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FIRST-YEAR UNIVERSITY STUDENTS' EXPERIENCES IN LEARNING THRESHOLD CONCEPTS OF ACIDS-BASES CHEMISTRY

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Abstract:

This paper interrogates the concept of threshold concepts (TCs) of acids-bases in the teaching and learning of general chemistry of first-year university students. Acids-bases chemistry has been identified by chemistry scholars worldwide as one of the threshold concepts (TCs) in chemistry that seems to be difficult and the culprit of most failures in chemistry. Acids-bases reactions are also central to learning of other chemical reactions within the discipline of chemistry and other science concepts in life sciences (biology) and physics. The paper is based on the challenges students experience in general chemistry, which tend to discourage students from studying chemistry or pursuing their studies in chemistry-oriented professions, such as medicine, engineering, agriculture, natural resources, and chemistry education; or responsible for students dropping out of the university education completely. To address this problem, we explored lecturers' and students' challenges that students experience in learning TCs of acids-bases chemistry and the students' perspectives of chemistry. A qualitative research methodology was employed in the study. Data was collected through classroom observations and student focus-group conversations. A thematic approach was employed to analyse data. Five chemistry educators and their classes were purposely sampled. Vygotsky's social cognitive development theory was used as a theoretical framework to understand the teaching-learning of acids-bases chemistry. Findings suggested that some students' experiences transformed them into self-directed learners. Researchers can investigate other avenues to the portal in teaching-learning TCs.

Keywords:

acids-bases, challenges, disciplinary threshold concepts, students' experiences

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1. Introduction

In all disciplines, there are concepts and learning experiences which are akin to passing through a portal (Meyer & Land, 2003). These are often known as threshold concepts (TCs) and are often the points at which students experience challenges. In the process of learning, students need to discard their prevailing ideas and assimilate new ones (Meyer & Land, 2003). The process could be troublesome in provoking new ways of thinking. In essence, acids-bases reactions are one of the threshold concepts in chemistry (Meyer & Land, 2003). Acids-bases chemistry is also one of the “gatekeeper” courses in science in all levels of education (Cooper & Pearson, 2012, p. 197). In one of our institutions, entry-level physics, chemistry, biology and mathematics subjects are studied by all first-year (freshmen) science students. Besides, the drop-out rate among first-year chemistry students at the researcher’s institution, is alarming. Dropout rates are much more in chemistry than in any science subject. 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.

Acids-bases reactions become important in learning other chemical reactions in chemistry discipline and in other science concepts such as biology, biochemistry and physics (Cooper et al., 2016). Despite acids-bases being one of the cornerstones of science, from secondary school through to graduate school, students have experienced challenges understanding and applying acids-bases theories. (Cooper et al., 2016). Acids-bases reactions further continue to present difficulties to university students in related courses such as biochemistry and organic chemistry.

This study explores the teaching-learning of acids-bases as TCs by chemistry educators and students at the university level. The first-year general chemistry course is a foundation for higher chemistry courses and other science programmes that consist of chemistry. Students do not have challenges with the definitions of Arrhenius, Bronsted-Lowry and Lewis acids-base models. (educators). The challenge is defining acids in the absence of protons being donated or hydroxide ions being produced and in terms of electrons that have been used to form bonds. Challenging concepts are the ones that deals with the buffer solutions, chemical formulae and equations, dissociations of acids and calculations to most freshmen in this study. Furthermore, the interconnectedness of acid-base chemistry concepts create a challenge to differentiate which concept a student should apply in the next step (educators and students). For example, dissociation of sulphuric acid with two hydrogen ions when it dissociates the first one is considered to be a weak acid and is reacting with water which is also a weak acid. It is a challenge to identify which one is a very weak acid between the dissociated sulphuric acid (HSO_4^-) and water. Freshmen are failing to determine pH of a weak acid and percentage ionisation. (Banda, educator). So, if they fail to master the concept of strong and weak acids dissociation and its chemical equations they cannot proceed to the calculations of pH and pOH. It is because they do not know which ion to substitute in calculations. If students think beyond what they have learned they could apply a concept built on first-year acids-bases and relate it to new ideas. Cousin (2006) claims that the TCs approach seeks to identify key concepts and mastering them would open students “to new ways of thinking” that leads to “transformative, irreversible and integrative” knowledge. In this study, the following questions were posed:

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

Research question 2. What are the perceptions of first-year educators of students' experience in learning threshold concepts of acids-bases reactions?

2. Related Literature Review

2.1 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. The 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.

2.3 Liminal Space

Liminal space is the "transition period between the moments in which students did not grasp a threshold concept and the moment of grasping the TC" (Timofte, 2015) as in the zone of proximal development (Vygotsky, 1978). The liminal space could be troublesome, confusing, and paralysing due to conflicts and configurations involved in constructing new meanings of complex concepts and identities. A liminal space is also where learners may oscillate between old and new understandings while training their minds to suspend what they previously believed. Students may also have to discard old knowledge to cope with the new threshold concept and integrate it cognitively (Batzli, 2016). It is also where some students seem to be "trapped" or "stuck", others spend a lot of time, others seem to pass through without challenges and still others never get into the liminal space. The students' different knowledge, ability and socio-culture that they bring to the classroom place them at different positions in the liminal. Positions, where the students seemed to be trapped, challenged and perplexed become "hot spots" for the process of negotiation and interpretation of TCs and learning (Batzli, 2016). The quest to explore and interpret is unique to each student which is driven by the desire to exit the liminal space.

3. Theoretical Frameworks

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, 1978). 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, 1978).

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, the potential level of development (ZPD) reached with the guidance of another's expertise and with the creation of a new ZPD from the learner's zone of far development (ZFD). ZFD is a space of insurmountable difficulty. Productive teaching-learning can occur within these levels (Mahn, 1999).

In this study, I used social cognitive development theory as a lens to see the flow of information from lecturer (educator) to students, from students to lecturer 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.

4. Methodology

A qualitative method was engaged in this study. Qualitative method is used to answer questions about experiences, meaning-makings and perspectives from the standpoint of the participants (Hammarberg, Kirkman, & De Lacey, 2016). So, action, case study, and phenomenology research methods were employed in this study. I engaged purposeful sampling techniques (Maxwell, 1996 cited in Taherdoost, 2016,). o identify the research context and participants. Research participants were provided with pseudonyms to protect their identities and location of study. Forty-seven (47) first-year chemistry students (participants) were grouped into six groups of participants ("A" to "F") for this study. There were thirteen (13) female and twenty-four (24) male students from five (5) groups in the study. Five (5) first-year chemistry educators also agreed to participate in this study. Ethics approval was granted by University of the Witwatersrand Research Ethics Committee (H 16/02/18). Informed consent was obtained from the participants. Qualitative methods were used to reveal problems in teaching and learning of acids-bases reactions which may lead to better learning and teaching.

4.1 Research design

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. The researcher sat in on each of the five (5) volunteered first-year educators' acids-bases reactions lessons. The videos captured interactions that would have been missed by just writing field notes. I also purposely sampled research participants who could illuminate the phenomena being studied. Further, data were collected from students' focus-group interviews. Questions were semi-structured but at times were asked based on the respondents' claims. The students discussed the challenges and causes of what they experienced in learning threshold concepts of acids-bases reactions. Students further discussed ways in which they individually and collectively responded to the challenges they experienced in learning TCs of acids-bases reactions. The conversations were video-recorded.

4.2 Data Analysis

Thematic analysis (Tanaka, Parkinson, Settel, & Tahiroglu, 2012) was guided by the research questions. Educators' post-classroom transcribed conversations created themes that were: students' participation, activities, educators' tasks, challenging concepts, different prior knowledge level, 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' different knowledge level, classroom interaction, and challenging concepts. Recoding data into categories was to enable a meaningful comparison of the subcategories Students' interview themes were finalised by combining them with classroom observation themes. Being lectured from 08.00 am to 04.00 pm, tutorials from 04.00 pm to 06.00 pm, abrupt changes in the timetable, lack of laboratory work, authoritative educators, too much information in one lecture, calculations, interrelated concepts, acid dissociation and students' confusion were themes generated. I drew comparisons across the group dynamics and individual students' statements. Subthemes emerged from this process which were: teaching strategies, pre-university learning culture, university learning culture and conceptually difficult. I defined and named the themes into two main themes of students' and educators' experiences. I also drew on direct quotes occurring within the participants' discussions. In this article, I focus on students' focus group interviews, educators' post-classroom observation conversations and classroom observations.

5. Results and Discussions

In this section, I report on the research findings from students' focus-group interviews and classroom observation. Each class was large, mixed-gendered, and had between three hundred (300) and fifty (50) students. The classroom environment is heterogeneous (upper, middle, working and lower classes) to which students must adapt. I engaged Vygotsky's social cognitive being a lens in explaining the dynamics of their classroom interactions and interrogated how these were impacted by being self-learners. The themes were grouped into six categories, which are interrelated and challenging concepts, teaching strategies, students' university experiences, students' learning culture, different knowledge levels and classroom interactions.

5.1 Challenging and Interrelated Concepts as observed by Educators and Students

Educators and students identified challenges in the understanding of calculating pH and pOH, acids-bases equilibrium. The theories of acids-bases (Arrhenius, Bronsted-Lowry and Lewis) are easy but how the bonding happens in the Lewis is difficult. Determining acid-base constants (Ka, Kb) of weak acids is very confusing to students as they did not know which ions must be ignored or are negligible, buffer solutions and chemical formulae of acids-bases. These concepts are referred to as threshold concepts (Land & Meyer, 2003, Cousin, 2006). Threshold concepts (TCs) are key ideas which are central to a discipline but may be difficult for most students to grasp. Furthermore, concepts within acids-bases chemistry are interrelated and also to other chemistry topics. Concentration is interrelated to pH which is inter-connected to pOH, pOH and pH are connected to concentration percentages. The pH and pOH are related to the water dissociation constant. Hence, students claimed that "the relations are too much that you may not fully understand which one you must use at a particular time". A student who fails to determine pH and Ka of an acid could likely not calculate concentration percentage. TCs 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). Dissociation of strong and weak acids are related to chemical bonding, chemical formulae and chemical equilibrium. Acids-bases reactions is related to chemical reactions, organic chemistry and thermochemistry. Dissociation of weak acids is an acid-base equilibrium that is based on chemical equilibrium. Students experienced challenges because they could not relate to chemical equilibrium, for example, a weak acid equilibrium which is ionising at equilibrium stage, has ionised and the concentration of ions have changed. Students were taking the concentration of the acid before and after ionisation to be the same. Students who have not yet internalised a TC may be learning new ideas in a fragmented way are apt to harbour misconceptions (Land & Meyer, 2003). These are the points at which some students seem to be stuck and fail to proceed to the next level. However, a student who has acquired a TC can transform her/his use of the ideas because she can integrate ideas into her/his thinking. Students must get TCs for the core disciplinary knowledge to make sense. 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 (Piaget, 1951).

5.2 Teaching Strategies as observed by first-year students

In large classroom, educators used "talk and chalk" and "PowerPoint". In addition, educators did not consider the students' socio-cultural, learning style and academic differences. Students 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. Hence, students felt bombarded by the course content instead of having concepts explained to them. Furthermore, educators' teaching was characterised by memorising "equations", "constants" and what happens when copper sulphate reacts! Students had been lectured to since entering the university. Instead, students preferred to visualise, go through the acids-bases reactions, and experience. Chemistry content was taught in abstract instead of hands-on, mind-on activities. Most of the teaching is done out of context. Students learn more by actively participating in learning experiences (Lave & Wenger, 1991). Situated learning creates meaning from the real activities of everyday life, where learning occurs relative to the teaching environment. Siyomba would prefer educators to teach the chemistry concepts "step by step" (known to unknown, simple to complex). Instead, the educator went "straight into details at a speed" so that students found themselves "left behind and needed time to catch up (Siyomba). 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). Poor and working-class students fail to adapt to the middle-class culture. Similarly, banking system of education was employed by educators. Banking concept of education “turns students into containers or receptacles to be filled by the teacher (Freire, 2005, p. 72).” A good teacher is one who completely fills the receptacles, and good students are those who meekly permit themselves to be filled. In banking, the teacher narrates and “makes deposits which the students patiently receives, memorise and repeats (Freire, p. 72).”

Authoritative educators hinder students from asking questions where they have not understood. Authoritativeness intimated students. It is a form of symbolic violence which some people feel subjugated whereas others ignore it (Bourdieu, 1985). Authoritative dominated the conversations in the classroom and does not recognise the socially imposed dominant mode as a natural norm when students do not have access to social and cultural capital it generates social and cultural violence. Nevertheless, some of the educators were constructivist. In constructivism, a teacher provides opportunities and contexts for learning to students. S/he is “a guide, facilitator and co-explorer who encourages students to question, challenge and formulator their own learning” from the concept being taught (Ultair, 2012, p. 195 citing Ciot, 2009; Cannelle & Reif, 1994; Ismat, 1998; Richardson, 1997)).

5.3 Students’ Experiences in the University

Students complained that there were many timetable changes. This, often without notice, resulted in having lectures beyond 4:00 pm, up to 6:00 pm, when students were supposed to be at their tutorial sessions. These changes often resulted in tutorials being moved to start two hours (6:00 pm) late. This meant that students were in class for the whole day, are tired and cannot remember what they learned. They cannot study and just go to sleep. 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. Furthermore, the chemistry content presented in class is so detailed that they have to research to get the key concepts. Students bring into class/university their culture, funds of knowledge and prior chemistry knowledge that is waiting to be built on. Additionally, educators bring into the classroom “culture different from that of their students, resulting in cultural clashes that lead to gaps in learning (Brown-Jeffy & Cooper, 2011, p. 68).” Njovu 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]”. Classroom has its own culture and structure which may create constraints and opportunities in learning for some students. Culture conflicts created opportunities for transformation. For example, Temwa was transformed by university teaching experiences. She learned “to zero-in in chemistry” (studying late into the night) to master what she learned during the day. Natasha said “… if you do not understand, you have to go and research”. Students employed the tools available to overcome the deficit in learning by watching video lessons on smartphones, laptops, tablets and computers (Kincheloe, 2005). Apart from YouTubes, students adjusted to using resources available at hand such as time, university culture, classroom structure and peers to master TCs of acids-bases reactions (Levi-Strauss, 1966)). To cross the liminal space/ZPD, students also changed their perspectives from being passive to being responsible for their learning.

5.4 Students’ Learning Culture

Students cross boundaries into the university and “encounters the culture of home, the culture of peers, the culture of school, the culture of the science classroom, and the overarching culture determined by the community in which the pupil lives" which are different from home culture and pre-university culture (Jegede & Aikenhead, 1999, p. 46). They construct their own meaning to succeed in chemistry because culture plays a role in the learning process. Students choose their personal strategies of learning, the pace of learning and who should engage with in collaborative learning. Tafuna exclaimed that "the way we study chemistry that makes a lot of people not to do well in chemistry". Students' study to pass the examinations but not for understanding. Students' learning culture have not transformed from secondary school to university level. 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). 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 context. Most students exclaimed that they did not see why they could fail at university if they were such "good students at secondary school". So, sort help from abler friends. Those who found themselves in the ZPD/liminal interacted with interacted with educators and more knowledgeable others (MKOs) within and outside the classroom formally and informally (Vygotsky, 1978; Meyer & Land, 2005). 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. For example, Siyomba disclosed 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". Hence, students in the interacting groups could enable each other by teaching each other to succeed individually and collectively

Besides, students seemed to be satisfied with memorising facts and procedures for success in tests and examinations, which means they failed to master TCs (Meyer & Land, 2003). In this case, students are trying to integrate new ideas or replacing previous ideas with new ones. This may lead to creativity, mimicry or quitting (Meyer & Land, 2003; Piaget, 1951). Students are also "overconfident", which Temwa termed, "a secondary school mentality". Students were overconfident because they met the entry qualifications of grade A in six core subjects. The students thought that university chemistry was a walk over. Some missed lessons on the introduction to chemistry that happened to be the foundation to complex topics. Students had no knowledge that acids-bases reactions is one of TCs in chemistry.

5.5 Classroom Interactions as observed by the Researcher

Each educator and students in their group experienced the teaching and learning differently. Chanda's engagement with students during the lesson on common ions in chemical equilibrium reactions created affordances and constraints. 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). Chanda tried to assist students to internalise the concepts of types of weak acids as they seemed to experience challenges. He cautioned the class not to memorise equations and conjugate acids-bases but to interpret, analyse and internalise the concepts applying Arrhenius, Bronstead-Lowry and Lewis definitions. For instance, "Do not memorise which is weak or strong acid?

1. $H_2CO_3 + H_2O \rightleftharpoons H_3O^+ + HCO_3^-$

2. $HCO_3^- + H_2O \rightleftharpoons H_3O^+ + CO_3^{-2}$

Which is the conjugate acid for carbonate base?”

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). Spots where students seem to be trapped may memorise, mimicry or quit.

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. He explained and demonstrated calculations of concentration, pH, pOH, acid-base equilibrium to the students. Hamoonga expected students to study and to attempt to answer the tasks in the handbook before coming to class. Only then were students able to talk to him, ask questions, and interact with him successfully. Throughout his lecturers some students copied from the board and others discussed among themselves. 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). Hamoonga guided the students step-by-step to find the final and correct answer. Educator code switched to vernacular on seeing that the students did not understand calculations of very weak concentrations. The educator is an expert in chemistry and students are legitimate peripheral participants (LPP) (Lave & Meyer, 1991). Learners develop conceptual understanding by participating with experts in problems related to their real-world activities.

Zulu, the educator demonstrated a few examples of problems with students on the chalkboard in a two-hour lecture. Some students were stuck at metallic oxides and metals to master the strong bases and weak bases. Similarly, at chemical equilibrium stage, and could not progress to acids-bases equilibrium level (ZPD) (Vygotsky, 1978). Students enter the ZPD and liminal space. They looked puzzled, looked at each other’s work and worked together as one of them took the lead and some of them asked questions. Other students were finding difficulties because they could not relate to chemical equilibrium, for example, a weak acid equilibrium which is ionising. The activity was socially mediated by Zulu by demonstrating more problems on the board and asking questions.

Inonge employed a constructivist approach to teaching and learning. Inonge interacted with students on introduction to acids-bases. She introduced hydrochloric acid reacting with water and identifying conjugate acid-base. Students did not experience any challenges in learning conjugate acid-base produced in the reaction. Some students experienced difficulties on auto ionisation of water and determining the equilibrium. Students discussed where they were seated calculated concentration, pH of weak acids and some demonstrated on the board to their classmates. For example, one of the questions was “what is the concentration of all the species present in 0.5 molar of that particular acid [acetic acid]? Now, what is the first thing that you do when you are given such a question?”. Most students experienced challenges in writing of balanced equations. Hence could not identify species present in the solution, neither proceed to construct ‘Initial Change Equilibrium (ICE)’ table nor calculate pH. These students enter the liminal and ZPD space because they failed to master the key concepts. Threshold concepts are fundamental understandings that are at the heart of disciplinary knowledge (Meyer & Land, 2003). Liminal space is also a space of creativity. 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. 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.

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. 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. According to Ika, students faced very few challenges in learning acids-bases "because they had learned these when they were at secondary school". Students experienced difficulties the only when it came to auto-ionisation of water and writing of formulae for hydroxide ions. Students experienced few problems in the three definitions because "water comes as acid and again as a base". Furthermore, students had few problems with calculations of pH because the students had "no prior knowledge in calculations of acids-bases reactions". Power relations in the classroom were reduced to sustain a supportive learning environment while maintaining his position as an educator (Freire, 2005). Together, the teacher and students construct pedagogies that identify what students want to know and engage with them to learn it.

5.6 Students' Different Chemistry Knowledge Levels as observed by Educators

Students possess differences of knowledge levels with Advanced Level chemistry, General Certificate of Education (GCE) Ordinary Level in chemistry, physical science and combined sciences. Some went to schools where teaching and learning standards of natural sciences were priority. Besides, there were second-year students who are repeating general chemistry. Interactions between student-student and student-educator generated constraints and affordances in teaching and learning. According to the educators, it was not easy to teach students possessing different levels of knowledge to get them all into the liminal space/ZPD. Additionally, students possess additional/alternative knowledge of Arrhenius, Bronsted-Lowry definitions, and some had not heard of Lewis's acids-bases definition before. Some students understood the concepts easily while others with less knowledge of chemistry found these difficult to understand. According to Inonge, capable students were able to understand in a "blink of an eye" (MKO) while others the educator has "break-down the concept" to make them understand. Students' with poor prior knowledge were left behind learning current ideas. The learning spaces were hybridised classrooms (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.

7. Conclusion

Zone of proximal development and liminal space represents a conceptual field of creative learning for students. By creative learning, I mean students analysing troublesome, difficulty, interrelated concepts of acids-bases, their funds of knowledge of chemistry, home culture and classroom culture and, making sense of the new ideas. Participants in the ZPD/liminal space are students from diverse socio-cultural background and educators. Thus, students are heterogeneous creating the classroom and ZPD/liminal space heterogeneous. ZPD/liminal space and university are unfamiliar territories to students that may create constraints and affordance for some students. The experience is unique to each student and respond differently However, interactions in ZPD/liminal space are according to the rules, roles and resources available. Students who experienced less challenges in adapting university teaching-learning culture and TCs of acids-bases assumed the role of more knowledgeable others (MKOs). MKOs possessed social, cultural and symbolic capitals. Both the affordances and constraints created by teaching strategies, TCs of acids-bases, abrupt changes in the timetable and students' pre-university culture make some students struggle but they also provide opportunities to challenge themselves to study more, form study groups, watched online lectures, did research and studied late into the night. Experiences transformed students into self-directed learners. Some students transformed into learners who approached learning with understanding and constructed meaning with little or no help from the educator. Students expanded their knowledge through research and watching on-line video lessons asynchronously, individually or collectively. Some students transformed from LPP in chemistry and member of university community to experts. New and unfamiliar territories are thresholds and students have to master both threshold concepts of acids-bases chemistry and university culture.

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