer solutions, acids-bases equilibrium and chemical formulae of acids-bases. Threshold concepts are core ideas that are transformative and provide a link between other concepts. Topics in chemistry are interrelated and failure to learn the current topic may create challenges in learning other topics. For example, chemical equilibrium is interrelated with acids-bases equilibrium, electrochemistry and biochemistry. The interconnectedness of these concepts provide the basis from which the educator can begin to interact with the students. The outcome of the identification creates affordances for students to learn rather than embracing all the details at once. For instance, Nshindano stated that “lecturers do not really tell us about the fundamental aspects of the topic. We spend two hours in a lecture and we understand nothing”. It also creates affordances for teaching because the educator knows which concepts to present as Chilala explained, “Yes, we have come to the university but they [educators] do not have to bombard us there and then”. The objective of engaging students with threshold concepts can be articulated by interactive lecturers, hands-on, mind-on activities and dialogues to make the learning of acids-bases more effective.

Active learning of threshold concepts makes "students think dynamically; they will not work or think in one direction but will try to apply different concepts that are stuck in their minds [that] will be brought in one direction" (Inonge). Lemon fruit and detergent are tangible objects that can represent citric acid and bases, respectively. Students should be able to construct meaning if they are capable of reasoning, interpreting, observing, and manipulating available resources to solve an acids-bases reaction. In this case, educators should encourage students to explore acids-bases reactions outside the classroom.

The Empirical Findings that Contribute to New Knowledge

The analysis was based on video-recorded interviews of both students and educators, lesson observations, and after lesson conversations with educators. Conversations with students revealed pedagogical issues that educators employed in teaching acids-bases reactions, the classroom culture that was very much different from home culture, not knowing how to study, and depending on the educator as the sole source of learning. The qualitative analysis provides further insight into the students' struggles with threshold concepts of acids-bases chemistry. The challenges in the understanding of reactions of acids-bases were the calculations of pH and acids-bases equilibrium without laboratory work. The analysing of educators' interviews revealed that, despite the large classes, student engagements could be done through peer learning or co-teaching. Nevertheless, the major finding is formulation of the threshold concept foundational course for first-year students. The threshold concept teaching approach and module may increase the mastering of key concepts and connect with other related chemical reactions in chemistry. In this context, students actively interact with the threshold concepts and transform it with other threshold concepts for a further ontological shift, for instance, interpreting the Bronsted-Lowry acids and applying it in the pH calculations of weak acids. By doing this, a student may transform beyond the ZPD/liminal space.

Implications for Science Education Research Community

TCs should be given much attention by educators' explanations that may provide links between concepts in acids-bases chemistry and other topics. Key ideas are basic and core which someone should know to understand challenging concepts. Key concepts which are at the centre of acids-bases chemistry are donating and receiving protons, donating, and receiving lone pair electrons, and dissociation of acids-bases into hydrogen and hydroxide or oxide ions. Neutralization, weak and strong acids-bases, acid-base constants, and calculation of pH of acids-bases and buffer solutions are also key ideas. A student has to master acid-base from this dimension. Failure to learn the current topic may create challenges. TCs have a cognitive and affective dimension that students struggle, grapple, and learn that cannot result from not being able to cope with the integration of the concepts. However, transformative learning has a strong affective dimension which consists of an amount of anxiety and risk.

Furthermore, liminal, third and ZPD spaces are learning or problem-solving spaces. Positions within the space are occupied by the educator and the students. These are social positions with power relations. Students bring to the learning space diverse culture and knowledge creating a hybrid space. The hybridised nature of the classroom generates tensions. Tensions highlighted the nature of mediation for students which both the educator and students could engage in. Each educator adjusted his/her teaching differently to ameliorate the challenges in teaching. Educators shared power with students to place them in a learning experience (Freire, 2005). Educators empowered students to choose their strategies of learning, the pace of learning and who they would engage in collaborative learning. Hence, educators were drawing on emotions arising from mastering TCs, students' diversity and tensions in the classroom to adjust their teaching. Hybridity and affective dimensions could be used as teaching resources.

Limitations to the Study

Firstly, the study was carried out in one university and cannot reflect all the perspectives of higher institutions of learning in Zambia. Secondly, the formulation and implementation of the threshold concepts foundation course to improve the transformative and integrative nature of mastering threshold concepts of acids-bases was not included in the research design (Meyer & Land, 2003; 2005). The untimely closure of the university prevented students from watching and discussing the recorded focus group interviews. So, the data analysed were not validated except by the educators. Finally, the inclusion of learning theories in the interpretations of data and discussions of relevant literature failed due to the COVID-19 lockdown as I was unable to refer to hard copies of books. So, I included secondary citations from other works of literature. So, the analysis and discussion may have missed some major ideas.

Recommendations for Future Research

Formulated threshold concepts pedagogy combined with constructivist teaching approaches, such as laboratory work, as intervention projects for first-year students, implementing the threshold concept pedagogy as a foundational course and evaluating the outcome of first-year chemistry results may add new knowledge. Acids-bases reactions are one of the thresholds of chemistry and general chemistry is the foundation course for higher chemistry programmes. The threshold foundation course may assist students in mastering acids-bases contents which they can connect to other chemical reactions in chemistry. Threshold concepts are integrative, transformative, irreversible, troublesome, and establish boundaries within certain areas of knowledge (Meyer & Land, 2005).

Funds of knowledge and different chemistry knowledge levels that students bring into the classroom are other possible areas of research. Funds of knowledge and different chemistry knowledge levels of acids-bases reactions were revealed to be the biggest challenges in teaching and learning of chemistry. Researchers can investigate how funds of knowledge influences the mastering of the threshold concepts of acids-bases chemistry and how funds of knowledge can be explored to promote teaching and learning. Some studies that discuss the understanding of household science and classroom science have been done by Hogg (2011) and Moll et al. (1992).

Personal Reflections

My desire to alleviate the high failure and drop-out rates in chemistry by first-year students at my institution propelled me to investigate this subject matter. Dropout rates in chemistry were higher than in any other subject. Acids-bases reactions were selected because it was a topic where most students seem to experience challenges. Threshold concepts were introduced to me as portals that, if not mastered, affect the students' progress to the next level (Meyer & Land 2003; 2005). Many science education scholars have researched in this field (Timofte, 2015; Furió-Más et al., 2012). To investigate the teaching and learning of threshold concepts of acids-bases reactions, one must study "what happens in the classroom". CHAT and learning theories were the theoretical frameworks employed to explain the teaching and learning process. Being immersed in CHAT that comprises first-generation (Vygotsky, 1978), Leont've's (1978) second-generation and Engeström's (1997) third-generation, gave me the opportunity to investigate the intellectual reasoning of the process of teaching and learning of chemistry. CHAT theoretical frameworks interwove well with situated learning

(Lave & Wenger, 1991), Bandura's (1977) imitative or vicarious learning, Piaget's (1951) cognitive development, Vygotsky's (1978) social learning theory, Bourdieu's (1977) theory of social reproduction, Kincheloe's (2008) method of multidisciplinary research and Freire's (2005; 1970) critical pedagogy expressed in the pedagogy of the oppressed.

I learned about the knowledge contained in the theories and the role they play in teaching and learning. Findings revealed that there are conceptual (cultural capital) and physical (resources) factors present in the classroom that influence quality interactions between student-educator, student-student, and student-curriculum. Moreover, the study revealed that students who came into universities are social beings and possess knowledge. They learn through interactions with lecturers and fellow students, with the resources available and with the chemistry curriculum in order to be successful in chemistry.

The classroom has a structure and culture which may be contradictory to students' pre-university schools and home cultures. This contrast creates affordances and constraints for some students and lecturers. However, students construct their own meaning, and educators must be aware of this. During my research, I learned about my own strengths and weaknesses. I am transformed by this study and my conceptual transformation is now a key to the success of my students and my colleagues.

Summary of Chapter Six

I have highlighted the major findings of this study. Discussed in details first were the conclusions and recommendations of the research questions. Contributions of the findings of the study to new knowledge, implications for science education, research community, and limitations of the study were discussed. The study investigated freshmen's high failure and drop-out rates in chemistry in my institution in Zambia. The findings reveal the interactions between student-educator and student-student in the classroom that influence the mastering of threshold concepts of acids-bases reactions. The lecture rooms were hybrid spaces that contain diversities of students and educators who came together to achieve common objectives, which included success in chemistry. The diversity is due to differences in students' levels of knowledge about acids-bases reactions and the variety of socio-cultural backgrounds they bring into the lecture rooms. Similarly, educators bring their own teaching strategies and chemistry knowledge into the lessons that may not meet the students' expectations. This generates constraints for some students and educators. Nevertheless, according to the findings, the constraints created opportunities for some students to expand classroom knowledge through research and group discussions. Likewise, educators adjusted their teaching strategies. This investigation also revealed that two hundred and fifty students (250) in one class and limited resources, failure of students to study and solve tasks in the handbooks, and inconsistency of students' attendance were some of the contributors to failure and dropout.

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APPENDICES

Appendix A: University of Witwatersrand Ethical Clearance

HUMAN RESEARCH ETHfCS COMMITTEE (NON-MEDICAL)

R14/49 Kampamba

cc: Supervisor : Dr F Otulaja

CLEARANCE CERTIFICATE

PROTOCOL NUMBER: H18/02/14

PROJECT TITLE

Acids-bases threshold concepts - A case of first year students' challenges in Chemistry teaching and learning

INVESTIGATOR(S)	Miss R Kampamba
SCHOOL/DEPARTMENT	Chemistry/
DATE CONSIDERED	16 February 2018
DECISION OF THE COMMITTEE	Approved
EXPIRY DATE	07 August 2021

CHAIRPERSON J Knight

(Professor J Knight)

DATE 08 August 2018

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10004, 10th Floor, Senate House, University. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

l/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and l/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved l/we undertake to resubmit the protocol to the Committee. I agree to completion of a yearly

progress report.

______________________ Signature

____/____/____ Date

Appendix B: Ethical clearance

SITY
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THE COPPERBELT UNIVERSITY

Office of the Vice Chancellor

Directorate of Research, Innovation and Consultancy (DRIC)

Box 21692, Jambo Drive, Riverside, Kitwe, Zambia
(+260) 967 000 116 or 972 884 356
jameson.mbale@gmail.com or *jameson.mbale@cbu.ac.zm*

7th July 2017

The Registrar

Copperbelt University

Dear Sir / Madam,

ETHICAL CLEARANCE FOR MS. ROYDA KAMPAMBA TO CONDUCT RESEARCH AND COLLECT DATA IN THE SCHOOL OF MATHEMATICS AND NATURAL SCIENCES

Ms. Royda Kampamba is a member of staff in the Department of Mathematics and Science Education in the School of Mathematics and Natural Sciences (SMNS) at the Copperbelt University (CBI]). Currently, she is on study leave pursuing a PhD in Chemical Education at Witwatersrand University, in South Africa. Her area of study is to investigate on the causes of high dropout rate among first year General Chemistry Students in Zambia. Ms Kampamba is applying for an Ethical Clearance, seeking permission to allow her collect data in the SMNS, The DRIC office supports her application and recommends your office for approval based on the condition that she abides by following ethical requirements / rules:

- the applicant has a responsibility to take account of all relevant evidence and present it without omission, misrepresentation or deception;
- data and information must not knowingly be fabricated or manipulated in anyway which might lead to distortion;
- desist from plagiarism, cheating and other forms of unfair practice. That's professional standards need to be observed in attribution of authorship, acknowledgement of sources, and correctness of references, or work of other scholars must be acknowledged;
- the confidentiality of information supplied by participants/respondents must be respected. However, any limits to confidentiality must be explained to participants; and
- participants should not be subjected to undue intrusion, distress, indignity, physical discomfort, personal embarrassment or other harm.

Yours faithfully,

Prof. Jameson Mbale.

Inaugural Director: Directorate of Research, Innovation and Consultancy (DRIC)

Copy to: Vice-Chancellor; Deputy Vice-Chancellor

Appendix C: Copies of Information Sheets and Consent Forms

School of Chemistry
University of the Witwatersrand, Private Bag 3, Wits 2050, Johannesburg, SA T: +27 11 7173414 F:+27 11 7173259. Phone: 0732273614.
e-mail: 1597251@students.wits.ac za

Lecturer's Participation Information Sheet

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in teaching and learning chemistry.

Research Student: Ms. Royda C. Kampamba, School of Chemistry

Hello, I am Royda Kampamba, a PhD student at University of the Witwatersrand, School of Chemistry. I am a chemistry education researcher whose focus is exploring the first-year chemistry students' high failure and dropout rate and finding ways of increasing chemistry students' retention.

Today, I want to invite you to get involved in a research that will include you, your students, and me as participants together. You are invited to take part in completing an online questionnaire, which will be followed by a one-to-one or focus-group interview that will last 20 minutes. There are 25 questions that you will answer 'Yes' or 'No' and give the reason/s why. This will take 30 minutes. Nevertheless, you are not obliged to answer every question. All information collected in this study will be confidential and anonymous. I will record videos of the interview. You are also invited to identify TCs of acids-bases and propose interventions. Being involved in this research means that I will be coming to your class twice a week to observe your teaching of threshold concepts of acids-bases. The video will focus on classroom teaching of TCs of acids-bases. Since each lesson is 2 hours, I will video-record 2 lessons per week for over 2 weeks. However, I will video-record 3 (Arrhenius, Bronstead-Lowry & Lewis models) lessons per lecturer. The purpose of this study, therefore, is to provide opportunities for students to internalize threshold concepts of chemistry. This study aims to: 1) identifying of TCs for teaching and learning of acids-bases chemistry; 2) explore students' deep learning of threshold concepts of acids-bases; 3) enhance lecturer's reflection on the teaching and learning of TCs of chemistry and 4) explore best practices for mastering of TCs in acids-bases.

During classroom related activities, I will record what happens in the class on video. The video will record your image, voice and what you do in class. I may also assist your students in answering some of acids-bases threshold concept questions. In addition to watching what happens during acids-bases lessons, we (lecturer and I) will watch selected parts of the video (clips) and may invite students to watch video with us and to have a discussion about what happened in class and why certain things happen the way they do. Anything you say will be kept confidential and I will never use it against you. I will respect your opinion. I will write about our discussions. I will not use your actual name when we write about what we discussed. I will ask you to choose a name you would like me to use in my writings about what we learn. We may also meet regularly to discuss what was happening in the class and why what happened happen. We will then discuss how we can learn TCs of acids-bases chemistry and related topics better. I want these discussions to be serious conversations. We are trying to learn together, from each other, how we can help students master TCs of acids-bases. I will audio-record our conversations.

I will then analyse the videos I chose for the meetings and write my impression of what happened. I will analyse how the student interacts with you and other students and how you interact with your students in class. If your images are in the video clips, I will get your permission to use the video clips. The overall goal of this research is to improve the quality of teaching and learning of TCs of chemistry in your class.

Should have any questions about your rights as a participant in this study, please contact: Human Research Ethics Committee (HREC) at 0117171408 or Shaun.Schoeman@wits.ac.za

Research Student: Royda C. Kampamba, Signature of Researcher:

email:1597251@students.wits.ac.za phone number: +260 (0) 977362667/+27(0) 832637962.

Should you feel that you have been harmed in anywhere by participating in this study please contact: The Research Supervisor, Femi Otulaja. Email: femi.otulaja@wits.ac.za, phone number +27 (0) 746430133.

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Lecturer's Informed Consent to Serve as Participant in a Research Project

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in Chemistry Teaching and Learning

Research Student: Ms. Royda C. Kampamba, School of Chemistry

Survey Questionnaire

Your participation in this research study is voluntary. You may choose not to participate and withdraw your consent to participate at any time. You will not be penalised in any way should you decide not to participate or to withdraw from the study.

I ……………………………………….. agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

Please circle the appropriate response

I agree that my participation will remain anonymous	YES	NO
I agree that the researcher may use anonymous quotes in her research report	YES	NO
I agree that all information I provide may be used in this research and publication	YES	NO

______________________	____________________	__________________
Name of participant	Signature of participant	Date
Royda C. Kampamba		06/08/2018
Name of Researcher	Signature of Researcher	Date

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Lecturer's Informed Consent to Serve as Participant in a Research Project

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in Chemistry Teaching and Learning

Research Student: Ms. Royda C. Kampamba, School of Chemistry

Semi-structured Interviews

Your participation in this research study is voluntary. You may choose not to participate and withdraw your consent to participate at any time. You will not be penalised in any way should you decide not to participate or to withdraw from the study.

I ……………………………………… agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

Please circle the appropriate response.

I agree to participate in interviews	YES	NO
I agree that the researcher may use anonymous quotes in her research report	YES	NO
I agree that my pseudonym name may be used in the final thesis or publication	YES	NO
I agree that the information I provide may be used anonymously by other researchers following this study	YES	NO

____________________	____________________	____________________
Name of participant	Signature of participant	Date
Royda C. Kampamba		06/08/2018
Name of Researcher	Signature of Researcher	Date

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Lecturer's Informed Consent to Serve as Participant in a Research Project

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in Chemistry Teaching and Learning

Research Student: Ms. Royda C. Kampamba, School of Chemistry

Lesson Observation

Your participation in this research study is voluntary. You may choose not to participate and withdraw your consent to participate at any time. You will not be penalised in any way should you decide not to participate or to withdraw from the study.

I ………………………………………. agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

Please circle the appropriate response

I agree that the researcher will attend my lessons	YES	NO
I agree that the researcher may video-record my lessons	YES	NO
I agree that the researcher and I may watch video clips	YES	NO
I agree that the researcher and I may discuss video clips	YES	NO
I agree that the researcher may audio-record our discussion	YES	NO

______________________	____________________	__________________
Name of participant	Signature of participant	Date
Royda C. Kampamba		06/08/2018
Name of Researcher	Signature of Researcher	Date

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Student's Participation Information Sheet

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in teaching and learning chemistry

Research Student: Ms. Royda C. Kampamba, School of Chemistry

Hello, I am Royda Kampamba, a PhD student at University of the Witwatersrand, School of Chemistry. I am a chemistry education researcher whose focus is exploring the first-year chemistry students' high failure and dropout rate and finding ways of increasing chemistry students' retention.

Today, I want to invite you to get involved in a research that will include you, your lecturer, and me as participants together. You are invited take part in the focus group discussion. This activity will involve identifying difficult concepts of acids-bases which discourage you from studying chemistry and the factors that contribute to your discouragement. The conversation will take 60 minutes. All information collected in this study will be confidential and anonymous. With your permission, I would like to video-record the focus-group discussion using a digital camera. Being involved in this research means that I will be coming to your class twice a week to observe your learning of threshold concepts of acids-bases for over 2 weeks. Since, each lesson is 2 hours, I will video-record 3 (Arrhenius, Bronstead-Lowry & Lewis models) lessons per class. The purpose of this study, therefore, is to provide opportunities for students to internalize threshold concepts of chemistry. This study aims to: 1) identifying of TCs for teaching and learning of acids-bases chemistry; 2) explore students' deep learning of threshold concepts of acids-bases; 3) enhance lecturer's reflection on the teaching and learning of TCs of chemistry and 4) explore best practices for mastering of TCs in acids-bases.

During classroom related activities, I will record what happens in the class on video. The video will record your image, voice and what you do in class. I will help your lecturer to answer some of your acids-bases threshold concept questions. In addition to watching what happens during acids-bases lessons, we (your lecturer and I) will watch selected parts of the video (clips) and may invite you to watch video with us and to have a discussion about what happened in class and why certain things happen the way they do. The viewing of video clips and discussion will last for an hour. Anything you say will be kept confidential and I will never use it against you. I will respect your opinion. I will write about our conversations. I will not use your actual name when I write about what we discussed. I will ask you to choose a name you would like me to use in my writings about what we learn. You and a small group of your classmates, your lecturer and I may also meet regularly to discuss what was happening in the class and why what happened happen. We will then discuss how we can learn TCs of acids-bases chemistry and related topics better. I want these discussions to be serious conversations. Again, I will respect your opinions and anything you say will never be used against you. We are trying to learn together, from each other, how we can help you master TCs of acids-bases. I will audio-record the conversations.

I will then analyse the videos we chose for the meetings and write my impression of what happened. I will analyse how the lecturer interacts with you and other students (both in the class and in the meeting) and how you and other students interact with your lecturer and with each another. If your images are in the video clips, I will get your permission to use the video clips. The overall goal of this research is to improve the quality of teaching and learning of TCs of chemistry in your class.

Should you have any questions about your rights as a participant in this study, please contact: Human Research Ethics Committee (HREC) at 0117171408 or Shaun.Schoeman@wits.ac.za

Research Student: Royda C. Kampamba, Signature of Researcher: email:1597251@students.wits.ac.za phone number: +260 (0) 977362667/+27 (0) 832637962.

Should you feel that you have been harmed in anywhere by participating in this study please contact: The Research Supervisor, Femi Otulaja. Email: femi.otulaja@wits.ac.za, phone number +27 (0) 746430133.

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Student's Informed Consent to Serve as Participant in a Research Project

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in Chemistry Teaching and Learning

Research Student: Ms. Royda C. Kampamba, School of Chemistry

Focus-group Interviews

Your participantion in this research study is voluntary. You may choose not to participate and withdraw your consent to participate at any time. You will not be penalised in any way should you decide not to participate or to withdraw from the study.

I ……………………………………….. agree to participate in this research project. The research has been explained to me and I understand what my participation will involve.

Please circle the appropriate response.

I agree that my participation in this focus-group interview will remain anonymous	YES	NO
I agree that the researcher may use anonymous quotes in her research report	YES	NO
I agree that my pseudonym name may be used in the final thesis or publication	YES	NO
I agree that the information I provide may be used anonymously by other researchers following this study	YES	NO

______________________ ____________________ __________________

Name of participant	Signature of participant	Date
Royda C. Kampamba		06/08/2018
Name of Researcher	Signature of Researcher	Date

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Student's Informed Consent to Serve as Participant in a Research Project

Project Title: Acids-Bases Threshold Concepts: A Case of First-Year Students' Challenges in Chemistry Teaching and Learning

Research Student: Ms. Royda C. Kampamba, School of Chemistry

View Video Clips

Your participation in this research study is voluntary. You may choose not to participate and withdraw your consent to participate at any time. You will not be penalised in any way should you decide not to participate or to withdraw from the study.

I ………………………………… agree to participate in viewing video clips. The research has been explained to me and I understand what my participation will involve.

Please circle the appropriate response.

I agree that the researcher may use anonymous quotes in her research report	YES	NO
I agree that video clips discussions be audio-recorded	YES	NO
I agree that all information I provide may be used in this research and publication	YES	NO

Name of participant	Signature of participant	Date
Royda C. Kampamba	[signature]	06/08/2018
Name of Researcher	Signature of Researcher	Date

Appendix D: Pre-intervention Survey Questionnaire

Knowledge of Threshold Concepts in Chemistry among Lecturers of Undergraduate Chemistry Students

Preamble

Threshold concepts (TCs) are key concepts that are fundamental and transformative to acquiring mastery in a discipline. Mastering the threshold concepts (key ideas) brings about real shift in the students' understanding of a disciplinary knowledge. Threshold concepts open new ways of thinking, doing and acting in a discipline. These core concepts are likened to stepping-stones to complex concepts. Threshold concepts connect to or open doors into the knowledge in that discipline. In a liminal space, the student is engaged with the process of internalising a threshold concept. A liminal space is an 'in-between' state in which students oscillate between earlier, less sophisticated understandings and the fuller appreciation of a concept (Land, Cousin, Meyer & Davies, 2005). TCs when deeply understood represents transformed and integrative understandings of a discipline without which a student cannot progress (Talanguer, 2015; Cousin, 2006).

The nature of acids-bases is one of the concepts in chemistry that have been identified as threshold concepts (Timofte , 2016). It is cardinal to learning other chemical reactions within the discipline and other concepts in biology, physics and careers in engineering (Cooper, Kouyoumdjian & Underwood, 2016). There are also TCs within acids-bases chemistry, which I will call secondary or subsets of chemistry TCs, which will be identified. This survey is designed to assess lecturers' knowledge and experience of threshold concepts of acids-bases in chemistry. It also assesses first-year students' challenges in learning chemistry. The responses provided will help determine whether the respondent has been introduced to TCs theory.

Lecturers' Background

Tick appropriate box.

I am a: ☐ Male ☐ Female

I have been teaching undergraduate chemistry at CBU for:

☐ 1-3 years ☐ 4-6 years ☐ 7-10 years ☐ more than 10 years

I am currently teaching: Which course (s) and year (s)?

…………………………………………………………………………………

…………………………………………………………………………………

Number of students in my class(es)?

……………………………………………………………………………………….

……….………………………………………………………………………………

Specific questions about threshold concepts in undergraduate chemistry teachings.

The following questions require a 'Yes' or 'No' answer with some explanations. Kindly answer each question to the best of your knowledge.

1. I teach acids-bases in my first-year Chemistry classroom to my students.

☐ Yes ☐ No

If yes, explain. ……………………………………………...
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………………………………………………………………………………………………

If no, explain. …………………………………………………………………………..
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2. I have the knowledge and experience in teaching threshold concepts in Chemistry.

☐ Yes ☐ No

If yes, explain. ……………………………………………...
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………………………………………………………………………………………………

If no, explain. …………………………………………………………………………..
…………………………………..……………………………………….…………………
………………...………….…………………………………………………………………

3. Teaching threshold concepts in acids-bases means connecting key ideas to other related topics in Chemistry. ☐ Yes ☐ No

If yes, explain. ……………………………………………...
...…………..…………………………………………………………………...…..………
………………………………………………………………………………..………………

If no, explain. …………………………………………………………………………..
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4. I am capable of teaching the concept of acids-bases to first-year Chemistry students.

☐ Yes ☐ No

If yes, explain. ……………………………………………………………………………………
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If no, explain. ……………………………………………………………………………………
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5. Teaching threshold concepts to students will help them to master Chemistry concepts better. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………………………
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If no, explain. ……………………………………………………………………………………
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6. Introducing threshold concepts of acids-bases in Chemistry teaching and learning is a good idea. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………………………
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If no, explain. ……………………………………………………………………………………
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7. Teaching threshold concepts requires changes in the lecturer's methods of teaching and students' learning methods. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………………………
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………

If no, explain. ……………………………………………………………………………………
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8. I have sufficient resources to support my teaching and learning of threshold concepts of acids-bases in Chemistry. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………………………
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If no, explain. ……………………………………………………………………………………
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……………….……………..……………………………………………………………………….

9. I have adequate knowledge and skills to support struggling students in learning threshold concepts of acids-bases in Chemistry. ☐ Yes ☐ No

If yes, explain. ………………………………………...
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……………………………………………………………………………………………..

If no, explain. …………………………………………………………………..
……………………………………..……………………………….…………………………
……………….……………..………………………………………………..………………

10. Identifying threshold concepts of acids-bases and its relationships with other Chemistry topics can help improve students' performances in chemistry.

☐ Yes ☐ No

If yes, explain. ………………………………………...
...………….…………………………………………………………………...…..………
……………………………………………………………………………………………

If no, explain. …………………………………………………………………..
……………………………………..……………………………….…………………………
……………….……………..……………………………………………………………….

11. I feel inadequately prepared to teach the nature of acids-bases without identifying the key ideas (threshold concepts). ☐ Yes ☐ No

If yes, explain. ………………………………………...
...………….…………………………………………………………………...…..………
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If no, explain. …………………………………………………………………..
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12. Teaching and learning of threshold concepts in Chemistry does not always improve students' marks. ☐ Yes ☐ No

If yes, explain. ………………………………………...
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If no, explain. …………………………………………………………………..
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13. A student who masters the threshold concepts in Chemistry is most likely to do well in Chemistry. ☐ Yes ☐ No

If yes, explain. ……………………………………………...
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If no, explain. ……………………………………………………………………..
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14. Threshold concepts in Chemistry should be taught to first-year students as a foundation course in learning Chemistry. ☐ Yes ☐ No

If yes, explain. ……………………………………………...
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If no, explain. ……………………………………………………………………..
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15. Encountering threshold concepts before accessing other concepts in Chemistry teaching and learning can make such a significant difference in students' learning of Chemistry. ☐ Yes ☐ No

If yes, explain. ……………………………………………...
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If no, explain. ……………………………………………………………………..
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16. Educators in higher institutions of learning are knowledgeable of threshold concepts in their disciplines. ☐ Yes ☐ No

If yes, explain. ……………………………………………...
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…………………………………………………………………………..…………………

If no, explain. ……………………………………………………………………..
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17. Teaching threshold concepts requires changes in the lecturer's teaching practice.

☐ Yes ☐ No

If yes, explain ……………………………………………………………..........……
……………………………………………………………………………………..………

If no, explain. ………………………………………………………………………………
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18. Introducing threshold concepts of acids-bases in Chemistry teaching and learning is a good idea. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………….
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If no, explain. ………………………………………………………………………
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19. I use student's performance information to improve my teaching.

☐ Yes ☐ No

If yes, explain. ……………………………………………………………………….
……………………………………………………………………………………………
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If no, explain. ……………………………………………………………………..
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20. My department is concerned about lack of improved performance in students' learning of Chemistry. ☐ Yes ☐ No

If yes, explain. ………………………………………………………………………
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If no, explain. ………………………………………………………………………
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21. The last 5 years have seen no improvement in the teaching of first-year Chemistry students in my department/school. ☐ Yes ☐ No

If yes, explain. ………………………………………………………………………
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If no, explain. ……………………………………………………………………….
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22. Students’ assessment (marks)☐en refle☐the standard of the School of Mathematics and Natural Sciences. Yes No

If yes, explain. ………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………

If no, explain. ………………………………………………………………………… …………………………………………………………………………………………… ……………………………………………………………………………………………

23. Lecturers’ learning communities (community of practice) are available in my department/university. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………….. ………………………………………………………………………………………… …………………………………………………………………………………………..

If no, explain. ………………………………………………………………………… ………………………………………………………………………………………… ……………………………………………………………………………………………

24. The time taken by students to learn threshold concepts in Chemistry may be influenced by prior knowledge of the concept. ☐ Yes ☐ No

If yes, explain. ……………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………

If no, explain. ………………………………………………………………………… ……………………………………………………………………………………………… …………………………………………………………………………………………

25. In teaching of acids-bases, I explore and use my students’ prior knowledge.

☐ Yes ☐ No

If yes, explain. ………………………………………………………………………. …………………………………………………………………………………………… ……………………………………………………………………………………………

If no, explain. ………………………………………………………………………… …………………………………………………………………………………………… …………………………………………………………………………………………

Appendix E: Interview Questions for Educators

Zulu (pseudonym).

1. Why is there not enough time to teach acid-base chemistry every year?
2. What is the difference between TCs (key ideas) and core or basic ideas?
3. Explain why threshold concepts of acid-base chemistry do not connect to other chemistry concepts?
4. Which teaching approaches connects threshold concepts to other related chemistry concepts?
5. What is the difference in teaching & learning TCs (key ideas) and core or basic ideas?
6. What makes mastering TCs by students become a key to understanding chemistry?
7. How would the introduction of teaching TCs of acid-base provide a foundation on which other concepts could be built?
8. What should change in the methods of students' learning chemistry?
9. What resources should be available in the department to support the teaching-learning of acid-bases?
10. What is the difference between TCs (key ideas) and core or basic ideas?
11. How do you identify the key or threshold concepts of Arrhenius, Bronsted-Lowry and Lewis acids-bases?
12. How does the identification of TCs of acid-base make the lecturer adequately prepared to teach?
13. How does the identification of TCs of acid-base and its relationship with other topics help improve students' learning?
14. What makes mastering TCs by students become a key to understanding chemistry?
15. What would make teaching TCs in chemistry to first-year students as a foundation course valuable?
16. What foundation does encountering TCs in chemistry lay?
17. Have been exposed or studied the theory of Threshold concepts?
18. Which teaching approaches connects threshold concepts to other related chemistry concepts?

19. Why are the students failing to cope with the pressure of work to study chemistry?

20. What changes in teaching-learning chemistry concepts do you anticipant?

21. What resources should be available in the department to support the teaching-learning of acid-bases?

22. What defines the department's standards if marks do not?

23. What is a community of learning? The interviewer explained the term CoP.

24. Why do you have to explore what the students already know in teaching acid-base to first-years?

Interview questions for Inonge (pseudonym)

1. Explain how acid-base chemistry is essential to a human body and in daily life?

2. What are core fundamental concepts in acid-base concepts?

3. Can you state these core fundamental concepts in acid-base concepts?

4. Describe how acid-base chemistry is a build up chemistry 5070 and 5124 of secondary school chemistry?

5. How would mastered threshold concepts of chemistry enable students to extend their knowledge outside the classroom and solidify a concept? What do you mean to solidify?

6. What new way of seeing and understanding of concepts which are brought about by teaching TCs?

7. Describe the engaging of students rather than talking to them by the lecturer when teaching TCs? Talk about students' learning methods when learning TCs of acid-base chemistry?

8. What role do teaching-learning resources play in teaching-learning of TCs of acid-base? Give examples of these resources?

9. How does the group website work and how do you create it?

10. How do compounds, atomic structure and chemical bonding related to TCs of acid-base?

11. Differentiate between basic, core and TCs concepts of acid-base chemistry?

12. Explain why not all students' thinking about a particular concept is transformed?

13. How do mastering a TC concept in chemistry makes a student to find new ways of solving a particular problem?

14. What will make TCs as a foundational course enable first-years see concepts in a new way and consolidate them?

15. What makes students to solidify concepts with much ease upon encountering TCs in chemistry?

16. In your opinion how can we sensitize educators in higher institutions of learning about TCs in their disciplines?

17. Discuss more on first-year students being treated as blank slates by lecturers?

18. When do failing a course is a student’s fault? When is a pedagogy used is he cause of failing of students?

19. State the type of performance that is useful as feed-back to students? How does it improve your teaching?

20. Why are you not sure of the department’s concern of lack of improved performance in students’ learning chemistry?

21. Explain why you have not answered the last 5 years performance in teaching of first-year chemistry students in the department?

22. How do marks reflect teaching and learning? You have just marked the first test, what is your reflection of the teaching-learning of first-year chemistry.

23. Are you part of the community of practice in chemistry department? What role does community of practice play in academic field?

24. What is prior knowledge in first-year chemistry? What is relationship between time of learning TCs and prior knowledge of students?

25. How do you explore your students’ prior knowledge of acid-base chemist

Interview questions for Hammonga

1. How does the teaching of TCs help students to master chemistry concepts?

2. What is the difference of being capable of teaching acid-base to first-year chemistry students and being knowledgeable of concepts?

3. Which TCs of acids-bases chemistry should be introduced in chemistry teaching and learning?

4. How are you assessing your students since there is little experimental training?

5. What do you mean by “keen students” and what makes them keen?

6. What kind of resources should be available to support teaching and learning TCs of acid-base chemistry?

7. How do mastered TCs logically enable students to do well in chemistry?
8. What is the difference between key ideas and core or basic ideas?
9. How do we reinforce a community of practice as chemistry lecturers?
10. How can you help to identify the key ideas?
11. Should TCs in chemistry be taught to first-year students as a foundation course in learning chemistry?
12. What role do TCs play in accessing other concepts in chemistry teaching and learning?
13. Why is it that when a student fails general chemistry it is not your fault?
14. As a department, what did you do to improve performance in students' learning of chemistry?
15. What has caused improvement in teaching and learning of first-year chemistry?
16. Explain why it is not applicable?
17. Suggest the day and time we can learn from each other the theories of TCs, community of practice, and theories of learning environment?
18. What role does prior knowledge play in mastering TCs concepts?
19. Why do you not have time for exploring students' acids-bases prior knowledge?

Chanda's interview questions

1. What is the difference between threshold concepts (key ideas) and core or basic concepts?
2. How does the identification of TCs of acid-base and its relationship with other topics help improve students' learning?
3. What resources should be available to support the teaching-learning TCs of acid-base chemistry?
4. What makes mastering TCs by students become a key to understanding chemistry?
5. What would make teaching TCs in chemistry to first-year students as a foundation course valuable?
6. Explain what makes acid-base chemistry as a foundational topic in first-year chemistry course?

7. How does the teaching of TCs of acid-base connect to other related topics in chemistry?
8. How do TCs of chemistry form a basis for a wider comprehension of chemistry?
9. How would the introduction of TCs of acid-base in chemistry teaching-learning give a firm foundation in the general chemistry course?
10. How can you teach acid-base chemistry as a stand-alone topic without identifying key ideas?
11. How should the TCs of acid-base be presented to students to improve their marks?
12. How should the TCs of acid-base be presented to students make a significant difference in students' learning of chemistry?
13. What is the student’s attitude to learning of chemistry which causes the student to fail the course?
14. How can the lecturer contribute to the failure of the student?
15. How is the learning environment of chemistry related to first-year students’ learning?
16. How do prior knowledge influence students’ rate of mastering TCs in chemistry?
17. How do you explore and use students’ prior knowledge?
18. Who do you like to learn more about how to explore and use students' prior knowledge of acid-base?
19. Who would you like to have a CoP introduced?

Aka’s interview questions

1. What is the difference between threshold concepts (key ideas) and core or basic concepts?
2. Have ever experienced difficulties in teaching TC of acid-base to first-year students?
3. Which difficulties?
4. What have you done about it?
5. Which other concepts in the course out-line is linked to key ideas of acid-base?
6. How are you teaching your students to master TCs of acid-base?
7. How do mastering TCs of acid-base help students master chemistry course?

8. Which higher related chemistry concepts does learning TCs of acid-base prepare students for?
9. Describe teaching and learning methods that will facilitate mastering of TCs theoretically?
10. What resources should be available to support the teaching-learning TCs of acid-base chemistry?
11. In the absence of chemistry laboratory, what do you do to enhance learning of chemistry?
12. What would make them connect to other topics with acid-base in chemistry and which are these topics?
13. Explain how teaching chemistry using TCs adequately directs a lesson?
14. What role does confidence play in learning TCs in chemistry?
15. Suggest two threshold concepts from your acid-base chemistry that should be included in the foundation course?
16. Why it is that encountering TCs makes easier to learn other chemical concepts?
17. What makes you think that all educators are supposed to have done threshold concepts?
18. Which methods can be you use to facilitate learning in the absence of chemistry labs?
19. Which other factors can make students fail the chemistry course?
20. What have you done about these factors?
21. How often do you do this?
22. What can you do to meet the students' academic needs in a large class?
23. What made the students' pass rate increase last 5 years?
24. Explain how classroom environment reflects the standards of the school and not students' marks?
25. Why did you not have any learning community?
26. How do the correct prior knowledge of chemistry assist students to quickly understand new concepts?
27. How do students' backgrounds affect your exploration of their prior knowledge?

Appendix F: Sample of transcripts of the educators' questionnaires and interviews

Hamoonga (pseudonym).

Questionnaire		Face-to-Face Interview		Comments
Statement	Response	Question	Response	
1. I teach acids-bases in my first-year Chemistry classroom to my students.	Yes, not applicable.	Explain why it is not applicable?	We do not teach acid-base, it comes at the end of the term 3. The curriculum is bulk and there seems to be no time to complete the curriculum.	He teaches first-years acids-bases but the topic has not been taught, due to an overloaded curriculum. It is also scheduled at the end of term 3 which is the end of the academic year.
2. I have the knowledge and experience in teaching threshold concepts in Chemistry.	I am not a trained educator. I was a research chemist for 32 years before I started teaching chemistry. I have no knowledge of theories of learning.			He is not a trained educator. 32 years as a research chemist. Thus, he has no knowledge of learning theories.

3. Teaching threshold concepts in acids-bases means connecting key ideas to other related topics in Chemistry.	Yes, I have experienced a relationship of topics/ concepts for 40 years of working as a chemist.	What role do TCs play in accessing other concepts in chemistry teaching and learning?	Once TCs are taught or mastered, it becomes a platform to explain or clarify other related concepts. It makes life simpler.	He has the experience of related topics or concepts of acids-bases for 40 years as a chemist.
4. I am capable of teaching the concept of acid-base to first-year chemistry students.	Yes	Explain how capability and being knowledgeable of acids-bases are different?	Being knowledgeable is able to acquire knowledge and pass the examination but cannot explain to others. Untrained educators to be articulate-able to teach others. People must be taught how to teach because teaching is a skill.	He has the ability to teach acids-bases but he is an untrained educator. Teaching is a skill and people must be trained how to teach so that they are articulate.
5. Teaching TCs to students will help them to master chemistry concepts better.	Yes	How does the teaching of TCs help students to master chemistry	TCs form a foundation which students should have. It is basic information to start	TCs help students to master chemistry concepts. TCs form a

		concepts?	with. If not understand, nothing to go anyway.	foundation, are basic information and if not understood nothing can be done.
6. Introducing TCs of acid-base in chemistry teaching and learning is a good idea.	Yes	Which TCs of acid-base chemistry should be introduced in chemistry teaching and learning?	ChemicChemical bonding, atomic structure and stoichiometry. Then followed by acids-bases secondary TCs of Arrhenius, Bronsted-Lowry and Lewis. TCs of Lewis are bonding and atomic structure. Bronsted-Lowry is dissociations of species, stoichiometry, equilibrium and acid-base constant.	Introducing TCs of acids-bases in chemistry is a good idea. Prerequisite knowledge of chemical bonding, atomic structure and stoichiometry be taught. Identified secondary TCs of acid-bases.
7. Teaching TCs requires changes in the lecturer's methods of teaching and students' learning methods.	No, I have no training in teaching methods of learning. I teach students and try to clarify where they			No training in teaching-learning methods. He tries to clarify where students have difficulties as he

	had difficulties as I go along.			teaches.
8. I have sufficient resources to support teaching and learning of TCs of acid-base in chemistry.	No, CBU does not provide anything beyond a whiteboard marker and board. You use textbooks you download from the internet.	What kind of resources should be available to support teaching and learning TCs of acid-base chemistry?	Students should have minimum resources: (i) stipend so that they are not hungry or worried about food; (ii) space to study without disturbance; (iii) books, PC or tablet, internet or phone which are working well and can access the information; (iv) university must be organised	He is dissatisfied, he is provided with only white-board and marker. His textbooks are downloaded. Students need stipend, space to study, books, PC or tablet, textbooks. Internet and phone. Above all an organised university.
9. I have adequate knowledge and skills to support struggling students in learning TCs of acid-base in chemistry.	Yes, I have a good lot of experience to intuitively help students who are keen to learn.	What do you mean by "keen students" and what makes them keen?	Keen students have an interest and when they do not understand they make an effort to get clarification. They do not overlook an opportunity to learn something. They take personal responsibility, knowing they have	He has good experience but, intuitively to help keen students. Keen students are Interested, make an effort to get clarification, seize an opportunity to learn and take personal responsibility.

			to be assessed.	
10. Identifying TCs of acid-base and its relationships with other chemistry topics can help improve students' performances in chemistry.	No, I do not understand the question if there is one here.	How can you help to identify the key ideas?	I ask students to bring out the key ideas by giving a problem or question to search out ideas. They will understand by giving the correct answer.	He did not understand the question so I had to explain during the interview. He has asked a question or problem to the student to research, students will bring out key ideas by giving a correct answer.
11. I feel inadequately prepared to teach the nature of acid-base without identifying the key ideas (TCs).	No, I know the key ideas.	What is the difference between key, core and basic ideas?		He feels adequately prepared without identifying key ideas because he knows the key ideas as a chemist for 32 years.
12. Teaching and learning of threshold concepts in Chemistry do not always improve students' marks.	No, TCs are key ideas of the topic of acid-base teaching. It is the logical way of teaching the topic and related			Teaching-learning of TCs in chemistry always improve students' marks because TCs are key

	concepts like chemical equilibrium.			ideas, is a logical way of teaching the topic and related concepts like chemical equilibrium.
13. A student who masters the threshold concepts in Chemistry is most likely to do well in Chemistry.	Yes, s/he has learned how to logically deal with the learning materials of acid-base.	How do mastered TCs logically enable students to do well in chemistry?	What is that you want to explain, to explain and continuity in the ideas, find a gap and fill it, it is not religion. I~~i~~t is easy to learn once the links are shown.	Learns how to logically deal with learning materials of acids-bases. Continuity in ideas, find a gap, easy to teach because links are shown, TCs should not be perceived as a religion.
14. Threshold concepts in Chemistry should be taught to first-year students as a foundation course in learning Chemistry.	Yes, I have no other theories of teaching students than following those outlined in standard textbooks.	Should TCs in chemistry be taught to first-year students as a foundation course in learning chemistry?	It is precedent by basic ideas are put in a foundation so that it does not become a religion.	He has no theories of teaching than those outlined in standard textbooks. These are precedent ideas which are followed by basic ideas. They are the foundation but

				not to be followed like a religion.
15. Encountering threshold concepts before accessing other concepts in Chemistry teaching and learning can make such a significant difference in students' learning of Chemistry.	No, I do not understand this question because I am not a professional educator.	What role do TCs play in accessing other concepts in chemistry teaching and learning?	Once mastered it becomes a platform to explain/clarify other concepts. Makes life simpler.	Unfamiliar with experiencing TCs, not a professional educator. Mastered TCs is a platform to other concepts, makes life easier.
16. Educators in higher institutions of learning are knowledgeable of threshold concepts in their disciplines.	Yes, they intuitively master key concepts although their quality of teaching can be improved in universities had professional science educators to give training workshops when lecturers are not professional science educators.			Educators are knowledgeable of TCs. They intuitively master key concepts. Their quality of teaching can be improved if educators are given training workshops by professional science educators.
17. Teaching threshold concepts requires changes in the lecturer's	No, I do not have experience in science education to competently			Do not have experience in science education. This will be

teaching practice.	answer this question.			sorted out during professional staff workshop.
18. If a student fails my Chemistry course, it is her/his problem (fault).	Yes, general chemistry is a simple course for students who have no serious social problems and are hardworking students. Students with social problems should withdraw until they are sure to pass the course.	Why is it that when a student fails general chemistry it is not your fault?	Examinations are set in such a way to make them pass and not to fail. It is based on what they learned. They all are qualified to study chemistry, they only have to be disciplined.	Student's fault because: the course is simple. A student with no serious social problems and hardworking can learn. Those with serious social problems should withdraw until they are ready to learn. Exams are set to make them pass, not to make them fail, based on what they learned, all students are qualified, they should be disciplined.
19. I use the student's performance information to improve my	Yes, performance alerts me and the students that are not working, optionally because	What do you mean by “keen students” and what makes them keen?	Keen students have the interest and when they do not understand they make an effort to	Performance alerts lecturer and students that they are failing, who are not working,

teaching.	they are failing. The concerned students should receive my help if s/he seeks it.		get clarification and do not overlook an opportunity to learn something. They take personal responsibility, knowing they have to be assessed.	and student should seek help. keen students take interest in their studies, get clarification when they not understood, seize opportunities to learn, take personal responsibility.
20. My department is concerned about the lack of improved performance in students' learning of Chemistry.	Yes, we are there as a department to help students in their professional training.			Department is concerned to help students.
21. The last 5 years have seen no improvement in the teaching of first-year Chemistry students in my department/school.	No, we have seen improvement but much more is needed because we have no practical chemistry teaching facilities.	As a department, what did you do to improve performance in students' learning of chemistry?	Not improved in teaching chemistry. Teaching chemistry has two parts: (i) Theory; (ii) practical. It depends on where you are learning, the ratios are 60% theory and 40% practical. There are no facilities for	Last 5 years, the department has seen improvement in teaching and learning of first-year chemistry. Teaching has not improved in the following: 2 hours of chemistry practical per term

			practical and usually, they have 2 hours every term. They are supposed to do chemistry practical of 2 hours per week. Ministry of education must start supporting higher education. We require tutors and demonstrators, i.e. graduate students to tutor and demonstrate to undergraduates.	instead of 2 hours per week. No practical facilities. MoE to support higher education and graduate students to be tutors to demonstrate for undergraduates.
22. Students' assessment (marks) often reflects the standard of the School of Mathematics and Natural Sciences.	No, we have no experimental training facilities in CBU.	How do you assess students since there is little experimental training?	Examinations are set in such a way to make them pass and not to fail. It is based on what they learned. They all are qualified to study chemistry, they only have to be disciplined.	There are no experimental training facilities, so marks do not reflect school standards. The exam is based on what they learned, All qualified to study chemistry but needs to be disciplined.
23. Lecturers' learning communities	No, see above.	How do we reinforce a community of	Require space where chemists can meet i.e. a common	No meeting space to run colloquia and seminars. So,

(community of practice) are available in my department/university.		practice as chemistry lecturers?	room where to run colloquia and seminars. This will develop a culture of asking and listening to others who know more.	a culture of asking and listening to more knowledgeable other is not there.
24. The time taken by students to learn threshold concepts in Chemistry may be influenced by prior knowledge of the concept.	Yes, students who have ‘A’ levels in pure science programmes do better in general chemistry.	What role do good prior knowledge play in mastering TCs concepts?	Students with good foundation do better; they don’t play when they are in university than O’level students. They are aware that they can fail. O'level students are excited to be at the university.	Students with A’ levels in pure science and good background do better. They are not excited about being at university, don't play and are aware of failing. O’level students are not.
25. In the teaching of acids-bases, I explore and use my students' prior knowledge.	I do not have time for this. However, where there is a glaring lack of knowledge, the reason students have been failing to handle the previous two terms' work since acids and	Why do not you have time for exploring students’ acid-base prior knowledge?	They are too many, there are close to 400 students in a class. Sometimes there are 2 classes in one. There are no individual staff offices where they can visit you and no classroom to	He has no time to explore students' prior knowledge. Glaring lack of knowledge is due to students' failure to handle the previous two terms' working i.e. avoiding

bases are taught during the third term. Usually, the student will have been avoiding assignments by him/herself and will have already failed two tests. There is very little one can do for such a student where there are no genuine tutorial facilities (that is empowered tutors who have material rooms and office rooms dealing with small groups of students who can have access to individual attention of the tutor).	give tutorial.	assignments and failed two tests. There are no genuine tutorial facilities. There are 400 students in a class which is a large number. It is two classes in one class. There are no separate staff offices for lecturers where students can visit and no tutorial classrooms.

Appendix G: Sample of classroom observation instrument

Group: Educator's Name:

Date: Time:

Topic:

Classroom Overview	Lecturer Activity	Student Activity
The culture and the context in which teaching-learning is taking place.	1. Subjected or task-based approach; 2. Student-centred approach; 3. Teacher-centred approach to teaching acids-bases reactions.	1. Working at their own pace; 2. Asking questions; 3. Following and solving tasks given; 4. Responding to lecturer's questions, 5. Passively receiving the information.
Resources.	1. Employ PowerPoint; 2. Computer Simulations; 3. Co-teaching with MKO students.	1. Students Individually interacting with the lecturer; 2. How students are interacting with the TCs of acids-bases; 3. Students working in

		pairs or groups or individually; 4. Student generated demonstrations of solving tasks.
Objective of the lesson.	1. Complete the topic; 2. Mastering of threshold concepts by students.	1. Master TCs of acids-bases; 2. Succeed in chemistry; 3. Quit the course

Formulated by the researcher (2019)

Appendix H: Post-classroom conversations

Chanda's video discussion

Researcher: Alright, watch the video clip and see somewhere were you defined in three different ways. You defined water as an acid, as a base using three theories.

Chanda: Yes, water was defined as an acid and at the same time as a base because it has a unique property of behaving in both ways depending on what you are exposing water to it will behave as an acid or base. And we can clearly see water, picture it in all the three definitions that I have outlined. We can see water as an Arrhenius acid because it is able to give a proton and the OH- and SO in that sense it is producing protons in water, so it is Arrhenius acid. At the same time, we can view it as a base because when you put it in water it is also producing OH- ions. So that is how H2O has this property of amphoteric or amphoteric, it can balance either way. So the students needed to see also that we are able to see H2O in all these 3 definitions.

Researcher: Did you mention water to be a weak base and a weak acid? Were there any problems with students to understand these definitions, to move from Arrhenius, to Bronsted-Lorry and Lewis?

Chanda: I didn't note any particular challenges with students with regard to water of being defined as acid and a base in all these three. Unless, if there were people who just couldn't show it out to me. But therefor seem to understand because of the nature of H2O. It's a solvent that can also participate in reaction and produce ions so in that sense it helped them to understand its dual nature.

Researcher: Back to the conjugate base and acid, what are the challenges in teaching these concepts?

Chanda: Well, I particularly have had no challenges in teaching these concepts except that I have noted that it is a little bit confusing to students to understand which one is a conjugate base and which one is a conjugate acid especially when it comes to acids to identify a conjugate pair in a chemical reaction. The confusion comes in when they start viewing the reactants as primarily the conjugates. But the emphasis that I have given them is that the reactants are the ones that produces conjugate acids and bases which will be connected to them because they are produced from these reactants. When they understand that it becomes easier for them to understand the concept of conjugation. In conjugation, we are simply joining reactants to products in pairs. We are saying here is an acid when it undergoes this reaction what is coming out of this acid, it releases a proton and when it releases a proton what does it remain to be? What remains to be is what we refer to as a conjugate base. Conjugate base in the sense that it is attached to the acid where it come from. So that is the way when they put that concept it is easy for them.

Researcher: Still weak acids and bases. How were the students interacting with each other and with the concept?

Chanda: I think things where made easier for them since we had already covered that part of the concept in the first part of chemical equilibrium. Because in chemical equilibrium we talked about acid dissociation, base dissociation and we were forming equilibrium reactions that are able to go in either direction, reversible reactions we dealt with that. So when we came to weak acids and bases it was easier now to connect this concept of acid and base to concept of reversibility, where we tell them that what we were teaching about reversibility of reactions is what now happens in weak acids and bases. A weak acid is able to ionize in one direction and then those ions are able to join back and form acid molecule, because they are coming from the 1st part. It appeared at least twice as far as I could observe that was easier for them to understand. The fact that we always associate weak acids and bases with equilibrium, where we deal with equilibrium constant to show the extent of ionization.

Researcher: As you were in front of explaining on acid-base reactions and one of them is equilibrium constant, I see others are listening attentively, others are writing, others are calculating, others are talking, others are standing. I think a good no.

Chanda: I think the reactors in there totally can't be the same because there are different levels of understanding of the concept. Some want to make sure that they take note of certain points they feel that they must not miss, while others want to listen more just writing in order for them to at least assimilate the concept that is going on. So they can explain of different reactions going in class.

Researcher: What are the different levels?

Chanda: It boils down to their abilities in the way they understand these things, give the same opportunity. So, it is in that sense that there are some that are quick to grasp the concept and those are the ones who usually want to pay more attention to listening than writing. And those who want to give themselves more time on the concept tend to concentrate on writing so that they can revisit that later on.

Researcher: What about those standing, it is also because of large numbers?

Chanda: Of cause, the room is not adequate for the number in this lecture, so they have to stand because they couldn't find seats to sit on.

Researcher: How do you manage students when you are teaching these concepts of equilibrium of acids and bases because they are different levels?

Chanda: I am able to keep eye contact with them. I am able to see what reactions are coming from them because of different levels of understanding or perceptions of concepts. So, it is a matter of being more sensitive to reactions that are coming from them as you teach. Sometimes, it will come from humming, it tells me that something is not clear to them. They tend to slow down in that particular part to give chance to others and even ask if they have any challenges on that particular part.

Researcher: How is the student's reaction to the calculations of concentration? But where theyable to?

Chanda: I think they were able to understand it especially those who have the consistency of attending class from the beginning when they understand the concept of H2 ions as the major chemical species in this topic. It becomes easier for them to connect that to ion concentration to pH because we are now telling them that we are finding a common way of expressing how much of this H2 is in this solution of acid or indeed in a base if we apply the concept of ionization there to determine also the concentration of OH- ions. When they clearly understand attachment of H2 ion concentration in H2O or acidity of that water, they are going to express that acidity in form of pH which is just a mathematical way of expressing how acidic this solution is. So we translate that concentration in to some value. At pH they didn't seem to have major challenges on that one.

Researcher: Why?

Chanda: Because of where we are coming from because we so much emphasize on H+ ion concentration when we just began with definition as you saw on the first and second definitions on the Arrhenius and Bronsted- Lorry. We so much talked about ions, so when we come to the point of pH we are now H+ telling them that the same H+ ion that we are taking about we now want to give a measure of its abundance in solution and that measure is what we are calling pH. So it becomes easier that way.

Researcher: Thank you very much.

Inonge's video discussion.

Interviewer: Welcome madam, can we just watch the first lesson? The first lesson was on the definitions and one of the definitions are Bronsted-Lowry acid-base. It is about donating and receiving a proton. Now my question is when you looked at the equation you wrote down you asked the students to identifying the one which was donating the proton, why?

Inonge: It arises from how Bronsted-Lowry defined what an acid is and what a base is.
Before I answer that, I started by asking students how they would define an acid from an ordinary level point of view and the definitions that were given were those of Arrhenius where he defined an acid as a substance that dissolves in water and produces hydrogen ions as the only positively charged ions but when we came to our lesson here our focus was on how Bronsted-Lowry defined what an acid and base are. And actually, before we started looking at that we had to identify what we mean by saying a proton, what exactly does it involve when we say you are a proton and we identified a proton as the hydrogen ions. Therefore that equation which was written on the board was to identify which one was donating and which one was accepting was befitting to be used because it enabled, opened up their dimension of thinking in the sense that one was actually donating with the definition that we had of Bronsted-Lowry helped us to identify which one was donating the hydrogen and which one was accepting the hydrogen ion. The one which was donating was qualified to be an acid and the one that was accepting qualified to be a base.

Interviewer: Ok, thank you. But do they understand why one is donating and one is receiving?

Inonge: Well, I don't think we went into those details for them we ended with what it means to donate and to receive and we didn't go into the aspects of why it donated and why it received.

Interviewer: Welcome to the conjugate base and base, which one is stronger? That was the question. Are there any challenges with mastering or learning of conjugates base or acid or base?

Inonge: Ok, with my group I don't expect them to have challenges on such question. Why? What we did first was we defined as a base is, and what we mean when we say conjugate base this is everything that remains after an acid donates a proton. Therefore, for them when we come to the concept of which one is stronger between a conjugate base and the base itself students wouldn't find it a problem because we had to qualify which one will be stronger. We said conjugate base of a strong acid is a weak base. So, basically, I don't expect them to have problems in answering or identifying such a particular question. Students understand it from a fact that we had to highlight which one is a strong acid and why it is a strong acid and how it becomes a strong acid and that qualifies them to have weak conjugate bases because of them being strong acids.

Interviewer: How are you experiencing teaching them?

Inonge: I find it interesting because I reached a point where they had to actually explain the concepts in their own ways, where they will ask questions based on what we were learning and not from far-fetched questions outside the topic. And I think that showed that they have direction that they are following. I think they are. I am finding it very interesting.

Interviewer: Let us watch lesson 2. Second lesson: weak acid and a strong base, strong acid, weak acid. As you were explaining these concepts you noticed that someone was not understanding. How did you noticed that she is not understanding? What were the visible indications that she was not understanding?

Inonge: What it is, is this, I am one kind of a person who interact with my learners very much and you can see from questions that they have understood, or they not understood. For me if they have understood they will ask me questions based on what we have learnt. But in a class where they all look surprised their gesture show even when they don't ask a question. You can see that my learners have lagged behind because there is a way in which they interact when they have understood. So, I was able to detect that part of equilibrium constant and the ionisation, dissociation constant that they have found a challenge in the sense that when we tried to explain the things together they were lost and this gave me an indication that there is a gap somewhere. So, we had to go a bit back and understand it from where the gap was noticed.

Interviewer: How would you have taught better this equilibrium dissociation constant concept?

Inonge: Ok, this concept of equilibrium dissociation constant, I think it could have been taught better by letting the learners firstly by exploring it on their own such as when they come to class they like ladders and we are just going to stuck in the gaps where they are lagging behind because like this I just went to class without them having the ladder. So, it was difficult to stick in the gaps of the ladders, why? Because they had missed a point from where I was explaining. I think I should first let them explore it on their own. Then, we come to class to cement everything.

Interviewer: In one of the videos I noticed you said 'can you be in pairs and start thinking?' What are you trying to do?

Inonge: There I am trying to expose them to think in pairs. Why? Because like that itwill be easier for them to interact with each other probably if one side of the pair understood they will be able to explain in a better way to the other person, probably even in the language that they use in the day today life rather than me explaining to them. So, they will get the concept easier, better and faster if they get it from the others.

Interviewer: Can you give an example of that question you gave them?

Inonge: I think I gave them to write the description of the dissociation for water where water is amphoteric and then we try to write the dissociation equilibrium of water. That is the question I gave them to describe in terms of letters and elements how they are going to end up with the equilibrium dissociation constant.

Interviewer: Why do you think the students are finding the equilibrium, the titration challenging?

Inonge: When we first started it was like Greek to them and found it to be very challenging, very, very challenging but with time and more examples, helping them to go to the board explain the concept, find, and calculate. I think that has helped for them to gain more confidence and today I can testify to that they are at all different level.

Interviewer: Madam, I have watched your last lesson where you are looking at solutions, the pH, ionisations, concentrations, and I think even the mole concentrations are there which is actually the concentrations, From that observation the students who are calculating and the others that are following or watching they seem to know what they are doing or to have mastered the concepts. Is it so?

Inonge: Yes, in the sense that they were able to articulate and make the information flow nicely on how the solutions dissociates, how you come up with the equations of a particular solution, how you plug in the figures. I think this gives me satisfaction because they able to connect to what they learned in the previous lecture and what they are about to learn now. Like I said earlier, when I come in as a lecturer, I will just help them to iron out the misconceptions that they might be facing,

Interviewer: Well did you come across any misconceptions?

Inonge: Oh yes. Like in the, it may not be necessarily be this one but in the calculation of the ICE table and the formulation of the data in the ICE table, where they were getting the initial concentration of hydrogen to be that of the concentration of the weak acid. So, when explaining I came in to actually help them to say that the hydrogen is not actually there in the beginning. We only get hydrogen ions at the end of the reaction

Interviewer: In short, you are looking at prior knowledge, knowledge from secondary school.

Inonge: Yes, but not really the knowledge from the previous lecture that they had.

Interviewer: But what makes them fail chemistry?

Inonge: I think what makes them fail chemistry for me is lack of practice. They run to what is coming and they are forgetting ironing out the little little problems that they face, forgetting that for me to understand this particular concept which have come they need to understand e.g. how the elements combine, the combination of elements and chemical formula. So, I think they overlook that as a result they find these things very difficult because they have that gap at the back of their minds.

Interviewer: How do you fill in the gap?

Inonge: Ok, it is difficult for me as a lecturer to fill in the gap. Why? Because they should have had this background in secondary school so when they come here this concept seems very difficult. Reason being to say they have missed that particular concept. So what I do like for my classes I advise them to get back to that and then start a new page on looking at symbols, valence and combination of these elements which helps them in a way for one to stand in front like that they should be able to have confidence, they should be able to communicate wisely, they should be able to understand the concept. If they do not understand the concept it is difficult actually for them to explain it to another person. But when I ask them to go back to the valences, symbols chemical elements and all those things it really helps them and gives them confidence.

Interviewer: What could have been done better apart from what is happening in the classroom where they just come?

Inonge: Yes, what could have been done better actually as they are talking about the pH, talking about the dissociation we actually practice these in the laboratory because when we practice that in the laboratory it enhances their understanding of these particular concepts rather than just talking about ions, dissociations, pH and everything else. As for me, it is ok but if we had a laboratory on these things it will actually help them to cement the concepts.

Interviewer: So I will take you back to 350 students each one comes with his/her background advanced level, ordinary level, physical science and chemistry. Are you finding challenges because they are at different points?

Inonge: Yes, some of them of about 5% have advanced level chemistry, ordinary level, have physical science, chemistry and most of them combined science. I am finding it as a challenge because others will understand the concepts within a brink of an eye, others will understand, it will take me time to actually rip the concept apart for them to understand that concept. So, it is a big challenge for me that is why in my group I have divided them in groups and in those groups it is in those groups where they take their challenges and the gifted students will be able to explain it at that level where I probably fail to reach. They are like my co-lecturers helping their friends who are not at that level.

Interviewer: Gifted students? What do you mean?

Inonge: They understand things faster, clear than the others before the others understand because some of them may come to class and get confused. So, what I do is every time I give them 5 minutes to present a lesson on what we are going to look at and I make sure it rotates if this week is one candidate of a group next week it is the other so everybody has a feel of how the concepts are flowing.

Interviewer: The students' learning of acid-base reactions, I have come back to the reactions of acid and bases whether they are weak or strong we have neutralisation, the pH and titration. How are they reacting to or learning the concepts?

Inonge: They are learning them just in class. As for me I feel it is not sufficient because you know when we talk about these neutralisation reactions, all those things we need to actually show the students what is actually happening. Therefore, my recommendations on how these guys should learn we may not have sufficient equipment in the laboratory but I am working so hard so that my students and I can go on All laboratories and do these virtual laboratories online which can help them to a certain extent but they are not 100% because they are not really touching the apparatus they need to manipulate these apparatus, they need actually calculate by seeing what is happening in the reaction. Because if we just talk about these things in class and everything, immediately they go outside the class they forgot about these concepts. So, I feel these things should trickle down to practice.

Interviewer: You mentioned a little bit in the first lesson that you are able to tell from the expression on the face. What other emotions are expressed in class especially when you are teaching difficult concepts?

Inonge: Some of them the expressions cannot be on the face or on their body like when I ask them to pair up. You find that in their pair they are struggling they don't really know what is happening; they don't really know what is going on in class so, I take time actually to sample through the pairs look at what they are actually doing and I find that they are actually lost. I take them back to what we were doing and bring them back into the lesson and incorporate them. That really shows me to say really, they were behind now we have brought them back into the lesson.

Interviewer: You have just completed teaching acid-base although you have not given a test. Have you made them master what you are going through?

Inonge: Not yet given a test. I don't know if I can call them mastering or have taken them into mastering everything. What I have done are tutorial questions that they practice them on and me I would love learner who are capable of extending what they have been learning to their real-life situation. I have asked them to come up with everyday use of acids. So, that will help them and bases to master even before I give a test they come up with all sorts of projects, little things so that they show that they are actually practicing what they are learning in class.

Interviewer: Can you give an example of real-life situations of acid-base reaction, buffer solutions and of all that stuff?

Inonge: I will give an example of agriculture we sometimes go out in the fields get some soil samples bring it to the lab and test it if we find that our solution is acidic, we actually have to look for a base to neutralise that particular acid. Therefore, I have asked them to say that we us these acids in our day to day lives, we use these bases in our day to day lives. So, come up with a project that can actually balance the two so that we can have a neutral ground on anything that we face or encounter in our day to day lives. I can also give you another example of things that we use in our day to day lives milko magnesium, a lot of girls are now using it as a prima on their faces so I want them to understand it from a point of what does it has in there which is basic which helps them not to sweat when they apply. So, those are things which I want them to explore.

Interviewer: Have they been in the village before?

Inonge: I think some I don’t know.

Interviewer: Where are the acids and bases used in the traditional set up?

Inonge: Some of them said yes. They use the ashes to actually kill the scent in the toilet. So, all these things they are saying they are going to corporate them how I don’t know. They are still doing this project probably can come up with a good project.

Interviewer: Thank you very much. We hop the results will improve this year.

Inonge: Definitely.

Appendix I: Threshold Concepts of acids-bases among First-Year Chemistry Students

Students' Focus-group Interview Questions

Preamble

My motivation for conducting this study is to explore why first-year students' failure and dropout rates in general chemistry are very high and try to find a remediation. The acids-bases chemistry has been chosen because it is cardinal to many chemical reactions in chemistry and it is one of the threshold concepts (TCs) in chemistry (Timofte , 2015; Furió-Más, Calatayud, Guisasola & Furió-Gómez, 2012). It is also a topic which most students experience difficulties. Chemistry is a prerequisite to other natural sciences and science careers. The researcher hopes to find remediation for first-year chemistry high dropout rate by exploring the learning environment. The learning environment has been chosen because it makes visible how lecturers interact with students and with the acid-base curriculum; students' interaction with lecturers, with the acid-base curriculum, and students' interaction among themselves.

Proposed questions for first-year acids-bases chemistry learning

Kindly answer the following questions to the best of your knowledge.

1. What was your ambition when you joined the School of Mathematics and Natural Sciences (SMNS) in this University?

2. State if, there is (are) any threshold concept (s) of acids-bases that dispirit you from studying chemistry?

3. Which of them is (are) the most difficult concept (s) of acids-bases? Explain why?

4. What factors led to your discouragement in the most difficult threshold concepts of acids-bases? Explain, please?

5. What do you think are the best practices for successful teaching and learning of TCs of acids-bases?

Appendix J: Sample of Students' Focus Scripts

First-Year Students Group Transcription of Volunteered Discussion

Group A

Interviewer: What were your goals when you came to the university?

Student (1): I want to study electrical engineering

Student (2): I want to study medicine. I want to major in cardiac surgery or neurosurgery.

Student (3): I want to major in mathematics. I wanted pure mathematics

Interviewer: Why do you want to major in pure mathematics?

Student (3): I just love mathematics.

Interviewer: Why do you want to study electrical engineering?

Student (3): There is job markets.

Interviewer: Why do you want to be a cardiac or neurosurgeon?

Student (2): We need neurosurgeons and bring a change in the health sector especially in rural areas.

Student (4): I want to specialise in cancer

Interviewer: If you go into medicine for money there is no money.

Student (3): For me mathematics is within me. It is my desire. I would like to follow what I want to do. It is not the because of the job market. I love it, mathematics.

Interviewer: Why do you want to study pure mathematics?

Student (3): I think there are few mathematicians or those who have done mathematics. I want to encourage them even girls they can do mathematics, it is not just men. of course, I will contribute to the country economically to those who have done are very few. It is not just for me even women can do it.

Interviewer: You have been learning chemistry and you have just had a test how are you finding chemistry?

Student (M): We were told two days before to study for a test and this gave us the pressure. The information is overloaded, the pressure to study for a test within a short time but the test was fair.

Student (M): The duration period given to sit for test in chemistry is two hours, the time is too short and you know a lot of information but the time you are trying to deal with the questions you find that the time is over. In the end you find that you didn't finish answering all the questions and yet you knew all the questions. I think that is one of the factors that cause students to fail chemistry. The other factor is these other subjects like mathematics when they make, mark step by step but in chemistry there are some lecturers who have a tendency of only marking the final answer not step by step that one contributes to high rates of failing in chemistry.

Student (M2): In our teaching and learning from secondary school to university is different we learn to pass the exams and not to understand the theory aspect. It has become a very big challenge of putting the theories into practice because most of the time we just want to understand the theory as part of the lesson. The practical aspect is lacking so much, the interest is very low, memorise this constant, equation e.g. what happens when HCl reacts with sodium hydroxide, what happens when copper sulphate reacts, we are only taught a few compounds, we want to experience what we are learning. It is a very big challenge especially for me because I learn better when I see something and not just hearing. You learn on something and then you begin to research to learn on your own without experiencing it is very challenging.

Interviewer: You have brought out very good points of learning to pass and not learning to understand and the difference between secondary school and university learning.

Student (M1): Some of us as he said we understand better when we see what we are taught not just to be told that this happens but when we see that this happens that is when you can get much information and learn to apply and not for the exam. What we know is that we learn, understand and apply in our daily lives.

Student (M2): It is a big challenge that we are learning things without doing practical even at secondary school. Even the way we do practical is just for formalities because they are there. We don't do them so that we can know things. E.G. Lecturer's approach is based on theoretical, quantum mechanics is a course which is much in technology in some countries they put much emphasis on practical aspect but here when I asked them they were learning quantum physics when they were in the fourth year. It is a big problem when you are about to graduate that is when you learn a little bit of it.

Student (M): Secondary school acid-base is different from university we studied from Zudal textbook. Calculating the pH at secondary school we memorised the formula towards the end of the last term to pass the examination.

Interviewer: How did you learn during the lesson when the concept of acids and bases was introduced?

Student (M): I was not there when the topic was introduced because our lecturer changed the times of meeting to 1 hour from 6am to 7am in the morning and I couldn't make it. So, I read on my own. At first, I was understanding until I reached the pH, how you can calculate the pH of a weak and strong acid it is a challenge to me.

Student (M1): For me before I go for a lecture, I watch tutorial lessons from an academic YouTube it was easier to understand because I had already watched.

Student (M): Like in industries acids and bases are the ones that they use.

Student (M): In manufacturing industries acids and bases that are found in some of the fruits have weak acids where they manufacture beverages there is a real-life application of calculating of pH acid.

Student (M): In the making of soap is a base, to neutralise the acid on the skin you are able to remove the dirty on the skin. The other aspect is agriculture fertilizers composes of bases and acids, studying acids and bases we learn to maintain the pH of the soil.

Interviewer: What could you have done better in learning acids and bases?

Student (M): I missed the introduction of the topic it was simplest question that I faced. So, what I do better is to continue watching these tutorial videos, do read different books and consult my colleagues those who are better because there are different questions concerning acids and bases.

Interviewer: Who is offering these e-tutorials? Are you downloading them?

Student (M): We download them through YouTube. It takes 1 hour to watch

Interviewer: Do you require the resources for this? Are you using a computer, a tablet or a laptop?

Student (M): I am using my laptop and my data bundles because sometimes there is no internet or it is weak. The computers in the computer lab are too slow to download many things.

Interviewer: Apart from the internet you said you do not have chemistry experiments in short there is no laboratory work.

Student (M): Yes, but we have just been introduced to the labs but the time we started learning chemistry there were no labs.

Interviewer: There were no labs when you started, now they have been introduced. How many hours per week?

Students: 2 hours a week because we are meeting once a week.

Student (M): I am using my own laptop as well and my data bundles. Watch the tutorial videos and read the questions concerning acids-bases. I seek assistance from the lecturer where I don't understand. I also ask questions in the lesson for clarifications. On the average, I understand what I am taught. I ask friends and read more.

Student (M): I am using my smartphone to download tutorials and my own data bundles. The campus Wi-Fi is not active in the campus but can be accessed at certain positions mostly the main library you can access the Wi-Fi.

Interviewer: You mentioned the point of learning from more knowledgeable other. How do you learn?

Student (M): I study together with those who are doing better than me, are hardworking students and are focused. Cooperative learning help them to learn from you, techniques of how they learn and research their work. A few techniques can be helpful to you. Education is continuous I do not want to have limited information e.g. acids-bases secondary school, Arrhenius is limited but university level is higher than secondary.

Group F

Interviewer: What were goals when you came to the school of mathematics and natural sciences?

Student (M1): My goal was to impact my community and develop it. I first wanted to do civil engineering then I realised that Zambia is a developing country and need a lot of infrastructure development as a nation. So, I chose to come here that I may be able to impact my community and develop it as much as I am able to.

Student (M2): Initially my goal when I came here looking at the fact that health problems are becoming a challenge in Zambia so I decided to pursue medicine. Although I didn't make a direct entry onto school of medicine my aim is to be an 'A' student so that I can make it there.

Student (M3): My goal was to pursue electrical engineering, power electrical. As a country we have challenges in power supply and generation; and I feel there are other areas in which we can look into rather than depending on hydroelectric power. I feel I will do great in this field because I enjoy chemistry, physics and mathematics.

Interviewer: There is something that have come out from the speakers, the first one said Zambia is a developing country and if I do my civil engineering, I will develop my society my community not just at industrial level but where I am coming from, not just the national level but my community. Last one says there are so many avenues that you can look at.

Student (M4): I want to study chemical engineering.

Student (M5): Study medicine due to lack of doctors.

Student (F1): Electrical mechanical engineering because women are intimidated by certain course due to the fact that you are a woman. I thought maybe I can be an inspiration to other women.

Interviewer: You want to inspire other girls into studying electrical mechanical engineering. Specifically, secondary school or college, which ones do you want to inspire?

Student (F1): I feel everyone should be inspired

Interviewer: Which field of medicine do you want to specialise in?

Student (M1): Eye to save people's eyes and reduce the number of blind people in Zambia.

Student (M2): Neurosurgery

Student (M3): In the construction industry most of the companies engaged are foreigners is expensive. Infrastructure doesn't meet the demands of the growing population.

Interviewer: What is standing in between that is preventing you to achieve the goals? How have find chemistry?

Students (M): Chemistry is challenging though sometimes it is just fine for example the test that we wrote for the first term it wasn't so difficult to handle but due to the fact that our study criteria was that good some people were finding difficulties in chemistry but all in all the paper that we wrote wasn't all that difficult looking at the topics that we had done that term. It is just the way that we study chemistry that makes a lot of people not to do well in chemistry.

Student (M): On my part the reason why, people fail chemistry because we think it is not real For example, when we talk about an atom most of the people don't know what it is because we have not seen it. But if you student an opportunity to view what it is just like a general structure and what it is being talked about. I am sure they will love and enjoy chemistry and well in it.

Student (M): I just want to concur with him it is difficult because we are mainly dealing with molecules that we are not able to see with our eyes and so when somebody talks of octahedral structure it is difficult to imagine how an octahedral structure looks like. So, if we have been given an opportunity to virtualise as we are learning chemistry it will be very helpful to students.

Students (M): I wouldn't be surprised that many students fail chemistry because actually chemistry is the mother of sciences and all sciences come from chemistry. Normally what I have heard from the returning students at CBU is that chemistry is more theoretical, ever since we have been at CBU we have not done any practical. Some students have said that they have been doing some practical but not in laboratories as it is normally supposed to be. Universities or higher institutions of learning can make it more practical than it is theory if chemistry will be a walk over for the students because nothing is possible if we do well in these other subjects even in chemistry we can do well as well.

Student (M): Myself I also find chemistry a bit challenging because it is more theoretical than practical. If it was more practical it would be easy for us to understand.

Student (F): In high school we were taught different compared to how things are here at university level because at high school the teachers try by all means to use the methods to try and teach us but here at university if you don't understand you have to go and research for yourself and they don't really put in all the different techniques because not everyone will understand things just by teaching they also visualise actually go through it and experience it.

Student (M): General understanding of chemistry is based on the topic introduction to chemistry I think many people don't take that topic serious once you miss that topic introduction to chemistry then you will find problems in all topics in chemistry e.g. in the introduction to chemistry we cover simple things like atom, conversion of units, molecules, what an element is , something like that. So if you miss that I don't think you can be able to understand complex topics like thermochemistry.

Interviewer: What topics are in introduction to chemistry?

Student (M): The fundamental part of chemistry in our society, and also you get to know the basics of it like where every matter comes from, the properties so that is what is essential about it.

Interviewer: Where you are saying that it is the fundamental and basic, to me you are saying the introduction to chemistry is basic or foundational. When you miss introduction, it is difficult to understand other topics. Actually, this is what I am coming to. If you miss the basics it is difficult to learn other topics, it is like you are building on. Now based on the introduction of chemistry is like a key to another room. Key concepts when you don't understand them you can't enter another room. The door is closed. And one of the key concepts is acids and bases. You have told me that chemistry is abstract, and you want labs. How many labs do you have in a week?

Student (M): We have just received the notice that we will be having labs. The whole of first term we had no labs like chemical equilibrium, introduction to chemistry, atomic structure those we never had any lab work. As the guys has already allotted to and the way these topics are arranged, you cannot study chemical equilibrium before you look at stoichiometry, mole concept to be specific. The way these topics are brought it is not easy to understand them. It is better to start with something like it will be unlocking the other topic, you start with a higher topic and then you start coming back it is not helpful at all may be that is why we are facing a lot of challenges in chemistry.

Interviewer: How was chemistry taught? Somebody said differently.

Student (M): The difference she was talking about is the approach between the students and the teachers. The approach here is different from high school level; high school level is more like a personal relationship with the teacher, they try to make you understand if you are unable to, but here as long as they have done their part, they have explained even if you don't understand is none of their business. So what she was trying to put out is the approach as well matters despite not having labs there must be a better way of teaching us or lecturing us it will also make a difference.

Interviewer: How would you like the lecturer to make it more sensitive or visible although you can't see it?

Student (M): Since we have got projectors hooked up in every class perhaps as they lecturer they can show us clips or slides at least can help us visualise atoms and structures that they form.

Student (M): As for me, in secondary school, the one who used to take us in chemistry he used to bring out projectors and those videos he used to show us we could see what is happening inside. If we are talking about chemical reactions, we will see what was happening in the interactions of those atoms and that created an impact in us that even when he is lecturing there, we were capable of picturing what was actually taking there. If that can be applied to other students, there I think they can get the basic concepts of chemistry and understand it and easily apply it in everyday life and other stuffs.

Student (M): For example, when we are doing chemical bonding there is what is called the boiler stick molten that one we used to use it when doing organic chemistry in high school to show as structures such as how carbon atoms are bonded to hydrogen so if they can just use those things such as the bone stick molten to show how an octahedral or tetrahedral is it is very easy for someone to remember. So I think they should implement such things such as using models or visual aids will help learners understand.

Interviewer: What concepts are challenging in acids-bases?

Students (M): **C**hallenges comes in naming acids; it is hard to explain something if you cannot name it and the fact that we have already allotted to it that we need the basics in order to do well in these other topics that can head of us. Some people have missed the concept of naming molecules it can be a challenge.

Student (M): We have different types of acids and each acid reacts differently with a base so there is where the problem comes in. The other is naming those acids more when it comes to weak acids those are difficult to name and you find that it is having a structural formula which is something else and you are supposed to name it. That is why even in organic acid is difficult where you have this ester reacting with an alcohol producing the acid. So, it becomes a challenge because those acids are reacting and the products that they are forming after the reaction are different. You find that this time you have three products after they react the other time you have two products or sometimes one product, so it becomes confusing.

Student (M): Another confusing concept is alkali and bases, how to differentiate the two especially in high students have difficulties in differentiating the two. Even when using the terms interchangeably, they want to refer to a base they will call it an alkali when they want to refer to an insoluble base they still call it an alkali so there is a misconception there between the two concepts.

Student (M): When an acid reacts with a base there will be some products that are formed but now the chemical formulae of acids were quite challenging to master and for you to know the chemical formulae which will be formed you have to know at least reactivity series of metals as the acid and base react at the end there which metal will displace another metal.

Interviewer: He has mentioned the activity or reactivity series. You can see that chemistry is interrelated; topics are related to other topics. You cannot learn one topic in isolation.

Student (M): Concerning acids and bases is actually a very interested topic. Major challenges comes as my friend has said that we learned it in high school but some of the concepts weren't talked about e.g. where acids and bases are defined in three forms according to Arrhenius theory, Bronsted-Lowry theory and Lewis theory which we didn't in high school. it is a challenge now to balance and differentiate the three theories on the theory part. So, those are the challenges that come with understanding acids, bases and salts.

Student (M): As not so challenging per se but sometimes it is just the language that is used that confuses us i.e. you may know what to do but if you did not take certain precautions you might end up failing the question. For instance, you are given a weak base and you know that it doesn't completely dissociate, then they give you an ionisation percentage of may be 15.8 you know that the change there is not negligible because of the high percentage. But just because the question said it is a weak base you can neglect that meaning the question can end up being wrong. The topic is quite ok, but it needs you to take the note of the slightest information that you have been given.

Student (F): Where the challenge can come in is the comparisons as he said between high

school and university may be the understanding the differences, in high school it was more basic concepts, and the definitions were basic but here you have to add more information. You need to pay more extra attention to details.

Interviewer: Do you mind giving examples of concepts which are challenging apart from the ones that you have mentioned?

Students (M): So far one of the challenging concepts is the one that deals with the buffer solutions; I haven't fully understood that concept. The other concept could be relationships, it seems like there are too many interrelate topics the pH being related to the pOH, it being related to the water dissociation constant, the relations are too much that you may not fully understand which one you must use at a particular time. It is a much-related topic in terms all the topics are related and so differentiating them sometimes becomes a challenge.

Student (M): Dissociation of the acid when they are reacting you will find that e.g. it is not easy to differentiate a weak acid e.g. we have the dissociation of sulphuric acid, you know it has two hydrogen ions when it dissociates the first one is considered to be a weak acid and you are reacting it with water which is also a weak acid. You find that since water behaves as a weak acid and as well as a base, it is a challenge to find which one a very weak acid is between the dissociated H_2SO4 as well as the water since it is also an acid. Now, this water is giving a hydrogen ion and another hydrogen ion which is coming from the weak sulphuric acid, it is difficult to see which hydrogen you are going to use there.

Student (M): Clarity in the difference between those hydronium ions and hydrogen ion. When you are about to write the equilibrium constants equations; they prefer us writing hydrogen ions rather than hydronium ions which actually are the ones which are produced in the solutions. So, there I find it a little bit confusing.

Interviewer: Someone mentioned the teaching aspect. Sometimes, you fail to ask questions. What could the lecturers have done better?

Students (M): As for me they should just allow a minimum number of questions there are cases there might be a lot of question and if a lecturer has to answer each and every question the rate at which the lesson is meant to move will be minimised. The lecturer may not finfish a certain target that they have. May be a specific number of questions should be allowed.

Student (M): The main reason for us to learn in class is for us to understand so if we give a limitation to the lecturers we may still have questions to ask because the limit has been reached, we may not be able to ask those questions. So, in my opinion, lecturers should allow as many questions as possible so that we should understand. At the end of the day it is better to do a topic in a week and we understand than do two topics in a week and then we do not understand, hence forth leading to failure. So lecturers should allow us to ask questions if necessary so that we are able to understand they should even allow us to ask them questions.

Student (M2): Well much has been said about acids and bases, it is not really challenging per se but as the earlier speaker said that sometimes it is the language used that sometimes confuses us. For instance, you may know what to do but if you did not take certain precautions you may end up failing the question e.g. you are given a weak base and you know that it does not completely dissociate then they give you an ionisation percentage of 15.8 and you know that definitely it did not… the change there is negligible because of the high percentage. Just because the question said that it is a weak base you may end up being wrong. The topic is quite ok, but it needs you to take note of the slightest information that you have been given.

Student (F1): For me the topic is okay. I think where the challenge is may come is the comparison as he has said between university and high school. May be to understand better the differences it is more basic; the definitions and concepts were more basic but in university we have to add more on to that information. May be there is where there be a bit of a challenge and you have to pay a bit more or extra attention.

Student (M2): I think I will be at logger heads with the previous speaker because it would not make sense for me to allow the lecturer to go on because the limit of questions has been reached if the class has not understood. The main reason why we should be learning in class is for us to understand. So, if we give limitations to lecturers, we still have questions to ask since the limitation has been reached, we may not be able to ask those questions. So, in my own opinion lecturers should be allowed to ask as many questions as possible so that we understand at the end of the day. It is better we do a topic in a week and then we understand than do two topics in a week and then we do not understand. Hence forth, leading to failure. So, lecturers should allow us students to ask questions whenever it is possible to understand, and they even allow us to ask them questions.

Interviewer: Would you mind giving examples of concepts that are a bit challenging apart from the ones that you have mentioned?

Student (M2): In acids and bases so far one of the challenging concepts I think is the one that deals with buffer solutions. I have not fully understood that concept and the other concept could be the relationships. There are too many relationships. It is more like an interrelated topic. You find the pH being related to the pOH; it being related to the water dissociation constant. So, the relations are too much that you may not fully understand which one you might use at a particular time. So, it is a very related topic. All the concepts are related so differentiating sometimes becomes a challenge.

Student (M2): Acids and bases just from the start it is quite when it comes to limitations it is quite complicated. The Arrhenius definition is easy to know a challenge to differentiate the three definitions mostly when differentiating the Bronsted-Lowry and Lewis model the limitations is quite complicated. Arrhenius concept is easy to know the limitations but when it comes to Lewis part the limitations are not so clear. So when you look up in the prescribed books it is not clearly indicated like the limitations of Lewis base or acid in general a Lewis model. It is the same on the Bronsted-Lowry not as it is done on Arrhenius model. It is one of the challenging concepts we have.