CHAPTER ONE

General orientation of the study

All we come to know is our own construction (Bettencourt, 1993, p.39).

1.1 Introduction

With the dawn of democracy in 1994 South Africa was accepted in the global community of nations. This new era has also brought about many societal challenges. One of the challenges facing the new democratic society was the limited knowledge and skills of the majority of its citizenry to engage with other nations in a competitive, technologically advanced and ever-changing political, economical, social and cultural environment. In an attempt to address this challenge, the new government introduced legislation such as the South African Qualifications Act, 1995 (Act 58 of 1995); the Skills Development Act, 1998 (Act 97 of 1998) and the Higher Education Act, 1997 (Act 101 of 1997), and other plans aimed at addressing the level of knowledge and skills of its citizens.

In its endeavour to further enhance the knowledge and skills of society, especially at school level, government began developing a new curriculum. The objective of the new curriculum, according to the *Revised National Curriculum Statement* (Department of Education, 2002a), was to take up the challenge posed by –

- the scale of change in the world (i.e. the growth and development of knowledge and technology and the demands of the 21st century, which required students to be exposed to different and higher level skills and knowledge than those required by the former South African curriculum); and
- the fact that South Africa had changed (the new South Africa required revision to reflect new values and principles based on the Constitution).

What does it mean to expose students to different and higher level skills and knowledge? How would a curriculum accomplish this?

The development of a new curriculum cannot be sufficient if it is not accompanied by the development of resources – both human and physical – to enhance higher-level skills and knowledge. According to Spady (1994) to successfully implement a curriculum to enhance skills and knowledge, that curriculum should focus on and organise everything around what is "essential for all students". This he said is to enable successful learning at the end of their learning experience. It also needs sufficient *resources* if students are to learn successfully. Resources here mean both the *physical* and the *human* resources required to enhance teaching. "Physical resources" are, for example, well-equipped classes, laboratories, libraries, etc. "Human resources" refer to administrators and lecturers who are qualified in their respective fields to contribute to successful learning. In the case of teaching, lecturers should not only be qualified, but also knowledgeable in the art of teaching a specific subject matter content.

This means lecturers should understand the content of their subject matter and the pedagogy to teach it successfully. Successful teaching is teaching that results in meaningful learning or understanding. Understanding something according to Wandersee and Griffard (2002) is "to explicitly connect it to one's prior knowledge and experiences in a non-trivial way" (p.29). Meaningful learning can therefore be enhanced when the lecturer has sufficient and relevant knowledge to understand how students use their prior knowledge during learning. To enhance meaningful learning the lecturer should be in a position to demonstrate the "grasp of, and response to the relationship between knowledge of content, teaching and the learning in ways that attest to notions of practice as being complex and interwoven" (Loughran, Mulhall & Berry, 2004, p.370). In fact, the knowledge described by Loughran *et al*., (2004) above is what Shulman (1986) termed "pedagogical content knowledge" (p.9). It is an understanding of the relationship between knowledge of content and teaching and learning, and enables the lecturer to represent and formulate the subject in a manner that makes it comprehensible for the student (Shulman, 1986; 1987).

The qualified and knowledgeable lecturer should not only have pedagogical content knowledge to succeed in his or her teaching. In addition, the lecturer should also understand the students' background and the factors contributing to students' learning. According to Ausubel (1968), the main factor contributing to learning is one's existing knowledge. The definition of understanding cited earlier highlights the important role that the individual's existing knowledge plays in learning and especially in understanding: One needs to connect newly acquired information to what is already known (referred to as one's "prior knowledge" in this study) in order to understand.

But what is prior knowledge? Different people have defined prior knowledge differently. Jonassen and Grabowski (1993) define it as "knowledge, skills or ability that students bring to the learning process” (p. 416). Dochy and Alexander (1995) describe it as "the whole of a person's knowledge" (p.228). What students bring to the learning process is therefore what they would use to acquire new knowledge. Based on these definitions, the rationale is that understanding students' prior knowledge would enrich lecturers’ teaching and learning planning of their lectures before engaging in teaching. On the whole, the lecturer should have an understanding of a student’s learning weaknesses and strengths on the basis of his or her prior knowledge. This understanding would help the lecturer in the planning of relevant and effective teaching and learning activities.

The purpose of this study is therefore to explore and understand students’ use of prior knowledge to construct understanding and generate meaning of selected concepts and processes on the topic of acids and bases. The study was based on first-year students studying towards a National Diploma in Analytical Chemistry at the Tshwane University of Technology in South Africa. For ease of reference, the topic on acids and bases would generally be referred to as "chemistry" where it is not specifically stated.

1.2 Background and rationale

Education and higher education institutions in particular, especially in South Africa, are faced with the challenge of adapting their programmes and curricula to satisfy the needs of an economy that has to compete in the global community. These institutions therefore have to produce graduates with the knowledge, abilities and skills that will ensure their competitiveness at all levels of the local and international economic landscape in which they participate. The economy for which today's institutions of higher learning (universities and universities of technology) are required to prepare their graduates can be grouped into three interrelated categories that cannot function separately (Castells, 1996). These categories are –

- an economy in which productivity and competitiveness are based on knowledge and information;
- a global economy which has the capacity to work as a unit in real time on a planetary scale of core activities; and
- an economy with technological, organisational and institutional capacity.

Undeniably, the kind of economy Castells describes here relies on *knowledge* and the individuals' capacity to create new knowledge. Individuals aspiring to participate in such an economy must therefore have the capacity to create new knowledge since knowledge in this economy changes as fast as it is created. This knowledge changes as fast as it does because (Castells, 1996) "new information and communication technologies allow fast processing and distribution of information throughout the entire realm of productive activity" (p.2). Institutions of higher learning, especially those in developing countries such as South Africa must therefore develop teaching and learning strategies, whose application would produce graduates capable of independently generating relevant knowledge. With this knowledge graduates would engage productively in the economy Castells describes above.

However, students entering the higher education system are different in terms of their individual learning abilities. Most of these students come from a schooling system of limited teaching and learning resources. In most instances these students' prior knowledge is less developed. Consequently they find it difficult to engage productively in higher-order cognitive learning. For example, in South Africa (Nkomo (1990), the majority of these students are the products of an inferior education system. They come into higher education studies with poor quality prior knowledge. Nkomo (1990) further argues that the segregated education system deliberately subjected Africans, Coloureds and Indians to intellectual underdevelopment. According to Nkomo (1990) this education system was meant to provide the then government with "an ideological cornerstone for the social segregation, economic exploitation and political oppression of these groups calibrated according to their location on racially hierarchical social system" (p.1).

In fact, most students who lack the capacity to learn meaningfully are products of teachers who themselves are the products of an education system that promoted an intellectually underdeveloped (mostly black) society. The teachers also studied under a system where resources were deliberately minimised for the three racial groupings mentioned earlier, while maximised for their white counterparts. As a result, schools and higher learning institutions meant for these communities could not develop teachers and other professionals at the competency level of their white counterparts. The "gap" between what was taught and learned by white and black citizens in South Africa was (and still is) apparent in different areas of the society. More significantly, the “gap” is apparent in the socio-economic, education and skills spheres.

Table 1: Mathematics and physical science performance by group, 1991 (Kahn, 2005).

	AFRICAN	COLOURED	INDIAN	WHITE
Mathematics				
Candidates (HG)	10 519	1 127	3 436	15 399
Passed (HG)	1 052 (10%)	715 (63%)	2 731 (80%)	13 543 (89%)
Physical science				
Candidates (HG)	10 6409	1 308	3 952	15 642
Passed (HG)	1 698 (16%)	1 033 (79%)	3 277 (83%)	12 769 (82%)

HG = Higher Grade (There are other grades, i.e. SG = Standard Grade; LG = Lower Grade. HG is weighted more than the two in terms of their difficulty.)

The statistics (Table I) provide what Kahn (2005, p.140) referred to as "some feel for the extent of the inequalities" in education under the apartheid education systems. These exclude statistics of what was happening in "independent homelands" in terms of education. In Mehl's (1990) words, "… this is an imbalance which any future government will need to address as an urgent priority" (p. 383) if any teaching and learning is to prepare students for what Gravett (2004) regards as the world of "super-complexity"(p.22). The world of super-complexity (Barnett, 2000; Barnett & Hallam, 1999) is the world that is rapidly changing; a world without stable meanings and a world in which the handling of uncertainty, ambiguity and contestability come to the fore. If this is the world students have to face when they enter their careers, a meaningful way should be found to prepare them for it.

In fact, in their study Howie and Pietersen (2001) highlight the state of teaching and learning in South Africa in terms of Grade 12 students' performance in the Third International Mathematics and Science Studies (Table 2). According to their report, the performance of South Africa's top students was not that well compared to that of the top students from other countries; they performed the same as average students from other countries. South African grade 12 students were the worst performers in the selected group.

Table 2: South African grade 12 students: Mathematics literacy compared to selected countries (Adapted from Howie & Pietersen, 2001, p. 10).

COUNTRY	MATHEMATICS LITERACY	OVERALL LITERACY
Netherlands*	560 (4,7)	559 (4,9)
Sweden	552 (4,3)	555 (4,3)
Canada**	519 (2,8)	526 (2,6)
New Zealand	522 (4,5)	525 (4,7)
Australia	522 (9,3)	525 (9,5)
Russian Federation	471 (6,2)	476 (5,8)
Czech Republic	466 (12,3)	476 (10,5)
USA*	461 (3,2)	471 (3,1)
South Africa*	356 (8,3)	352 (9,3)
International mean	500	500

( ) Standard errors appear in brackets
* Unapproved sampling procedures and low participation rates
**Did not satisfy guidelines for sample participation

Studies such as this one show the need to enhance students' learning abilities in order to improve performance. This will help to avoid such performances as described above (Howie & Pietersen, 2001; Kahn, 2005). With the legacy described and illustrated above, how does higher education and science education in particular take up the challenges of the "new economy" described earlier by Castells?

Some approaches to overcome these challenges are suggested. For science education at higher education institutions to equip graduates to compete in the new economy requires a holistic approach. Such an approach is characterised by the belief that the teaching and learning in general, and of science in particular, should be based on and influenced by factors surrounding the environment in which learning takes place. The environment includes, but is not limited to teaching and learning facilities, the student, the lecturer and the learning content.

There are many factors (cultural, social, economical, linguistic, the nature of learning content and the prior knowledge of both the student and the lecturer) that affect teaching and learning. However, not all of these factors can be studied in detail or at the same time in one study or within a limited prescribed time. Only students' prior knowledge of science and more specifically their prior knowledge of concepts of acids and bases and related practical work processes are the focus in this study.

The motivation to focus on prior knowledge was prompted by the fact that first-year students entering higher education for the first time bring into the learning situation established ideas and notions inconsistent with those of lecturers and scientists. In addition, this knowledge is insufficient and irrelevant and/or littered with 'misconceptions' since (Erduran & Scerri, 2003) teaching still continues to reinforce a 'rhetoric of conclusions', "a tradition that perpetuates the learning of conceptual outcomes while neglecting the learning of strategies that enable knowledge growth in different fields of scientific enquiry" (p.7); making learning science meaningfully, difficult (De Jong, 2000; Gabel, 1998; Johnstone 2000a; Taber 2000).

Furthermore students at this level have not yet been assimilated into the culture of learning at a higher level and the learning culture of the institution they are studying at. For a better assimilation of new first-year chemistry students factors that contribute to their poor and/or good performance such as prior knowledge must be understood to reduce the inhibiting effects of other factors such as culture of learning on their performance. Prior knowledge of students was also identified as the area of focus because successful construction of knowledge is knowledge-dependent (Glaser, 1984) and that prior learned concepts (Reif, 1985) are "logically the building blocks of the knowledge used to deduce important consequences, make predictions and solve problems" (p.133).

How then do students with limited or a lack of prerequisite knowledge engage in higher order cognitive learning processes in chemistry? To answer this question, an attempt was made to understand how the specific prior knowledge of concepts and their relationships or lack thereof manifested in students' abilities to learn and apply these concepts in practical learning situations. The rationale was therefore that understanding *how* students use these concepts would help lecturers develop strategies that would enhance students' ability to engage in higher-order cognitive learning processes and prepare them for the world of "super-complexity" (Gravett, 2004) and the "new economy" (Castells,1996).

1.3 Purpose statement

The main purpose of teaching is to facilitate and enhance learning by students. However, teaching often has limited success in guiding students from their pre-instructional conceptual frameworks to new understandings (Bodner, 1986). That is, teaching does not always result in the lecturer's intended learning. This is so because of the complexities surrounding teaching and learning. The failure to achieve intended learning outcomes in some instances could be ascribed to the limited understanding of lecturers and instructional designers of factors that affect teaching and learning.

According to von Glasersfeld (1995) lecturers too often prepare their teaching strategies and procedures from "the naive assumption that what we ourselves perceive and infer from our perceptions is there ready-made for the students to pick up, if only they had the will to do so" (p.5). This attitude makes it even more difficult for students to learn in general and to learn chemistry in particular; especially students coming from poorly resourced teaching and learning backgrounds. This attitude (based on the practice not to assess students' prior knowledge before teaching) is prevalent in most schools in South Africa. In addition (Gabel 1999), students encounter problems learning chemistry because of the many abstract concepts in chemistry. Students are sometimes taught without the use of analogies or models. This makes chemistry difficult to understand and learn. The abstract nature of chemistry is further compounded by assumptions that lecturers make about the levels of students' knowledge and their ability to learn in a particular domain. How, then, do we overcome the effect of the legacy of poor teaching and learning resources, especially in science learning?

Questions occupying most instructional designers' and lecturers' minds, are *what* factors affect successful teaching, *how* they do that, and how they could be *overcome* to achieve intended outcomes of teaching? The different knowledge bases that students (i.e. first-year students) bring into the learning situation is what instructional designers and lecturers especially chemistry lecturers need to understand if they are to answer the question: *How do I help my students to learn if I do not know what they know, how they know it and how they learned it?*

The purpose of this study is therefore to understand how students construct understanding and generate meaning during learning. Understanding students' learning in this study was based on von Glasersfeld's (1996) view of learning. According to this view learning is a constructive activity in which students themselves carry out knowledge construction. Within this perspective the lecturer does not dispense knowledge but provides students with opportunities and incentives to build knowledge. With this understanding of learning, some of the questions asked about understanding students' knowledge construction may be answered.

1.4 Research question(s)

Major question

How do first-year chemistry students use prior knowledge in the learning of chemistry concepts?

Research sub-questions

(i) *What is students' understanding of selected chemistry concepts and processes before engaging in a first-year practical work activity?*

(ii) *How do students use their prior knowledge of selected chemistry concepts and processes to construct understanding and generate meaning during learning?*

1.5 Aims and objectives of the study

The aim in this study was to understand how students use prior knowledge in constructing understanding and generating meaning of concepts and processes during the learning of acids and bases. To achieve this (students' knowledge construction), an attempt was made to answer research questions posed earlier. These questions were answered by establishing:

- *Students' understanding of selected acid-base (chemistry) concepts and related processes in a first-year practical work activity.*

Acid-base equilibria or "acids and bases" are a common topic in many first-year chemistry curricula. Acids and bases are, according to Brown, Le May Jr, Bursten and Murphy (2006) "important in numerous processes that occur around us, from industrial processes to biological ones, from reactions in the laboratory to those in the environment" (p.669). In the light of this it was important that concepts mostly considered 'confusing' among many first-year chemistry students had to be studied in order to enhance their understanding and their subsequent usage by students. These concepts were *acidity* (or *aqueous acidic solution*), *acid strength, concentration, equivalence point* and *endpoint.*

- *Students' use of prior knowledge of selected acid-base (chemistry) concepts and processes to construct understanding and generate meaning during learning*.

Titration is a process commonly used (e.g. by chemists) to determine the concentration of solutes in a solution. It (titration) involves combining a sample of the solution with the reagent solution of known concentration. Titrations are conducted using any of the acid-base, precipitation or oxidation-reduction chemical reactions (Brown *et al.,* 2006). In the teaching of chemistry, concepts selected for this study contribute significantly in the understanding and performance of acid-base titrations. Understanding these concepts would therefore enhance the students' meaningful learning of acid-base concepts and the titration processes involved.

In conclusion, understanding (by lecturers) how students construct understanding and generate meaning of concepts and/or processes as building blocks of knowledge, will according to Gravett (2004) go a long way to help in "getting the 'ordinary' students enrolled at higher education to engage in higher-order cognitive learning processes that the more academic students tend to engage spontaneously" (p.23). In the light of this, the outcomes of the study would enhance lecturers' understanding of the quality of students especially those with less developed prior knowledge and its manifestation in their construction of knowledge during learning.

With this understanding lecturers will be in a position to help students adapt to their new learning environments because (von Glasersfeld, 1996) one can hope to induce changes in students' ways of thinking only if one has some inkling as to their domains of experience, their concepts and the conceptual relations they possess at that time.

1.6 Significance of the study

Generally the study was to explore and understand students' background in terms of prior knowledge and how this manifested in new learning of science and, more specifically, selected acid-base (chemistry) concepts. In the light of this its significance was that:

- It could bring a rich understanding and more knowledge to lecturers, curriculum developers and researchers about what Dochy (1992) referred to as the "student model". According to Dochy this model is an instrument used to gain a clear understanding of the students' prior knowledge in order to make hypotheses about their perceptions and reasoning strategies employed in achieving current knowledge.
- It could also help the lecturer to enhance the learning of science by a better course design and instructional support, using information from students' prior knowledge and their application of this knowledge in practical situations (Dochy, Valke & Wagemans, 1991; Dochy, 1994; Dochy & Kulikowich, in press). The results of the study could also inform the development of frameworks to accommodate understanding between the student and the lecturer in terms of the objectives of teaching and learning.

1.7 Literature review

The focus of the literature review was on aspects of teaching and learning with specific emphasis on chemistry (acids and bases) teaching and learning. As the study leaned more towards the constructivist view of learning, knowledge, its quality and usage were areas focused on in this literature review. The review on prior knowledge emphasised three important aspects namely –

- prior knowledge as a major factor in learning;
- prior knowledge as a barrier towards meaningful learning; and
- prior knowledge as a facilitator of meaningful learning.

(i) Knowledge as a major factor in learning.

Since this study was conceived within the constructivist view of learning, it was important to review knowledge in general and from the constructivist perspective in particular. This knowledge (Glaser, 1984), is the source from which new meaning/knowledge is constructed. Understanding knowledge was therefore paramount as it is the outcome of learning and at the same time guides new learning.

(ii) Prior knowledge as a barrier towards meaningful learning.

One of the characteristics of knowledge (or prior knowledge) is that it inhibits learning. This is the case when one has incomplete, not well-organised and inaccessible knowledge. Inaccessible knowledge cannot be utilised (Dochy, 1992). For this study, it was important to understand this characteristic in order to enhance the understanding of students' learning (and/or their prior knowledge).

(iii) Prior knowledge as the facilitator of meaningful learning.

A facilitating effect (Dochy, 1992) of prior knowledge is mostly recognised as contributing positively to learning. Three types of the facilitating effects of prior knowledge were identified. They are (1) the direct effects of prior knowledge, which facilitate the learning process and leading to better results; (2) the indirect effects of prior knowledge, which optimise the clarity of the study material; and (3) the indirect effects of prior knowledge, which optimise the use of instructional and learning time. Although these characteristics were not the focus of the study, it was important to understand them, as they are part of an individual's knowledge infrastructure.

The review also focused on the origin of science and its nature, with particular emphasis on the nature of chemistry. As the study deals with teaching and learning (knowledge construction), it was also important to highlight areas of teaching and learning in general, and teaching and learning of science, particularly chemistry. As far as teaching and learning in general and teaching of chemistry are concerned, the foci of the study were on the following:

- Understanding learning and knowledge 'acquisition';
- Origin, nature and learning of science; and
- Practical work in science teaching and learning.

(i) Understanding learning and knowledge acquisition.

For purposes of understanding the importance of learning and the context in which it occurs it was imperative to explain *what* learning and knowledge were and *how* knowledge is acquired. There are many views on learning, but three views (behavioural, cognitive and constructivist) were considered relevant to and are briefly discussed later in this study.

(ii) Origin, nature and learning of science.

Science, relative to other subjects, is not easy to learn (Gabel, 1999) because of its nature. With this in mind, it was important to discuss the origin, nature and the learning of science. This is done in an attempt to show how students and lecturers respectively conceptualise it.

(iii) Practical work in science teaching and learning.

Practical work or laboratory activities have had a distinctive and central role in the science curriculum. Science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Lunetta, 1998). Therefore, practical work is discussed to demonstrate its importance in science learning and in helping in the facilitation of this study. The literature review also focuses on how education, and science education in particular, contributes or should contribute and could contribute to learning to equip graduates with relevant knowledge and skills for the 'new economy'. The literature therefore focuses on factors that affect teaching and the complexity of learning, especially the learning of chemistry.

1.8 Research methodology

It is apparent from the discussion above that the qualitative method would be appropriate for the study. Qualitative research methods (Denzin & Lincoln, 2003) are situated in activities that locate the observer in the world. That is, they study things in their natural setting in an attempt to make sense of, or to interpret, phenomena in terms of the meanings people bring to them (p.4-5). In this study the natural setting was a chemistry laboratory and the phenomena under study were prior knowledge of concepts and their use in constructing understanding and generating meaning during learning.

1.8.1 Research design.

The design of a research project plays a major part in the outcomes of an empirical study. According to Denzin and Lincoln (2003), a research design describes a flexible set of guidelines that connect theoretical paradigms to: (1) strategies of inquiry and (2) methods for collecting empirical material. In fact Janesick (2003) regards a research design as the 'spine' on which the researcher must rely in his/her research project. The spine is elastic; therefore the research design should also be seen in the same light. That is, as being elastic in terms of which strategies and methods should be employed at any given time of the study.

As this study was to be in-depth three *instrumental case studies* were used. An instrumental case study (Stake, 2003) provides insight into an issue or redraws a generalisation. With the three case studies an attempt was made to provide insight into students' construction of understanding and generation of meaning from their prior knowledge during learning. To better understand students' use of prior knowledge during learning the constructivist-interpretive design was used to elicit information from students engaging in the learning of 'acids and bases' concepts and/or processes through practical work activities. This paradigm was selected on the basis that the nature of the reality within which the study was conducted was multiple, constructed by human interaction, holistic and divergent (Patton, 1990).

1.8.2 Instrumentation.

Instrumentation (Fraenkel & Wallen, 2003) involves the whole process of preparing to collect data; where the selection or design of the instruments, the procedures and conditions under which the instruments are to be administered are important. The process of data collection is therefore important as it affects the data collected. In a research study such as this one, it is important to know what the study's intent is and how we intend doing it. To guide the procedures and conditions that may be "ideal" for conducting a study, Fraenkel and Wallen (2003) suggest questions that, when answered correctly in relation to the objectives of the study, may yield desired outcomes (see Table 3).

Table 3: Instrumentation questions

Question to researcher	Answer from this researcher
Where data would be collected? (**Population of interest**).	From first-year chemistry students during practical activities at the Tshwane University of Technology.
When would data be collected? (**Time).**	At the end of the semester, when topics that are practically and theoretically relevant to the study have been covered.
How would data be collected? (**Data collection methods**).	Prior knowledge state test, interview and observation.
Who would collect the data? (**Research instrument).**	The lecturer responsible for practical work (in this case, the researcher).

Since a research design (Denzin & Lincoln, 2000) situates researchers in the empirical world and connects them to specific persons, sites, groups, bodies of relevant interpretive material, etc.-responding to these questions would indicate –

- the population of interest;
- the time period at which the study would be conducted;
- the methods and instruments that would be used to collect data; and
- the instrument(s) for data collection.

(i) Data collection methods.

A population must be identified for data to be collected. Fraenkel and Wallen (2003) describe a population as "the group of interest from whom the researcher would like to generalise the results of the study" (p.97). In this study, "population" refers to all first-year chemistry students studying towards a Diploma in Analytical Chemistry at the Tshwane University of Technology. Since not all members of this population were practically accessible, the sample was selected from students who volunteered for the study. However, it should also be stated that generalisation was not intended.

The quality of research data depends to a large extent on the appropriateness of the selected data collection methods. In this study, only qualitative data collection methods were used. Marshall and Rossman (1995) list four methods relied on for qualitative data collection, namely participation in the setting; direct observation; in-depth interviewing; and document review. However, for the purposes of this study, observation, interviews and a practical work report were used and complemented with a prior knowledge state test.

(ii) Data collection process.

Social collaboration between individuals (Tobin, 1990) fosters the understandings to be clarified, elaborated, justified and evaluated. The rationale is that, in this social collaboration, any differences of opinion between individuals would be an "ideal" environment for individuals to construct understanding and generate meanings of concepts and processes in a practical situation. The differences in opinion (if any) would enable the researcher to capture the conversation and collect data. In fact, the prior conceptual understanding would be established from translating or interpreting students' talk to their object manipulation or vice versa. The existence of relevant prior knowledge students have when engaging in practical activities would therefore be established through their discussions of practical work activities.

Data collection involved the formation of dyads. Each dyad was provided with a practical work task. It was also important that students understood the purpose of the practical task. The task was a ‘mixture’ of closed-ended and open-ended tasks. According to Hofstein (2004), students conduct experiments on specific instructions in a closed-ended task, while in an open-ended type task they are involved in "experiences such as asking relevant questions, hypothesizing, choosing a question for further investigation, planning an experiment, conducting the experiment (including observations) and finally analyzing the findings and arriving at conclusions" (p. 253). For this study, the task had features of both types of tasks. In some instances they were provided with information and in some instances no structure or guidelines for the task were provided.

The reason for using a mixed-task approach was necessitated by the experience of the *pilot study*. In the pilot study it was apparent that students at first-year level were not ready to engage in an exercise that demanded higher order cognitive skills, owing to their academic background and lack of experience in discovery inquiry exercises in practical work. During a pilot study students spend most of the practical activity asking for explanation of the aspects of the practical work activity. Most of the time was therefore occupied by explaining practical work aspects to students.

According to Piaget (1964), the ability to design and carry out an open-ended inductive experiment depends on the student's ability to carry out formal reasoning operations. In fact, Kirschner and Meester (1988) indicate that this ability is possessed by only a *third* of students starting university. This means that two thirds of first-year university students lack this ability. The mixed-task approach (or "divergent laboratory approach", according to Kirschner & Meester, 1988, p.90) where some parts of the experiment are predetermined and standardized for all students was found *ideal* for this study. With this approach, students are expected to interact both physically (by object manipulation) and mentally with objects to achieve the goals of the task.

The empirical study process involved four data collection methods described earlier. The type of data collected depended on the sequencing of the methods (see Figure 1). For example, it was important for students to write the prior knowledge state test before performing practical work activities. This was done so that students' responses in the prior knowledge state test could guide the framing of questions for the interview and observations during practical work activities.

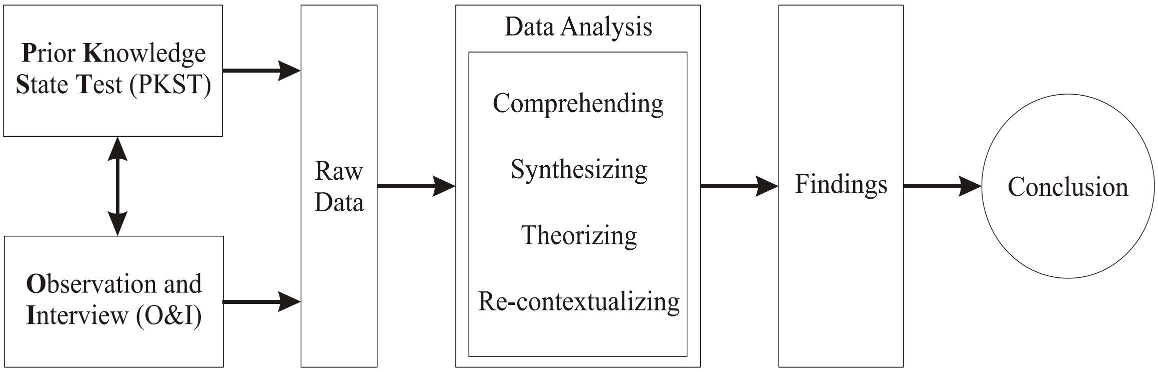

Figure 1: The empirical study process.

Information collected during the interview and observation stage of the process was used with data collected from the prior knowledge state test. The prior knowledge state test elicited students' *initial* understanding of concepts. It elicited information about how students interpreted concepts that they used for reasoning during practical work activities. A relation could therefore be established between how students constructed understanding and generated meanings on the basis of their prior conceptual understanding.

(ii) Data management and analysis.

The challenge of data analysis, especially qualitative analysis is to make sense of massive amounts of data collected (Patton, 1990). This is done by reducing the volume of information through the identification of significant patterns emerging from the information, and the construction of a framework that can later be used to communicate research outcomes. Morse (1994) lists four cognitive processes (Figure 1) that are integral to data analysis in qualitative research. They are: comprehending; synthesizing; theorizing; and re-contextualizing. "Comprehending" refers to learning about the setting before the study begins. "Synthesizing" is merging several stories, experiences or cases to describe a typical composite of behaviour or response. "Theorizing" is the constant development and manipulation of malleable theoretical schemes until the "best" one is developed.

"Re-contextualizing" is the development of an emerging theory so that it may be applied to other similar settings and to other similar populations (p.25-34). Some aspects of the four processes were used for analysis in this study.

(iv) Addressing issues of trustworthiness.

In any research study it is important that a researcher is able to defend the findings of his or her research. In qualitative research this is not an easy task, as the method is value-laden. According to Janesick (2003), the researcher is an instrument whose background about the research topic plays a major part in the credibility of the findings. Because of the importance of the credibility of the research instrument, it is important therefore that in qualitative research attention is paid to issues relating to the trustworthiness of this instrument (the researcher) as far as its ability of conducting the study is concerned.

In an attempt to enhance trustworthiness in this study, only factors relating to credibility and confirmability were addressed. Credibility (Hoepfl, 1997) is the extent to which findings accurately describe reality. Credibility was established through 'triangulation' of sources of data. The sources of data were: (1) observation and the interview report sheet (2); the prior knowledge state test answer sheet; and (3) the practical work report. Data collected was interpreted and compared to determine if data from sources had convergent meanings. The iterative nature of the study (in data collection methods) also played an important role in establishing credibility and confirmability. For example, responses from the prior knowledge state test were used to confirm students' understandings during observations and the interview. Reviews by peers on students' understanding were also sought and used to confirm the findings.

(v) Delimitations and limitations of the study.

Not everything can be researched at a given time and place. It is also not possible in research to avoid aspects that limit the effectiveness of a research project. It is therefore also important to indicate the delimitations and limitations within which this study was conducted.

- Delimitations.

As this study was about prior knowledge, which was earlier described as pervasive (Dochy & Alexander, 1995), it was important to indicate the delimitations within which it was to be conducted. The study was specifically on "inhibiting effects" of learning by way of the three types of prior knowledge. The three types of knowledge are *declarative knowledge*; *procedural knowledge*; and *conditional knowledge*. According to Marzano and Kendall (2007) "declarative knowledge" is the knowledge of vocabulary terms and facts. A vocabulary term according to these authors refers to a word or phrase about which one has an ‘accurate’ but not necessarily a deep level of understanding. Facts, on the other hand, are seen as presenting information about specific persons, places, things and events. "Procedural knowledge" (Shuell, 1985) and "conditional knowledge" (Alexander, Schallert & Hare, 1991) refer to the individual's ability to do various procedures necessary to complete some task and the understanding of *when* and *where* declarative and/or procedural knowledge is applicable respectively. Any subject, including chemistry, according to Marzano and Kendall (2007) can be described in terms of how much of these three types of knowledge it comprises.

The study was conducted at the Faculty of Sciences of the Tshwane University of Technology. Since the faculty is located at three different campuses and constitutes different fields of study and departments, students of the Department of Chemistry were chosen from one campus, namely Ga-Rankuwa. This campus was chosen because it is where the researcher is stationed and most of the students on this campus are from provinces, which are historically rural, with limited teaching and learning resources in schools.

- Limitations of the study.

The following were significant limitations of the study:

- Prior knowledge by its nature is pervasive. There are different definitions of prior knowledge. Studying prior knowledge therefore requires consistency of definitions and descriptions. In this study, the limitation was that only three types of prior knowledge could be described. Studying prior knowledge is therefore limited by its nature.
- Studying knowledge has the limitation that knowledge is not static; it changes between individuals and within an individual as fast as it is acquired. In this way, the results of the study cannot be replicated. Hence generalisation is not possible.
- Sampling of participants is difficult, as one cannot select an ideal sample for the project. This is so because it could not be predetermined how participants would fare during the study.
- There was limited choice in the selection of the sample as the choice was confined only to those students who volunteered to participate in the project. However, this limitation did not have much impact on the sample composition in terms of gender, geographical location of the students' previous schooling (i.e. provinces) and their performance on the prior knowledge state test.
- As the focus was on students with previously disadvantaged academic backgrounds (generally these are students with poor quality prior knowledge), this became inhibitive, as some participants had inadequate experience to engage sufficiently in discussions between members of the dyad. A detailed discussion on the limitations is provided in Chapter 5.

1.9 Summary

This chapter orientates and highlights the background of the study, the rationale for the study and the specific purpose of the study. The chapter introduces the literature to be covered (in Chapter 2) It also illustrates *what* methods and *how* the methods the researcher intends on using (Chapters 3 and 4). Finally, the orientation explains the significance of the study (in Chapter 5) within the socio-economic and educational realm in which this study is conducted.