

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction.

In the previous chapter the problem to be investigated was outlined, along with the research questions and the aims of the study. Emphasis was placed on the background to the problem, the rationale for the study, the questions to be answered after the study and the purposes of the study.

In this chapter the literature related to the problem investigated is reviewed. The emphasis is on the following four aspects:

- (1). constructivism as the theoretical framework underpinning the study. It gives constructivist's views of teaching and learning, views of knowledge acquisition, and its implications for teaching of chemistry;
- (2). the process of teaching and learning science. It outlines the nature and structure of science and its implication for the teaching and learning of science (chemistry);
- (3). the role, aims and reasons for doing practical work in chemistry. First, a brief description of the role of practical work and its importance in teaching science is given. Then, based on the different types of practical work a critique of the current practices of doing practical work is outlined. Finally, the reasons for proposing the investigation of practical work are given.
- (4). the nature and advantages of micro-science equipment compared to macroscale equipment. The cost-effectiveness as well as environmentally-friendly aspects and manipulative benefits of the microchemistry equipment are compared to macroscale equipment. The key issue is to show how the

microchemistry kits are suitable within a Mozambican context, especially where chemistry lessons are taught currently without practical work.

2.2. Constructivist Theory.

This sub-section gives an overview of the origins of constructivism, as a philosophy and theory of learning. The main theories related to constructivism, and the implications of constructivism are also discussed. The reason for this is that constructivism is the theoretical framework underpinning this study. As a philosophical perspective on knowledge and learning, constructivism is internationally recognized (Jaworsky, 1997).

When writing about the dominance of constructivism over the current educational practice Yeany, cited by Matthews (1998, p. 990) states:

“A unification of thinking, research, curriculum development and teachers education, appears to now be occurring under the theme of constructivism ... there is lack of polarized debate.”

In fact, despite some criticism of the effectiveness of the constructivist theory, the educational system of the majority of countries has adopted it, and much of the current educational research is based on this philosophy and learning theory.

2.2.1. Origins and basic Ideas about Constructivism.

In order to give the psychological roots of constructivism it is inevitable that one should mention the contributions of Piaget (1896-1980) and Vygotsky (1886-1934). The main contributions have been their work in the field of developmental psychology and its implications for education. Due to their focus on psychological aspects of knowledge acquisition, Piaget and Vygotsky are generally considered to belong to the psychological constructivist school of thought.

The table below summarizes the common aspects and differences between Piaget's and Vygotsky's theories.

Table 1: Comparison between Piaget's and Vygotsky's Theories.

Criterion	Piaget's Theory	Vygotsky's Theory
Approach and method	Child-centered approach; Reliance on genetic or developmental method.	
	Inner restructuring of children's thought; child as a lone seeker in interaction with natural world.	Formative influence of society and culture upon children's thoughts. Child masters the world by means of psychological processes through tools offered by adults and culture.
Knowledge	Knowledge is actively constructed through the action of an individual.	
	Action appears first and foremost as a spontaneous physical interaction between child and physical world. The Child is a natural seeker, and creates his own understanding, from concrete to abstract ideas by discovering the effect of his actions on the natural world.	The interaction of the child with physical world is organized and controlled by society and its representatives. In the earliest stages of the child's development the meaning the child makes has sociocultural connotation (viz. parents and other people to whom (s)he relates).
Psychological functioning	Both are against the idea that a child's mind is a sack filled with discrete skills and pieces of information. Both sought a systemic explanation of cognitive functioning.	
	Four main developmental stages of an individual; and Individual operations are elements of a whole system, determined by nature.	Mental development does not coincide with the development of separate psychological functions, but rather depends on changing relations between them. The development of each function depends upon the progress in the development of the interfunctional system.
Learning process	Learning occurs by an unassisted interaction between the child's mental schemas and the objects of the external world.	Learning occurs by collaboration between the child and adults who introduce symbolic tool-mediators to him/her in order to teach him/her how to organize and control their natural psychological functions through these cultural tools.
Role of language	Little influence of language in developmental thinking. Thoughts contribute to development of language.	Cognitive development can be thought of as a dynamic pattern of engagements and there is separation between intellectual and verbal function. Language or signs direct behaviour.

Source: After Kozulin (1998) and after Daniels (1998)

There are two key aspects in which Piaget and Vygotsky agree. Firstly, that knowledge is actively constructed in the mind of an individual; and secondly, that individual structure and external factors play important roles in constructing knowledge through the internalization process.

Although both view learning as an individual and intellectual construction arising from children's activity in the world, they differ in the mechanism by which it occurs. Piaget emphasizes the individual and his/her internal structure, whilst Vygotsky emphasizes the importance of language, society and culture. Because of this position Vygotsky's theory is considered a theory of social cognition or theory of social learning (Matthews, 1994).

When referring to constructivism, much of the educational research literature either classifies it as radical or social constructivism. However, for the purpose of this research report this distinction will not be used, because it is believed by the researcher that they are linked, and in a practical teaching or learning situation one cannot explicitly distinguish one from another. Thus, in this study when constructivism is mentioned, it refers to either theory, except when a specific distinction is made.

Constructivism, as philosophy and theory of learning, impacts on our view of the content of science and this will have direct implications for classroom teaching and learning (Carr *et al.* 1994). For example, Bell and Driver cited by Matthews (1998, p. 990), when comparing constructivist and positivist views of science state:

"Rather than viewing truth as the fit between sense and impression and the real world, for a constructivist it is the fit of our sense impressions with our conceptions: the authority for truth lies in each of us."

This phrase, more than differentiating how the truth is viewed, shows a view of science and scientific knowledge that poses clear challenges to the teachers and learners who use the constructivist approach to aid in the teaching and learning of chemistry.

It is important for teachers and learners who use constructivist view of teaching and learning to clearly state the implications of constructivism. For example, Matthews (1994, p.144), citing Bell & Driver, gives six main points summarizing the constructivist view of learning:

1. Learning outcomes depend not only on the learning environment but also on the knowledge of the learner.
2. Learning involves the construction of meanings. Meanings constructed by students from what they see or hear may not be those intended. Construction of a meaning is influenced to a large extent by our existing knowledge.
3. The construction of meanings is a continuous and active process.
4. Meanings, once constructed, are evaluated and can be accepted or rejected.
5. Learners have the final responsibility for their learning.
6. There are patterns in the types of meanings students construct due to shared experiences with the physical world and through natural language.

Each of these points has practical implications for the teaching and learning of science. But, they need to be elaborated more in order for a teacher or a learner to apply them. The next section outlines other modern theories directly related to constructivism which shed more light on some of the six aspects presented above.

2.2.2. Other Modern Theories Related to Constructivism.

This sub-section presents some modern theories which give more insights and show the applicability of a constructivist view of learning and teaching in a practical teaching and learning environment.

The following theories are considered: situated learning, metacognition, scaffolding and the zone of proximal development (ZPD). Although there are other modern theories of learning; the main reason for selecting these is because they are directly related to the problem investigated in this study. Hence, direct inferences can be made about how to apply them in the teaching and learning of chemistry.

2.2.2.1. Situated Learning.

If learning is about preparing learners to be actively engaged in social life, then what is learned and the environment in which the learning process occur should be based on the local reality and practices. This statement summarizes the key assumption of situated learning as a theory of learning.

As a theory of knowledge acquisition and instructional strategy, situated learning uses an interdisciplinary approach exploring the situated character of human understanding and communication (Lave & Wenger, 1991).

The key ideas of situated learning with regard to the nature of knowledge acquisition and the learning process are well summarized by William Hanks in the foreword to Lave's & Wenger's book (1991):

1. Learning is a way of being in a social world, not a way of coming to know about it. Learners must be engaged, both in the context of their learning and in the broader context. Without this engagement, there is no learning, and where the proper engagement is sustained, learning will occur.

2. If learning is about increased access to performance, then the way to maximize learning is to perform, not to talk about it – demonstration is context-specific and explanation context-independent.
3. The apprentice's ability to understand the master's performance depends not on their possessing the same representation of it, or of the objects it entails, but rather on their engaging in a congruent way.

These three key ideas are still not practical enough to guide teacher's activity in a classroom situation. The table below summarizes the four major premises guiding the development of classroom activities and its main implications.

Table 2: Premises and implications of situated learning in the classroom.

Guiding Premise	Practical Implications
Learning is grounded in the actions of everyday situations.	Learners learn content through activities rather than acquiring information in discrete packages organized by teachers.
Knowledge is acquired situationally and transfers only to similar situations.	Content is inherent in the doing of the task and not separated from noise, confusion, and group interactions prevalent in the real work environments.
Learning is the result of a social process encompassing ways of thinking, perceiving, problem solving, and interacting in addition to declarative and procedural knowledge.	Learning is dilemma-driven rather than content-driven.
Learning is not separated from the world of action but exists in robust, complex, social environments made up of actors, actions, and situations.	Situations are presented that challenge the intellectual and psychomotor skills learners will apply at home, in the community, or workplace.

Source: after Brown *et al.* (1989)

The researcher is in agreement with the multidisciplinary approach advocated by this theory, as well as the use of content grounded in activities related to the context in which the learning is based.

The one objection to this theory is that it overestimates the role of society and context in the learning process, and undermines the role of the person in the learning process. In addition to that the researcher also corroborates the critiques of Anderson *et al.* (1996) on the situated learning when they argue that it is possible to generalize some skills taught in the classroom to outside the school, but that skills practiced outside the school environment are not necessarily generalizable to the environments within the schools.

2.2.2.2. Metacognition.

Metacognition will be referred to in this study as a regulation process. According to Piaget and Vygotsky, it is understanding the process of knowledge acquisition and reflecting on it.

Based on that, metacognition refers to higher order thinking which involves active control over cognitive processes engaged in learning (Manning, 1984). In the classroom situation, the following activities can be considered metacognitive in nature: how to approach a given task, monitoring comprehension, and evaluating progress toward the completion of a task (Livingston, 2000).

Central in metacognition is the constructivist's metaphor that "learning is constructing" (Thomas & McRobbie, 2001). This learning theory is based on the learner-centred approach, the ultimate responsibility for the learning process being on the learners, because it includes thoughts about (1) what he or she does or does not know and (2) regulating how he or she goes about learning a certain subject or task (Huitt, 1997).

The researcher's objection to this theory is that having learners thinking about their capacity to learn, and their success in the past as well as finding out their interest and knowledge in the subject they wish to learn, is a complicated task which requires the active participation of the teacher. In fact, these higher order

thinking processes should specifically be taught by the teacher who should create an opportunity to exercise these activities in the classroom..

2.2.2.3. The Zone of Proximal Development (ZPD).

Vygotsky's contribution to education is well known by his theory of the zone of proximal development (ZPD). Another significant aspect of Vygotsky's work is that he stresses the importance of culture and the central role of language during the learning process (Galant, 1998).

The zone of proximal development (ZPD) is defined as (Wertsch, 1984, p.9, citing Vygotsky):

“The distance between the actual development level determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.”

In summarizing the impact of Vygotsky's theory on teaching Mandana (1998) refers to three main aspects with clear implications for classroom practice:

1. Curriculum should be designed to emphasize interaction between learners and learning tasks.
2. With appropriate adult or teacher help, learners can often perform tasks that they are incapable of completion on their own.
3. Assessment methods must take into account the zone of proximal development. What children can do on their own is their level of development and what they can do with help is their level of potential development. Assessment methods must target both the level of actual development and the level of potential development.

The researcher agrees with the individualized approach of teaching advocated by the ZPD theory because it allows all learners to progress according to their capacities and abilities, one of the key issues addressed in the process of democratization of education. It is an ideal aim of any system of education.

But, there are practical issues around the effective implementation of this theory. Firstly, it takes time for a teacher to work with each learner during a normal teaching period in order to help each one shift from the actual level of development to the potential level of development. The second issue is related to the first one, but it focuses on the ability of the teacher to identify the problems, and coach the learner until he or she can perform by himself or herself the task. The teacher needs to be very perceptive to pick up problems, identify their nature and help the learner to perform the task without his or her help.

In conclusion, it is important to note that the ZPD theory is directly related to the scaffolding theory. In this case, scaffolding refers to the particular kinds of support (teacher, textbooks or other learning material), which should be adjustable to the needs of learners and may be removed once the learners have developed the desired knowledge and skills (Wood, 1986; Scott, 1998).

2.3. The Process of Teaching and Learning Science.

The process of teaching and learning science depends on the nature and structure of the discipline. In fact, Matthews (1998) argues that teachers should understand the nature of their subject, and that teachers' understanding of their subject will influence the way they teach, and consequently the way their learners learn the subject. Hence, the nature of the subject also influences the way the subject is taught and learnt. Therefore, in order to investigate what is being learnt it is important to know the teacher's views of a specific subject (Rambuda, 2002).

In a review of the different approaches used in its acquisition, Chalmers (1982) identifies four different views of scientific knowledge:

1. as proven knowledge (naive inductivism view);
2. as a set of hypotheses to be falsified (based on Popper's theory);
3. as a set of well structured theories (based on Lakatos' and Kuhn's theories),
4. as an incommensurable body of science (based on Feyerabend's theory).

Each of these views is based on its respective philosophical perspective of science and the process of knowledge acquisition. The science teacher will define his or her teaching and learning strategies according to the view she or he holds.

There is a strong link and relationship between chemistry as a science and chemistry as a school subject. One of the operational definitions of chemistry is that it is "a natural science, concerned with the study of properties, interactions and changes of which the matter is composed (McMurry & Fay, 2001, p.3). Below four examples are given to show the nature and structure of chemistry as a science and how it has a direct influence on chemistry teaching.

The first example is given by McMurry and Fay (2001, p.3) when they state:

"In chemistry or any other science, theories are not laws of nature. All they do is representing the explanations of the experimental results that we can come up with at the present time."

In this positivist and inductivist view of science is implicit the suggestion that chemistry is not absolute in character, and that theories are fallible. The perception that teachers and learners have of theories and laws influences their beliefs and attitudes towards science. For instance, many consider the laws and theories of chemistry to be unquestionable truths that exist objectively.

The second example is concerned with the structure of chemistry. In an attempt to define the basic concepts of chemistry, Taber (2001) identified three pairs of

what he considers key concepts in chemistry: elements and compounds, atoms and molecules, and chemical and physical changes. For the author these concepts are so important that he suggests that (Taber, 2001, p.21):

“(1) It is difficult to form a detailed appreciation of chemistry without a fair understanding of what is meant by these terms, and (2) practicing chemists and chemistry teachers without a clear understanding of what these ideas mean.”

The researcher agrees that these concepts are basic for teaching and learning chemistry. Nevertheless, there are other related concepts such as, substance, chemical bonding and structure which are equally important and are explicitly or implicitly present in any chemistry lesson. So, in a practical teaching situation it can be dangerous to reduce basic concepts of chemistry to those presented by Taber. This can lead to teachers and learners giving a lesser focus on other concepts which are equally important but were not named ‘basic concept’.

The third example of how the nature and structure of chemistry has a direct influence on the teaching and learning of the subject is related to its complexity. As Gabel (1998, p. 243) points out:

“In chemistry concepts are usually defined in terms of other previously learnt concepts, and to understand a chemical concept it is necessary to see how it fits into a wider structure of ideas.”

Because of this complexity the author suggests a constructivist approach to the teaching of chemistry by proposing that “students must be helped to make the connection to develop their own conceptual framework.” (Gabel, 1998, p. 243).

The fourth example is related to the levels at which chemistry can be taught. When considering the nature of chemistry education, many researchers have suggested that chemistry can be taught at three different levels (Johnstone & Wham, 1982; Nakhleh, 1994; Gabel, 1998, Anderson *et al.*, 2002): At a macroscopic level (concerned with observable properties of matter), a microscopic level (concerned with the atomic and subatomic particles, such as

atoms, ions, molecules, protons, electrons, etc.), and a symbolic level (concerned with signs, symbols and other graphic representations used in chemistry). These authors have pointed out that students at all Grade levels have difficulty shifting from one level to another, mostly because of their reasoning difficulties or the teaching strategies used.

2.4. Practical Work in Science.

This section of the literature review gives some additional insights into practical work. It deals with three main aspects:

1. ***Historical perspective:*** to show how practical work as a teaching strategy has evolved throughout the different periods in the history of science.
2. ***Aims and purposes of practical work:*** to show what the main reasons claimed for doing practical work are, and to investigate whether or not they correspond to the current practices.
3. ***Types of practical work:*** to show that the practical work done can fall into different categories depending on the criteria used to classify it.

There are many names used to label the same teaching strategy (e.g., practical work, labwork, experimental work, laboratory exercises, etc). In this study the term practical work will be adopted, and it is used to mean “doing experiments or practical exercises with scientific apparatus, usually in a science laboratory” (Woolnough, 1991, p. 3).

2.4.1. Historical Perspective of Practical Work.

This section gives an historical overview of the origins and evolution of practical work since it was established in school science to the present.

The origin of practical work as a teaching strategy is frequently traced back to the middle of the nineteenth century (Woolnough & Allsop, 1985; Hodson, 1990 and Gott & Mashiter, 1991). Since the establishment of practical work in school science, three main periods of development can be identified, these take into consideration the theoretical framework used to do practical work.

Each stage of the development of practical work is briefly described below. It is important to note that the division into three periods mentioned was based on the Woolnough & Allsop (1985) article, “100 Years of Practical work” and also on the Gott & Mashiter (1991) article entitled “Practical Work in Science – a task based approach?”

First period (±1850-1958): The main features of practical work in this period are demonstrations. At first the demonstrations were exclusively performed by teachers rather than learners, up to the ±1920s, and in the later stage of this period were performed by learners individually or in groups. Despite the inclusion of learners, individually or in groups, on doing some demonstrations the aim of practical work remained the same: “to introduce, illustrate or refine concepts”, and “to illustrate concepts or phenomena so that pupils could ‘see’ them in action” (Gott & Mashiter, 1991, p.56).

This approach to practical work was based on the learning theory which maintains that knowledge can be transmitted and that learners have empty minds into which scientific knowledge can simply be transferred.

Second period (±1960-1970): Most of the features of practical work during this period were designed to overcome the dissatisfaction with the way practical work was performed and conceived in the previous period.

The theoretical framework underpinning practical work in this period was the constructivist view of teaching and learning. The basic premise of this theory is

that learning is a personal construct. Based on this an open-ended investigational approach to practical work is advocated, in order to “reveal the mismatch between pupils’ preconceptions and the concepts which are the desired learning objective.” (Gott & Mashiter, 1991, p. 57).

Practical work was undertaken in such a way as to awaken the spirit of investigation, and to develop in the learner the inquiry process used by a scientist, or “being a scientist for a day” (Woolnough & Allsop, 1985, p. 6).

In this period practical work was still linked closely to theory, and was conducted in order to illustrate or derive it. In chemistry, for example, the strategy was to use theoretical principles to predict the outcomes of reactions, and then to test these predictions experimentally (Gott & Mashiter, 1991).

After several decades of implementing this approach to practical work (which is still in practice in many countries today), science education researchers and teachers started showing dissatisfaction with it.

Third period (±1990 –present): This stage can be considered still to be in progress, because it is not yet complete, and in some instances it is merely a declaration of intention with few examples of successful implementation of the principles and ideas advocated rather than the practice of science educators.

This period may be considered as the result of the dissatisfaction with the previous period’s approach. The criticisms were mainly related to the practice and effectiveness of practical work; see for example, Woolnough & Allsop (1985); Tamir (1991); Millar *et al.* (2002) and Niedderer *et al* (2002).

The way considered forward was to bear in mind the process of science, which takes the ‘scientific method’ into account. Science process skills are, thus, advocated to develop procedural knowledge rather than emphasizing the declarative knowledge promoted in the previous period.

According to Millar & Driver (1987, p. 39), there are three main domains for process science:

1. processes applied to investigate phenomena of the world;
2. intellectual processes applied to learn science, and
3. teaching processes that are adopted in classrooms.

When assessing practical teaching situations a research program can focus on one or two or all of the three domains depending on the intent of the study. In this study all three aspects will be considered when assessing the approach used in chemistry teaching.

An alternative approach to traditional practical work suggested by Pavelich and Abraham (1979), Woolnough & Allsop (1985); Tamir (1991); White (1996); Staer *et al.* (1998), Millar *et al.* (2002), and many others in the literature, is the open inquiry laboratory format.

Although relatively new, 'process science', when applied to practical work is considered untenable as argued by Millar & Driver (1987). Thus, if we consider this approach to be the current paradigm, we could consider it to be under scrutiny, and that sooner or later a new paradigm will begin to appear.

Finally, it is important to note that many developed countries have gone through these three periods of development of practical work, and actually fit into the last period. However, depending on the level of development of a country and how practical work is conducted in school science, some countries may be considered still to be in the first or second period.

2.4.2. Aims and Purposes of Practical Work.

In many cases, practical work in school chemistry occupies a large amount of time in the syllabuses (Hodson, 1990; Gott & Mashiter, 1991; Lubben & Millar,

1996 and Staer *et al.* 1998). Due to the importance of practical work (for various reasons) it implies that it should be emphasized in the syllabus.

Despite this emphasis on practical work, there is at present a large amount of research criticizing its current practice, for example, Woolnough & Allsop (1985), Hodson (1990), Lubben & Millar (1996), Johnstone & Al-Shuaili (2001), among many others. Most of the criticisms come from countries with a long tradition of practical work in schools. Lunetta (1998), in his historical perspective on practical work traces the start of this criticism to the 1970s, mainly because there were identified “serious mismatches between goals for science education and learning outcomes visible in schools.” (Lunetta, 1998, p.250).

While there is agreement concerning the importance of practical work for science teaching, in the light of present criticism of current practices there is no unified position about the reasons for doing practical work. Three examples that show the different views about the aims of practical work are given below.

The first example is from Woolnough & Allsop (1985), and is based on psychomotor and ‘process science’. They identify three main aims related to practical work:

1. ***Developing practical scientific skills and techniques:*** according to these authors there are four main skills that need to be developed, namely: observation, measurement, estimation and manipulation. The main assumption underlying this aim is that “one cannot be a craftsman unless one can manipulate one’s tools.” (Woolnough & Allsop, 1985, p.41).
2. ***Being a problem-solving scientist:*** The underlying assumption for this aim is that of developing in the learners the habit of working as a scientist. For that purpose the authors identified four main steps for learners as they work like a scientist: (1) formulate or be given a problem; (2) formulate

possible hypotheses or ideas to solve the problem; (3) select possible ways of testing the hypotheses, and (4) perform and evaluate the results of the experiment.

3. ***Getting ‘a feel’ for phenomena:*** for these authors the reason behind this aim is that “obtaining the knowledge through first-hand experience builds up a more meaningful grasp than can be acquired through theoretical argument alone.” (Woolnough & Allsop, 1985, p. 46).

The second example of the aims of practical work focuses more on psycho-motor aspects, and is given by Pavelich & Abraham (1979):

1. To acquire fundamental techniques and procedures;
2. To have experience with aspects of scientific inquiry; and
3. To enhance learner’s thinking ability toward more abstract thinking processes.

The third example is given by Johnstone & Al-Shuaili (2001), when they address two sets of aims, the first based on psycho-motor skills and the second based on affective aims.

1. To gain manipulative and observational skills, and the ability to plan experiments and interpret experimental data;
2. To develop interest and enjoyment of the subject, and develop a feeling of reality for the phenomena talked about in theory.

These different expressions of the aims of practical work cover essentially three domains: psycho-motor, affective and ‘process science’. The latter being the most advocated domain because of the observed mismatch between the aims of practical work and the outcomes in the former two.

One of the aims of practical work, frequently referred in the 1960s and 1970s is that which claims that practical work can be used to foster conceptual understanding or theoretical aspects treated in the classroom. However, some current researchers on practical work argue that there is little evidence that practical work can contribute to conceptual understanding of a science (Woolnough & Allsop, 1985; Gott & Mashiter, 1991; Tamir, 1991; Johnstone & Al-Shuaili, 2001 and Anderson *et al.*, 2002).

In a statement about the desirable role of practical work and its separation from theory Woolnough & Allsop (1985, p. 38-39) state:

“Stop using practical as a subservient strategy for teaching scientific concepts and knowledge since there are self-sufficient reasons for doing practical work in science and neither these, nor the aims concerning the teaching and understanding of scientific knowledge, are well served by the continual linking of practical work to the content syllabus of science.”

From the statement above we can infer that practical work cannot be used to foster theory or declarative knowledge. Nevertheless, this study endeavors to enquire how practical work can contribute to conceptual understanding of chemistry content. This assumption is based on the idea that:

“The fundamental purpose of any laboratory work is to help students to make links between two domains: the domains of real objects and observable things, and the domain of ideas.” (Millar *et al.*, 2002, p. 9).

In the statement above is implied that during practical work there is a link between theory and the laboratory work performed in which the former is dependent on the latter. This claim, and the claims that practical work can contribute to improving learners' motivation towards chemistry, will be tested in the study.

2.4.3. Types of Practical Work.

As referred earlier, practical work occupies a central place in the science curriculum in many countries. However, practical work in science is varied in type and intention (Millar *et al.*, 2000).

Due to the complexity and variety of tasks performed in the laboratory there are many criteria used to classify practical work. Four different examples of classification of practical work are given below.

First, is the model proposed by Woolnough & Allsop (1985). They proposed a general classification of practical work into four groups, taking into consideration what is intended by teachers and curriculum developers when they do practical work:

1. **Illustration of theory:** practical work is used to support theory;
2. **Exercises:** practical work is used to practice procedures, skills and techniques;
3. **Experiences:** practical work is developed to give learners a 'feel' for phenomena;
4. **Investigations:** practical work is developed to allow learners to experience scientific inquiry, or 'being a scientist for a day'.

The second example of classification of practical work uses the 'level of inquiry' as the criterion. This model, first devised by Schwab and later cited by Staer *et al.* (1998) as well as Millar *et al.* (2002), is the level of inquiry on a rating scale of 4 levels of inquiry (see the table below).

Table 3: Levels of Openness of Inquiry in Laboratory Activities (after Staer *et al.*, 1998, p. 220).

Level	Problem	Apparatus	Procedure	Answer	Common name
0	Given	Given	Given	Given	Verification
1	Given	Given	Given	Open	Guided inquiry
2	Given	Given	Open	Open	Open guided inquiry
3	Open	Open	Open	Open	Open inquiry

The third example takes the ‘openness of the task’ as criterion. This model proposed by Lunetta & Tamir, cited by Millar *et al.* (2002, p.10), identified four types of practical work:

1. whether its overall approach is inductive or deductive;
2. whether it precedes, follows, or is integrated with the related theory;
3. the extent of student co-operation;
4. whether the data is received first- or second-hand or from a simulation.

The fourth example, proposed by Domin (1999), takes into consideration the laboratory instruction styles to identify four types of practical work with three descriptors used to characterize them. The table below summarizes the model proposed by this author.

Table 4: Descriptors of the Laboratory Instruction Styles (Domin, 1999, p.543).

Style	Descriptors		
	Outcome	Approach	Procedure
Expository	Predetermined	Deductive	Given
Inquiry	Undetermined	Inductive	Student generated
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student generated

The four styles given above show a diversity of criteria used to classify practical work. While the second and fourth examples take the task as the key aspect for classification, the first example is based on the aims of practical work, and the third example is based on a mixture of elements. Although based on different criteria, the second and fourth models of classification have many similarities.

There is no model that is better than another; each model has its strengths and weaknesses. It is up to the researcher to choose the model which is suitable to the purposes of classification.

This study will use the first, second and fourth models of classification to investigate the practical work performed by learners in the experimental schools.

2.5. Micro-science Equipment.

In this study the concept of micro-science equipment refers to the microchemistry kits, and it fully embodies the definition given by Singh *et al.* (1999, p.1684):

“Microscale chemistry is a laboratory-based, environmentally safe, pollution-prevention approach by using miniature glassware and significantly reduced amounts of chemicals.”

For the purposes of this study the word “glassware” should be replaced by “plastic”, because the microscale chemistry kits referred in this study are made of plastic and were produced in South Africa by “Somerset Educational”, a manufacturing company, in collaboration with “the RADMASTE centre”, who developed the kits. The acronym RADMASTE stands for “Research and Development in Mathematics, Science and Technology Education”, and it is a centre situated at the University of the Witwatersrand in the Faculty of Science.

Microchemistry kits can be used as an alternative to macroscale equipment. This was clearly shown by Singh *et al.* (1999, p.1684), when they state:

“Microscale chemistry can be implemented without compromising educational standards or analytical rigor, and its techniques are amenable to industrial R&D applications.”

In addition to its educational and analytical effectiveness, microscale chemistry has three main advantages when compared to the traditional equipment (Bradley and Vermaak, 1996; Singh *et al.* 1999; Bradley 1999;):

- Reduce or eliminate the use and production of chemicals;
- Increase laboratory safety, thus it can be performed in a conventional classroom;
- Save time required to perform an experiment and save space required for the storage of chemicals and equipment;

Despite these safety and cost-effective advantages, microscale chemistry has been criticized for the disadvantage of not contributing to the development of specific manipulative skills and techniques related to the handling of traditional equipment such as test tubes, Bunsen burner, burette and other traditional measuring instruments (Bradley, 1999).

Because of its advantages, microscale chemistry kits can be used as an alternative for practical work in schools where traditional equipment is not available. According to Bradley & Vermaak (1996, p.101), microscale techniques were introduced in various African countries with a low profile of practical work, such as Ghana, Kenya, Uganda, Malawi, Zimbabwe and Lesotho. In recent years many other African countries are adhering to the initiative.

In conclusion, it is important to stress that the, microchemistry kits are an extremely viable alternative for schools where no practical work is conducted, or where traditional equipment is used, especially in countries with a low income. Common factors in such countries are: low income per capita; a predominantly rural population; an economy based on primary products; and a relatively recent experience of political independence (Allsop, 1991, p. 31).

Based on these facts the implementation of the microchemistry kits is an attractive possibility for schools in a Mozambican environment, where in many cases, practical work is simply not done regularly because of various problems. Mkhwanazi (2003, p.22), based on a literature review of the studies on practical work conducted in South Africa, identified six main reasons why practical work is not done properly in some schools:

- Shortage of funds;
- Lack of personal and environmental safety;
- Inappropriate teacher competency;
- Syllabus constraints;
- Lack of equipment and
- Lack of services like water and electricity.

These conditions are very likely to be the same or worse in Mozambique, a country with many more problems in its education sector and with a much lower income than South Africa.

2.6. Implication of Constructivist Theory for Practical Work.

As stated at the beginning of this chapter, the underlying learning theory used as the theoretical framework in this study is constructivism.

After describing the nature of science (section 2.3), the aims of practical work (section 2.4.), and the advantages of microscience equipment compared to traditional equipment (section 2.5), it is important to show what are the implications of constructivism on practical work.

The table below summarizes the implications of constructivism on practical work.

Table 5: Propositions of Constructivism and Implications for Practical Work (After Shiland, 1999, p. 107-108).

Propositions of Constructivism	Implications for Practical Work
<i>Learning requires mental activity</i>	Modify labs to increase the cognitive activity of the learner. • Have students identify the relevant variables; • Have students design the procedures or reduce the procedure to the essential part; • Have students design the data table; • Use a standard lab design and the worksheet; • Have students suggest sources of error in the lab and modifications to eliminate these sources of error, and raise questions about the lab.
<i>Naive theories affect learning</i>	Design labs to learn what these are. • Move the lab to the beginning of the chapter; • Have learners make predictions and explain them before the lab.
<i>Learning occurs from dissatisfaction with present knowledge</i>	Design labs as problems to challenge their present knowledge. • Rewrite the lab as single problem whose solution is not obvious.
<i>Learning has a social component</i>	Design labs to include group and whole class activities. • Give the learners an opportunity to discuss their predictions, explanations, procedures, and data table before doing the lab, and give them an opportunity to present their results after lab.
<i>Learning needs application</i>	Design labs to require learners to find or demonstrate applications. • Give learners an opportunity to demonstrate applications after the lab. Learners need opportunities to use new ideas in a wide range of contexts.

The propositions and their implications presented in the table above can guide teachers when planning and carrying out practical work using a constructivist approach.

2.7. Directions from the Literature.

Based on the literature survey conducted in this chapter it is possible to make some inferences which will guide the analysis of the results and the conclusions drawn by the research. In summary, the key aspects of the literature review are:

- 1).** Constructivism is a learning theory which in essence assumes that knowledge is constructed in the mind of the learner.

This assumption has many implications for the teaching and learning of science. For example, (1) it is necessary to define the content of the lesson based on the context of the learner (situated learning), (2) the learner should know his or her potential within the learning process (metacognition), and (3) the teacher and his or her colleagues should help learners to overcome difficulties faced when performing a task (scaffolding and ZPD).

- 2).** The nature and structure of a subject determines the way in which the subject is taught or learned. Views held by the teachers will influence the way in which he or she teaches the subject.

Chemistry is a complex discipline. It has some basic concepts which the learners must know if they want to understand it meaningfully. In addition to that, many concepts within the field of chemistry are highly related to others and learning one concept depends on the pre-requisite knowledge of another.

There are three levels in which chemistry can be taught: macroscopic, microscopic and symbolic. Learners often have difficulty understanding the representation of matter as well as reasoning from one level to another.

- 3).** Practical work has been recognized as a key component and strategy when teaching school science since the middle of the nineteenth century. During its more than 125 years of existence, three main periods of development can be identified.

Despite its recognized importance in teaching school science, there are divergent opinions about the aims and purposes for doing practical work, some focusing on psycho-motor aspects, others on affective aspects or a combination of both; but most researchers are sceptical about practical work's ability to contribute to conceptual understanding.

- 4). There are different types of practical work. The criteria used to classify practical work range from aims, degree of freedom, level of inquiry and level of openness of a laboratory task. This research will use the aims proposed by Woolnough & Allsop (1985), and levels of inquiry outlined as guiding models for the classification of the practical work performed by the learners during the field study.

Propositions of constructivism can be used to infer practical guiding principles for teachers who intend to use the constructivist view of teaching and learning practical work.

- 5). Microscience equipment, because of its relatively low cost, reduced amounts of reactants, relatively low impact on the environment, and easy to handle qualities can be used as an alternative means of teaching practical work in countries with low income.

2.8. Conclusion.

This chapter has reviewed literature related to the problem investigated in this study: The Lack of practical work in chemistry teaching in Mozambican junior secondary schools.

The information gathered in this literature review will be used as the theoretical framework to judge the data collected from the field (chapter 4 and chapter 5).

From that perspective, conclusions will be drawn in order to verify the extent to which the objectives were achieved and to find the answers sought for the research questions.

The next chapter describes the instruments, procedures and design used to investigate the problem of the study.