DEVELOPING INSTRUCTIONAL MATERIALS THAT ADDRESS CHALLENGES FACING TEACHERS IN SECONDARY SCHOOL CHEMISTRY INVESTIGATIVE PRACTICAL WORK; A CASE OF KAJIADO COUNTY, KENYA

By:

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DECLARATION

I confirm that his thesis is my original work and has not been presented in any other university/ institution for certification. The thesis has been complemented by referenced works duly acknowledged. Where text, data, graphics, pictures or tables have been borrowed from other works- including internet, the sources are specifically accredited through referencing in accordance with anti-plagiarism regulations.

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DEDICATION

I dedicate this work to my mother Hella, my husband Peter and my children Pamela and Lewis; you are a great source of inspiration.

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I am greatly indebted to my supervisors, Prof. Nicholas Twoli and Dr. David Khatete, for their guidance, patience and constant encouragement throughout the development of this work. I thank them most sincerely for their resourceful contribution towards the completion of this study.

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ABBREVIATIONS AND ACRONYMS

ADDIE	Analyse, Design, Develop, Implement and Evaluate.
AQA	Assessment and Qualifications Alliance
CDC-HKEAA	Curriculum Development Council-Hong Kong Examinations and Assessment Authority
CERG	Chemical Education Research Group
DBR	Design-Based Research
DBRC	Design-Based Research Collective
IDM	Instructional Design Model
KCSE	Kenya Certificate of Secondary Education
K.I.C.D	Kenya Institute of Curriculum Development
K.I.E	Kenya Institute of Education (currently KICD)
KNEC	Kenya National Examinations Council
MOE	Ministry of Education
NSTA	National Science Teachers Association
SCIPW	Secondary Chemistry Investigative Practical Work
SCORE	Science Community Representing Education
SMASSE	Strengthening of Mathematics and Science in Secondary Education
STSE	Science, Technology, Society and Environment

ABSTRACT

Secondary school Chemistry teachers use various instructional materials to guide the teaching of Chemistry practical work. Many of them however face some challenges in their endeavor to implement investigative type of practical work in their classes. They often require instructional materials that would support the implementation of learner-centred investigative practical work. The purpose of this study was to develop a model of exemplary instructional materials that can support secondary school Chemistry teachers in engaging learners in investigative practical work by addressing the challenges they faced when teaching practical work. The study is based on constructivist theory of learning which proposes meaningful learning by construction of knowledge gained through context-rich, experience-based activities. The study used Design Based Research (DBR) design methods for analysis, design, development and evaluation of the exemplary materials. DBR uses iterative design to develop workable interventions in educational practice. Forty two (42) government secondary schools in Kajiado County formed the target population. Baseline data revealed that teachers needed support in content knowledge, scientific practices, scientific literacy practices and teaching strategies for participation practices and for assessment of learning. Instructional materials for a total of six lessons were designed as derived from the Form one Chemistry topic on acids, bases and indicators. The first prototype of materials designed was appraised by 47 chemistry teachers in pre-service training, three experienced Chemistry teachers and two Science Education experts from the University. The feedback was used to redesign and refine the materials producing the second level prototype which was tried out by three other teachers with their Form one students. Feedback gathered from the try-out was used to re-design and refine the instructional materials leading to production of a third level prototype that was used by five teachers as the practicality and effectiveness of the materials was evaluated. Lesson observation, teacher's logbook, teacher interviews, learner questionnaire and concept maps were used to determine the practicality and effectiveness of the materials in a classroom set-up. The instructional materials were found to contain guidelines that teachers could use in guiding learners through investigative practical work. Teachers indicated that their objectives were achieved and learners were motivated to learn chemistry and were able to understand the concepts. The feedback was used to redesign the materials thus developing the final model of exemplary materials. The structure of such materials was detailed and a model for the development of instructional materials for investigative practical work referred to as Secondary Chemistry Investigative Practical Work (SCIPW) proposed. Chemistry teachers can use the model to develop materials that guide them through use of learner centred strategies in practical work. Developers of instructional materials should also use such experimental structures that support investigative practical work.

CHAPTER ONE

INTRODUCTION AND BACKGROUND OF THE STUDY

1.1. Introduction

This section considers the background, meaning and justification of the study. The chapter provides background to the study, rationale for the study, statement of the problem, objectives of the study and research questions. Consideration is also given to the significance of the study, assumptions of the study, scope and limitations of the study, theoretical framework, conceptual framework and definitions of key terms.

1.2. Background of the Study

Chemistry is a branch of science taught at secondary school level in many countries including Kenya. Chemistry knowledge and skills are useful in many areas of human life such as food production, better health, better social living conditions and industrial production (Gili, 2010; Twoli, 2006). Effective teaching and learning of Chemistry is therefore of paramount importance.

The government of Kenya recognizes the importance of science in technological development and is therefore committed to implementing strategies that will ensure the provision of quality education (Ministry of Education Science and Technology, 2005). However, performance in Chemistry at Kenya Certificate of Secondary

Education (KCSE) level has been low over the years, as evidenced by KCSE performance results in Chemistry theory and practical papers shown in Table 1.1.

Table1.1. National KCSE Chemistry performance for the years 2006 to 2012

YEAR	**Theory Paper 1** (Maximum Score 80)	**Theory Paper 2** (Maximum Score 80)	**Practical Paper 3** (Maximum Score 40)	**Mean Score** (Maximum Score 200)
2012	22.36	17.18	**16.38**	55.92
2011	18.43	16.99	**11. 91**	47.31
2010	18.78	16.19	**14.87**	49.79
2009	12.49	14.93	**10.86**	38.23
2008	18.28	15.74	**11.46**	45.48
2007	19.67	19.22	**11.82**	50.78
2006	20.79	17.56	**11.48**	49.82

Source: Kenya National Examinations Council (KNEC) 2007-2012 Reports

From the table, it can be noted that student performance in Chemistry has been very low over the years with the practical papers posting very low grades. Though a steady increase of mean scores in the last three years is observed, the grades are still very low.

Of particular concern was the performance in Chemistry subject in Kajiado County. Table 1.2 shows the student performance in Chemistry in Kenya Certificate in

Secondary Education (KCSE) examinations for Kajiado County for the period 2006 to 2011. The available data was in terms of points from a grading system where ‘A’ represents the highest grade of 12 points and E represents the lowest grade of 1.

Table 1.2: Kajiado County performance in Chemistry for the years 2006 to 2011

Year	2011	2010	2009	2008	2007	2006
Mean Score (Maximum score 12 points)	3.52	3.39	3.49	3.46	3.74	3.82

Source: Kajiado County Education office.

The table shows a worrying trend in that the mean score is very low. Practical examination has great influence on Chemistry performance because the examining body; Kenya National Examinations Council (KNEC) has a policy in place that the candidate must attain a mean grade that is not lower than a D+ in the practical paper (D+ represents four points out of a maximum score grade A which is twelve points) in order to achieve an average mean grade of B (9 points) in the Chemistry subject (KNEC Examination Regulations, 2012). The yearly KCSE examinations reports have also pointed out weaknesses in theory questions where learners were expected to give precise descriptions of procedures drawn from practical experiences (KNEC, 2008; KNEC, 2011; KNEC, 2012). This shows that poor performance in the practical paper affects the overall performance in Chemistry.

These reports have constantly advised teachers to expose learners to more practical work that involves investigations (KNEC, 2008; KNEC, 2011; KNEC, 2012). One such report (KNEC, 2008; 103) concluded:

> Teaching of Chemistry as a science subject should be approached by use of investigatory methods. Experiments should be performed in all topics that demand them. Discussions of results and clear explanations should be given after every experiment.

The poor performance in Chemistry can therefore be attributed to lack of quality practical activities among other factors. Achimugu, (2009) related poor performance in Chemistry to the teachers' inability to conduct quality practical sessions. Lack of adequate instructional materials has been found to affect the quality of practical work carried out in schools (SCORE, 2007; Orado, 2009; Nyangai, 2010),

1.2.1. Scope of investigative practical work in secondary school Chemistry

From the learner's performance (Table 1.1), it can be assumed that the method used to teach practical work does not achieve the objectives of chemistry learning in secondary schools. This could be due to the nature of practical work activities carried out. Continued poor performance in chemistry in developing countries has therefore attracted a great deal of interest of educators and researchers. In an effort to improve performance, active student-learning approaches such as investigative inquiry have been emphasized in all forums of education (Trowbridge et al, 2004).

There has been continued reform in science education world over geared towards investigative approaches of science learning which involves practical work (SCORE, 2007). Trowbridge et al (2004), argue that the notion of investigative inquiry approaches to learning the content and process of science has been central in the recent years yet the challenges to investigative teaching are still evident and the shift from traditional expository methods has been very slow. Krajcik et al (2003) claim that the approaches of pedagogical reforms to bring inquiry into classrooms present core challenges for the field of science education. They, therefore, point out that research-based curriculum materials can address these challenges and provide improved tools for learning for teachers and students through development of appropriate instructional designs. Instructional design is the entire process of creating instructional materials in a consistent and reliable fashion in order to facilitate learning most effectively. Jonassen, (1999) defines instructional design as the application of theory to create effective instruction.

1.2.2. The role of curriculum materials in Chemistry investigative practical work

Instructional materials serve as learning materials for both students and teachers. They can serve as a primary source of science content, present specific views about the nature of scientific practices, and how scientific knowledge is developed. Materials can also serve as a primary influence on how teachers should teach science (Krajcik et al, 2003). A study by Grossman & Thompson (2004) found that the teachers spent an enormous amount of time searching out curriculum materials for their classes and that the curriculum materials they encountered did, indeed, powerfully shape their ideas about teaching and classroom practice. Curriculum materials also provide potential learning opportunities for the teachers who use them (Ball & Cohen, 1996). Teachers have long been dependent on textbooks to help guide their instruction. Yet textbooks are not necessarily of high quality and can limit, rather than support the teachers' strategies.

Several reviews of curriculum materials have presented a rather grim view of the value of science instructional materials (Krajick et al, 2003). Kesidou & Roseman, (2002) showed that the materials they examined covered many topics at a superficial level, focused on technical vocabulary, failed to consider students' prior knowledge, lacked coherent scientific explanations of real-world phenomena, and provided students with few opportunities to develop explanations of phenomena. Yandila et al (2003) quoted teachers as facing difficulties in implementation of learner-centred approach due to, among other factors, lack of exemplary teaching materials and inappropriate textbooks. A study by Krajcik et al (2007), found that curriculum materials available did not build on student-learning investigation.

Curriculum materials are considered an important tool for teachers attempting to change their teaching practice (Ball & Cohen, 1996; Ottevanger, 2001; Motswiri, 2004). It is important for teachers to be supported through exemplary instructional materials into changing their current practice to inquiry approaches that involve investigations. Van den Akker (1998) and Ottevanger (2001) observed that teachers needed help with lesson preparation, subject matter, teaching sequence and learning effects. In their view this can be done through use of appropriate instructional materials.

Various studies aiming to explore the characteristics of effective exemplary curriculum materials indicate that they support a positive effect on teachers' implementation efforts (Gallagher, 1999; Ottevanger, 2001; Motswiri, 2004). Studies by Van den Akker (1988), Motswiri (2004), Bekele & Melesse (2010) and Sunzuma et al (2012) indicated that curriculum materials that contain large amounts of specific and concrete guidelines on how to plan, organise and conduct a lesson can have great potential in supporting teachers in innovative curriculum implementation. Krajcik et al (2007), Karaduman & Gültekin (2007) and Motswiri, (2004) claim that exemplary materials based on learner-centred activities enhance learning and support teachers in preparation and conduct of lessons.

Curriculum materials such as textbooks and laboratory workbooks containing proper guidelines in organizing and supervising investigative activities could ease teachers' work in planning and carrying out practical lessons thus encouraging teachers to use the learner-centred teaching approaches. Using the cited experiences, there is need, therefore, to develop a model of appropriate curriculum materials for investigative practical work in secondary school Chemistry.

1.3. Statement of the Problem

A lot of time and resources have been invested in programs geared towards improving science learning in Kenya with a view of enhancing technological development of the nation. Concerns have, however, been raised over continued poor performance at the end of course examination (as shown in table 1.1). A number of studies have been carried out to establish the causes of poor student performance in Chemistry in KCSE examinations (Orado, 2009; Nyang'ai, 2010; Achimugu, 2009; Kamau, 2004; Inzahuli, 2007). Some studies have associated poor performance in Chemistry with low quality practical work (Hofstein, 2004; Hattingh et al, 2007; SCORE, 2008; Orado, 2009; Bekele & Melesse, 2010; Sunzuma et al, 2012). The results of the studies point to some of the factors that affect quality practical work as poor teaching strategies and lack of quality and adequate learning materials.

Acting on recommendations of various studies, the Kenyan government invested in science education through science teacher in-service training project known as Strengthening of Mathematics and Science in Secondary Education (SMASSE) (Ministry of Education Science and Technology, 2005). The in-service training equipped teachers with the necessary skills to develop good teaching practices and encouraged them to use learner-centred teaching approaches. The teachers however, have not been able to interpret and translate student-centered learning into practice (Kisangi & Ateng', 2006). Chemistry learning is still highly characterized by lecture method; where practical work is implemented, it only requires students to follow instructions developed by the teacher or from textbooks instead of allowing students to engage in lesson activities in a meaningful way (Motswiri, 2004). Orado (2009) also argues that the practical activities the students were involved in fostered the acquisition of mainly basic scientific skills leaving out key integrated scientific skills such as experimental design and hypothesis formulation. Motswiri (2004), notes that even in cases where resources such as chemicals and equipment are available, practical work in schools does not involve investigative type of instruction.

According to Brush & Saye (2000) active participation of students through investigations brings an inquiry learning approach to classroom instruction. Hubber & Moore (2001) argue that 'hands on' activities in science practical work do not guarantee scientific investigation. The common laboratory experiments where procedures are provided to be followed step by step do not provide enough opportunities for students to use their minds to solve problems. They may therefore not develop science process skills and conceptual understanding of the content matter (Chiapetta & Koballa, 2010; Hubber & Moore, 2001; Trowbridge et al, 2004). These activities can however be extended to investigation by using teacher supported brainstorming activities to guide learners in planning investigations and allowing the learners to provide a product of their investigation and to present it in class.

The suggested approach to practical work may require a model of materials that guide both the learners and the teachers through appropriate investigative activities. There is however, almost no concrete research in Kenya that has provided such model of instructional materials. Other studies on Chemistry practical work in Kenya seemed to focus attention on factors not related to the ability of Chemistry curriculum materials in supporting investigative practical work (Thiong'o, 1986; Orado, 2009). There is no comprehensive study done in Kenya to determine the relationship between instructional materials and the quality of practical activities carried out by secondary school Chemistry teachers. There is need therefore, for such a study to provide teachers with exemplary instructional materials that contain a large amount of specific and concrete guidelines for the teacher on how to plan, organise, and conduct practical lessons.

This study provides teachers with insights into characteristics of exemplary materials aimed at engaging learners in designing and carrying out investigative practical activities. Such activities can develop process skills and boost conceptualization, thus boosting performance in Chemistry. The teachers can use the model of the exemplary materials to develop materials in all areas of practical learning in Chemistry and other science subjects. The use of curriculum materials with such guidelines has also been explored in the context of South Africa, Namibia (Ottevanger, 2001) and Botswana (Thijs, 1999 and Motswiri, 2004). Results of these studies show that exemplary curriculum materials can be a useful support tool for teachers' implementation of teaching strategies and can help them to organise and execute learner-centred lessons adequately. Thijs (1999) found that as a result of using such materials, teachers also generated new ideas on ways to increase student involvement in their lessons. This can be regarded as one way of empowering teachers in developing and managing Chemistry instructional materials for practical lessons.

1.4. Purpose of the Study

The purpose of this research was to develop exemplary curriculum materials that would influence secondary school students' participation in Chemistry practical work. This entailed coming up with a model for the development of the materials for practical work that engaged learners in designing and carrying out investigations in Chemistry.

1.5. Objectives of the Study

The specific objectives of the study were;

1. To find out the current practices in the teaching of Chemistry practical work in secondary schools.

2. To find out the opportunities provided by curriculum materials for support of investigative practical work in Chemistry.
3. To identify the challenges that Chemistry teachers faced in the use of learner-centred investigative practical work in Chemistry.
4. To develop an instructional model for constructing instructional materials that support teachers in the use of investigative practical work in secondary school Chemistry.

1.6. Research Questions

To achieve the objectives of the research, the researcher attempted to answer the following research questions:

1. What were the current practices in the teaching of Chemistry practical work in secondary schools?

2. What features in the curriculum materials provided opportunities for support of investigative practical work in Chemistry?

3. What challenges did teachers face in the teaching of investigative practical work in Chemistry?

4. What are the characteristics of a model that can be used in the development of instructional materials for investigative practical work in secondary school Chemistry?

1.7. Significance of the Study

The results of this study are useful to a variety of persons. One group is secondary school Chemistry teachers in evaluating their teaching strategies and recognizing strengths and weaknesses in their current practice. The study has provided an exemplary model for development of instructional materials which provides a framework for effective teaching of Chemistry practical work. The teachers can use the model materials as a guide in preparing their own instructional materials applicable to their particular classes thus shifting teacher practice in practical work from providing ‘hands on’ learner activities to learner-centred investigations.

Further, the study provides insights to designers of instructional materials on the type of materials that would support teachers in conducting learner-centred investigative practical activities that engage learners intellectually. The findings of the study help curriculum developers and education policy makers to recgnise the need for development of Chemistry curriculum and assessment practices that enhance student-based practical learning.

The findings of this study can also guide teacher trainers in equipping the teacher trainees with appropriate skills useful in preparation of instructional materials that provide student-centred practical work in schools.

1.8. Limitations and Delimitations

The materials developed for this study were based on one topic in the Chemistry content syllabus. This is because in depth understanding of the characteristics of the materials was required. The iterative nature of the DBR design used in the study also required developing prototypes of the same materials. However, since the study allows successive reviews of the materials, it was possible to identify and overcome weaknesses in the design of the materials. Once the characteristics of such materials are outlined, more materials can be constructed from other topics in the Chemistry syllabus and other science subjects.

The study covered practical work in Chemistry particularly the ability of instructional materials to support the teachers in implementing investigative practical learning. The study did not cover student-centred learning of theoretical concepts in Chemistry. This is because many Chemistry concepts can be demonstrated practically and therefore if the teachers use student-centred investigative approaches, most teaching would involve practical activities that make conceptualisation of theoretical ideas easier.

The instructional materials referred to in this study are the written curriculum materials such as textbooks and laboratory manuals. Other physical resources were not considered in the study. The experiments involved in the study can easily be carried out using simple improvised apparatus even in the absence of Chemistry laboratories.

1.9. Assumptions of the Study

This study was based on the assumption that a good number of Kenyan government secondary schools offered Chemistry or physical science (Chemistry option) as a teaching subject. This is because the system of education that is used in Kenyan government schools require that students learn all the three sciences (Physics, Chemistry and Biology) in the first two years of secondary education and at least two of these subjects up to the final year of their secondary education (KIE, 2006; Wosyanju, 2008).

1.10. Theoretical Framework

The purpose of the study was to provide insight on instructional materials that would support learner-centred type of investigative practical work in secondary school Chemistry learning. This intention suits the constructivism theory of learning which propose meaningful learning for students. Constructivism is a philosophy of learning founded on the premise that, by reflecting on their experiences, the learners construct their own understanding of the world they live in. Learning is simply the process of adjusting their mental models to accommodate new experiences (Smith & Ragan, 1999). Constructivism is considered to be a learner-centered theory that focuses on the knowledge of interpretation and experience-based activities (Brooks & Brooks, 1999).

Constructivism is a synthesis of multiple theories fused into one form. It is the assimilation of both behaviourist and cognitive ideals. A number of theorists developed constructivism theory. According to Kliebard (1992), Dewey created an active intellectual learning environment in his laboratory school during the early 20th century. He argued that active learning conditionalises knowledge through experiential learning. Piaget, (1956) believed that knowledge is the ability to transcend what one knows into a broader or improved understanding of material and the experiences in which the material is presented. Piaget was of the view that knowledge was constructed in the mind of the learner through a process of adaptation which is the ability to adjust to one's environment. It is therefore necessary for practical work and learning materials to be based on learners' prior knowledge. Vygotsky (1978) is known for introducing scaffolding and the zone of proximal development into classrooms. The zone of proximal is referred to as the distance between a child's independent learning abilities and the learning that is guided or from a more knowledgeable other. This can be attained through collaborative, cooperative and problem based learning.

Group learning is emphasized as a part of constructivist practice because emphasis on student's pre-existing knowledge makes it important for students to make their knowledge explicit. This can be done by encouraging them to voice their thoughts and ideas to peers creating awareness of one's own self-knowledge and self-learning often referred to as "metacognition". Group learning provides the social context consistent with the basic constructivist notion that learning occurs within a given context. Contextualized learning is learning that relate to real life, "authentic", tasks. Classroom activities should therefore relate to real world application (Hall, 2014). During investigative practical activities knowledge is socially constructed through human interaction, shaped by context and purposes, and validated through a process of negotiation within each other. This fulfils constructivist learning requirements.

Social constructivism used in educational settings stresses interaction over observation. Student discussions in the classroom are grounded on social constructivism. Discussion plays a vital role in increasing student ability to test ideas, develop reasoning skills and build deeper understanding in learning.

Teaching is facilitating students' learning by creating a learning environment conducive to inquiry, setting up problem-solving situations to stimulate both student interest and cognitive thinking about important scientific ideas, and supporting students' attempts to solve problems (Jonassen, 1999). This leads to a more learner centered approach, with the teacher as a guide and facilitator of learning rather that the sole source of knowledge. Further, in a "constructivist classroom" students are freer to participate in the planning and, even, the assessment process. Figure 1.1 summarises constructivism theory of learning.

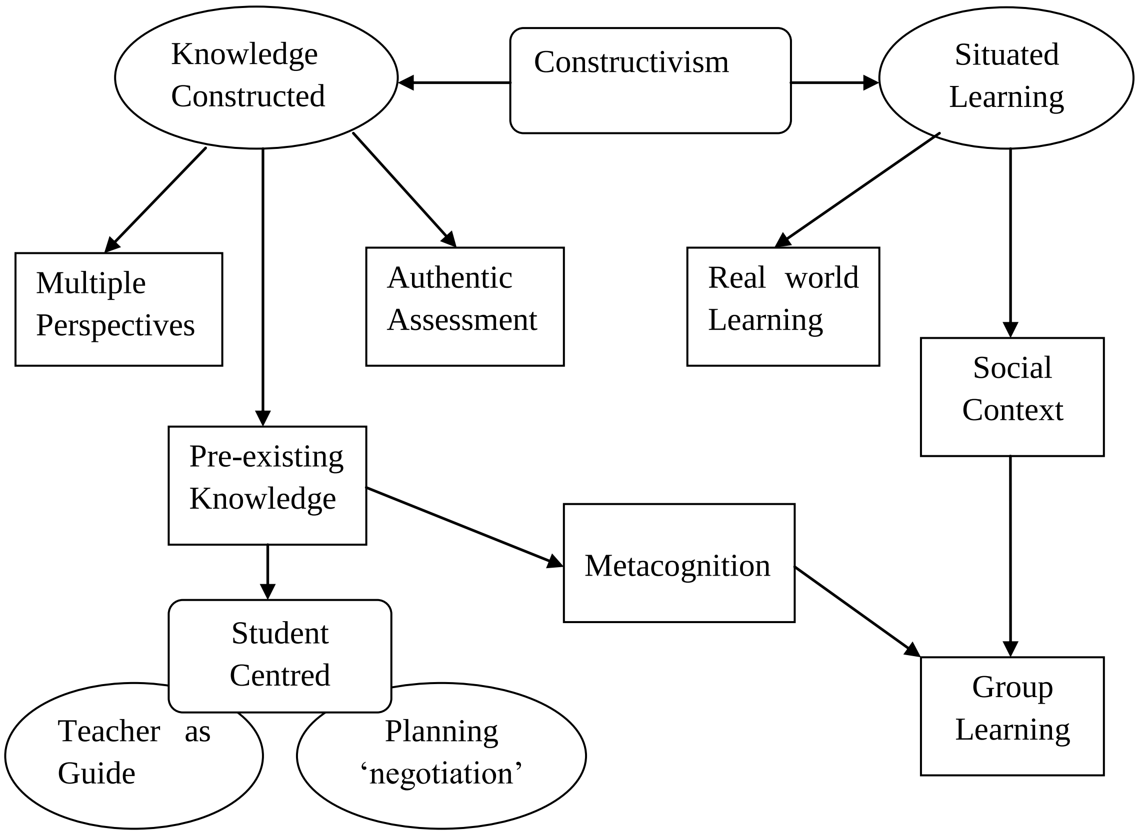

Figure 1.1: Constructivism theory of learning (Source: Hall, 2014)

Fundamentally, constructivism indicates that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. This implies that learning in constructivist environment is an active process where knowledge is constructed from (and shaped by) experience and emphasizes problem solving and understanding through use of authentic tasks, experiences, settings and assessments (Christie, 2005; Brooks &

Brooks, 1999). Learning involves collaboration between instructors, students and resources but is a personal interpretation of the world that builds on the learner's prior knowledge and experiences developing life-long learning (Christie, 2005). Constructivist learning therefore iindividualizes and contextualizes students' learning experiences, uses authentic tasks to engage learners, helps students develop processes, skills and attitudes, requires negotiation of meaning. It also focuses on knowledge construction, not reproduction, provides for meaningful, problem-based thinking, requires reflection of prior and new knowledge and extends students beyond content presented to them (Hall, 2014; Christie, 2005; Brooks & Brooks, 1999; Jonassen, 1999).

The findings of a research carried out by Hidir & Gultekin (2007) on the effect of constructivist learning principles based learning materials on students' attitudes; success and retention indicate that constructivist principles-based learning materials increase students' academic success and retention in learning. Learner-centred teaching practices recommended by examiners in KNEC reports are grounded in views of knowledge, learning and teaching informed by a constructivist perspective (Brooks & Brooks, 1999). The principles of constructivism form basic considerations in the preparation of instructional materials for use in science classrooms (Jonassen, 1999).

1.11. Conceptual Process

For learning to be effective, appropriate learning activities should be carried out. These activities should be based on learner engagements as proposed by constructivism. Designing such learning activities require a consideration of learning goals, learning materials, teaching strategies and assessment practices (Sunal & Haas, 2002). Considering that this study aimed at providing a model for developing learner-centred practical work materials, the study focused on instructional design strategy that involves designing, developing and evaluating instructional material prototypes. Such developmental research characterizes the situation with all its complexity instead of identifying a few variables to hold constant (Aksela, 2005; DBRC, 2003). This design consist of multiple dependent variables including climate variables such as collaboration among learners and available resources; outcome variables such as learning of content and system variables such as dissemination systems, and learner characteristics (Barab & Squire, 2004).

The variables may therefore not be distinctly separated and handled on their own (Aksela, 2005; Barab & Squire, 2004). However, the study considered the content of instructional materials for practical work with an aim of finding out the characteristics in these materials that support investigative type of practical work. It also considered teaching strategies currently used by teachers (including student engagement in designing practical work) and challenges that teachers faced in teaching practical work as the conditions of the complex independent variables while a practical model for the understanding of concepts and acquisition of skills (learning outcome) were handled as the outcome of manipulation of the content of instructional materials. The proposed instructional strategies were designed in instructional materials and developed through various stages of refinement. The study involved prototyping and refining of prototypes in a cyclic approach of design (Ottevanger, 2013). The study is therefore conceptualised as shown in Figure 1.2.

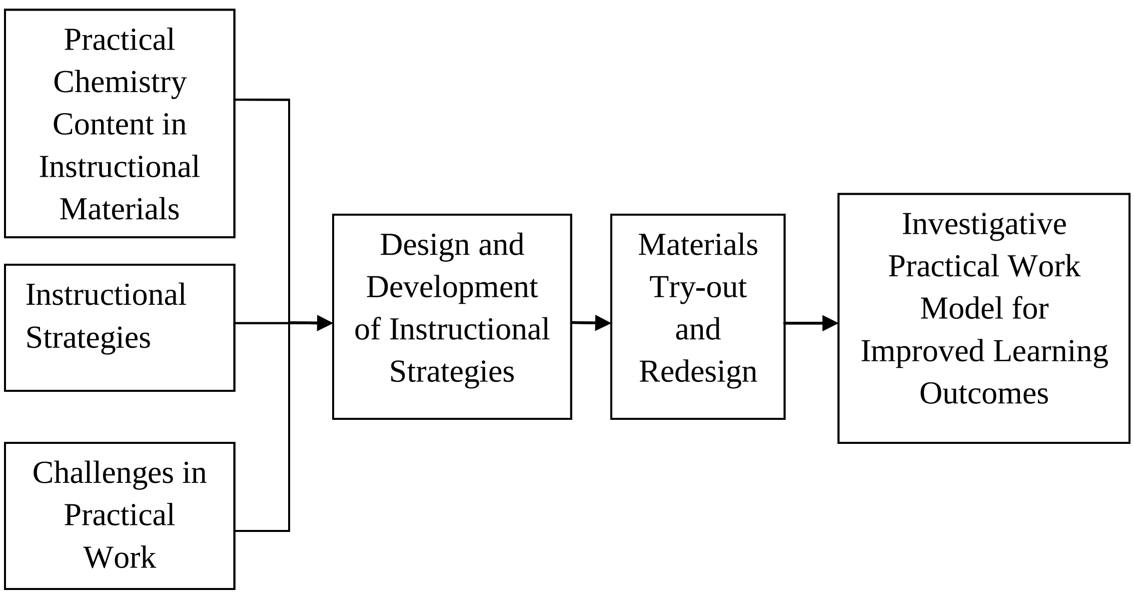

Figure 1.2: Conceptual process of the study (Adapted from Reiser et al, 2003 & Ottevanger, 2013)

The practical work materials developed were used to support the teachers in facilitating more student-centred investigative practical work in their chemistry classrooms. The instructional materials were designed around a system of key design principles for supporting ambitious learning in science (Reiser et al, 2003). The process involved identifying learning content, producing an instructional sequence including both student and teacher materials, reviewing the materials, testing materials with teachers, evaluating the materials for practicality and effectiveness in supporting investigative practical work and redesigning the materials to produce a model for investigative practical work.

1.12. Operational Definitions of Key Terms in the Study

Concept map- a tool that illustrates the connections of concepts as understood by the map creator.

Constructivism- a philosophy of learning founded on the assumption that learning is a process of constructing meaning of a new experience based on prior experiences.

Contextualized learning- Learning that takes place when teachers present information in a way that students are able to construct meaning through practical activities based on their own experiences.

Curriculum/instructional materials - learning materials that a teacher or learner would use in the courses in order to teach or learn Chemistry; these include textbooks and laboratory manuals.

Instructional design- a construct referring to step by step prescriptive procedure for creating instructional materials in a consistent and reliable fashion in order to facilitate learning most effectively.

Interactive teaching- Teaching that allows feedback, reflection and dialogue which encourages students to put together knowledge and skills by connecting with information and experiences provided by the teacher scaffolding.

Iteration- the repetition of a process or a procedure applied to the result of previous application typically as a means of approaching a desired target or result.

Meaningful learning-implies that as a result of instruction, the learner is able to relate new materials to previously acquired learning, and see the new knowledge in the light of what they already know and thus find new meaning.

Pedagogy- the method and practice of teaching and concerns the study and practice of how best to teach.

Prototype – an early model of instructional materials built to test the process of construction of instructional materials from which practical work model materials are formed.

Scaffolding- is the support given during the learning process which is tailored to the needs of the students with an intention of helping the student achieve his/her learning goals.

Student-centred learning- an approach to education focusing on the needs of the students, rather than those of others involved in the educational process, such as teachers and administrators.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

In this chapter the literature related to the importance of practical work and development of instructional materials based on constructivism for teaching practical work is reviewed. The chapter provides the theoretical understanding necessary for the development and use of instructional materials for Chemistry practical work. A brief description of the importance of investigative practical work is highlighted. Then, a critique of the current practices of doing practical work is developed and the challenges that Chemistry teachers face in the teaching of Chemistry through practical work are outlined. The nature of materials used in teaching Chemistry and their effectiveness in achieving learner-centred practical learning is also discussed. The key issue is to show how practical lessons can be structured to support learner-centred investigative practical work and how such materials can be developed.

2.2. The Role of Learner-Centred Investigative Practical Work in Chemistry

The learning of Chemistry has been found to be most effective when it involves hands-on activities. Stoffelsma & Kwetu (2004) pointed out that scientific knowledge is best developed from practical experience perspective. Science educators have suggested that there are many benefits accruing from practical work. It arouses curiosity and maintains interest in Chemistry, helps students develop science process skills, promotes development of scientific attitudes, reinforces theory, helps development of manipulative skills, enhances understanding of concepts and principles, encourages participation in class and helps verify laws and theories (Hofstein, 2004; Millar, 2004; Twoli, 2006; Achimugu, 2009). Students usually enjoy practical work in the laboratory and, when offered a chance to experience meaningful learning experiences, they become motivated and interested not only in their laboratory assignment but also in studying science.

There are many ways in which practical work can support learning in science. SCORE (2009) identifies some of these as; development of skills, development of personal learning and thinking skills, experiential learning and independent learning (Figure 2.1). Any single activity might focus on one or more of these purposes.

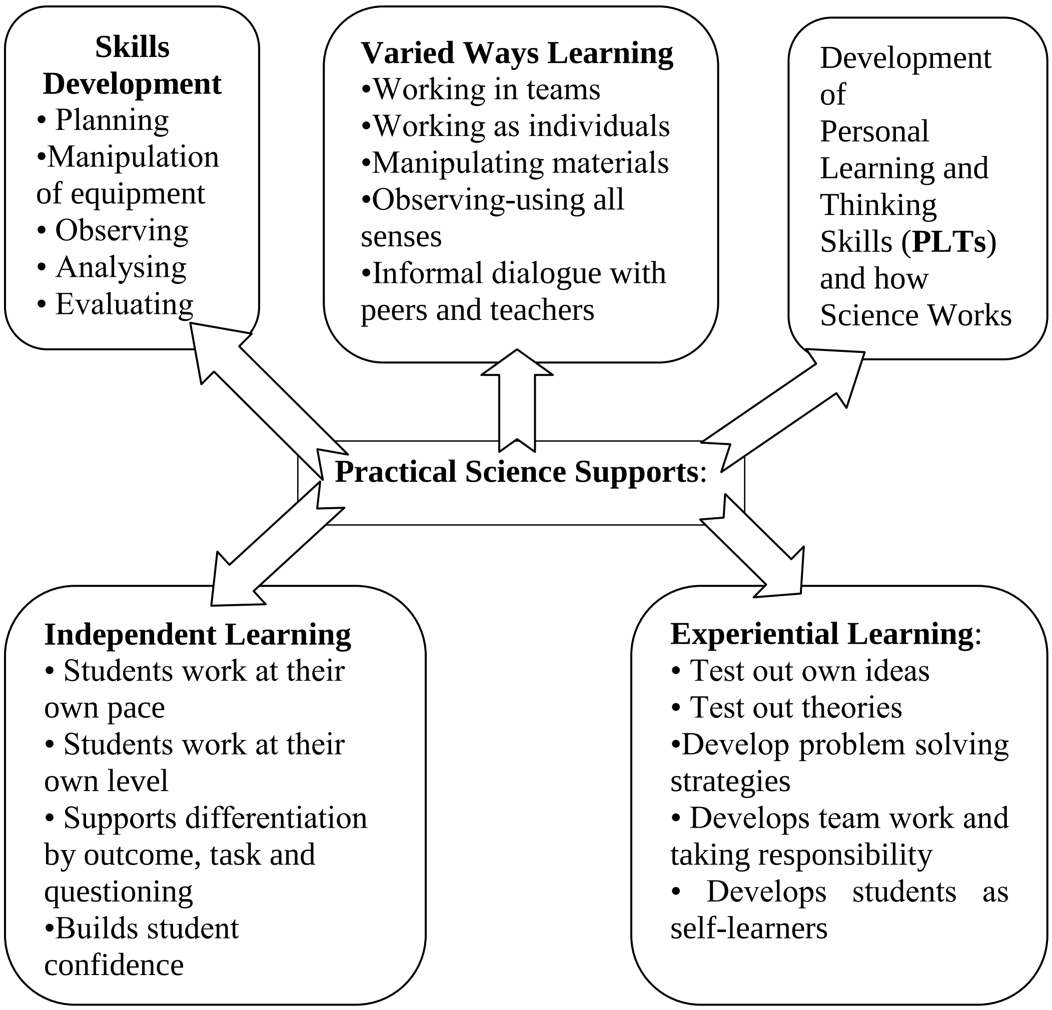

Figure 2.1: How practical work supports science (SCORE, 2009)

Teaching through investigation develops curiosity, increases intellectual potency, intrinsic motivation, memory retention, learner self-confidence and permits time for students to mentally assimilate and accommodate information and develop multiple talents (Trowbridge et al, 2004). Educational psychologists and educators (Piaget, 1956; Slavin, 1988; Vygotsky, 1978; McCombs & Whisler, 1997) acknowledge that the most meaningful learning takes place if the learning environment encourages self-motivated and self-driven learning. This can be achieved through learner-centred investigative activities (Achimugu, 2009).

Over the past few decades, a paradigm shift in curriculum has occurred where the teacher acts as a facilitator in a student-centered classroom (Blumberg, 2008). Various terms have been used to describe these activity based instructional approaches. These include; constructivism, inquiry approaches, active learning, learner-centred and student-centred approach (McCombs & Whisler, 1997; Bekele & Melesse, 2010).

2.3. The Current Situation of Practical Work in Secondary School Chemistry

Despite the many advantages associated with practical work and great attempts by the teachers to use practical work in the teaching of Chemistry, many science educators have expressed significant doubts about the effectiveness of practical work in teaching scientific knowledge and skills (Abrahams & Millar, 2008; CERG, 2009; Dikmenli, 2009; Kennedy, 2011). Motswiri (2004) argues that classroom practices in most secondary school Chemistry lessons are characterised by chalk-and-talk and little practical work. In cases where practical work is implemented it only requires students to follow instructions developed by the teacher or from textbooks where the learners are supposed to strictly carry out the activities as per the instructions; sometimes without much interest or thought on what they are doing. Hodson (1992:176), for example, writes that:

> As practised in many schools, it (practical work) is ill-conceived, confused and unproductive. For many children, what goes on in the laboratory contributes little to their learning science or to their learning about science and its methods. Nor does it engage them in doing science in any meaningful sense… At the root of the problem is the unthinking use of laboratory work.

Woolnough & Allsop (1985), Pogrow (1993), Osborne (1993) and Motswiri (2004) express similar doubts. They argue that teachers do appear to value laboratory activities but observed practice shows that they do not implement them in a manner that facilitates the type of learning intended as learner-centred. Instead, when laboratory investigations are implemented they are often used to confirm something that has already been dealt with in an expository lesson, only requiring students to follow a recipe in order to arrive at a predetermined conclusion (Tobin et al, 1990; Pogrow, 1993). A study of the effectiveness of practical work as a teaching and learning method in school science by Abrahams & Millar (2008) concluded that the teachers' focus on practical lessons was predominantly on developing students' substantive scientific knowledge, rather than on developing understanding of scientific enquiry procedures. Practical work was generally effective in getting students to do what is intended with physical objects, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect.

Motswiri (2004) noted that teachers preferred to demonstrate to whole classes instead of allowing students to engage in lesson activities in a meaningful way.

Tobin et al (1990), argues that constructivist learning requires the learner to live through some kind of concrete experience and take some time for reflective observation.

2.4. Challenges Teachers Face in Secondary school Chemistry Practical Work

Although student-centred learning has evidently a number of advantages, there are a number of challenges confronting teachers in the implementation of quality practical work. Barraket (2005) found that there was a challenge in the development of the course material to move from lecture format to implementing activities to facilitate the student-centered approach. Slavin (1990) as cited by Wachanga & Mwangi (2004) cautions teachers who believe students can simply be placed in-groups and allowed to discover information or skills, because activities supplement, but do not replace, teacher instruction.

Studies have also shown that current laboratory practical work does not focus on students facing their own misconceptions (Dikmenli, 2009; Ottander & Grelsson, 2006). Discussions held during practical work can aid in discovering new knowledge and help to define the misconceptions entertained by the learners. Laboratory work can be used to provide concrete experiences and opportunities for the learners to face their own misconceptions. Dikmenli (2009) argues that time should be set aside for discussions before, within and after the experimentations in laboratory.

Another consideration is time. Bekele & Melesse, (2010) found that teachers felt the content required to be covered is too large to allow for student-centred learning. Felder and Brent (2009) however stated that implementing activities do not take a significant amount of time, once the ideas are generated. What may require much time is planning and organising the learning activities. These points to the need to develop curriculum materials that are detailed enough to ease planning and organising of the activities. Such materials would support the teachers by assisting them in lesson preparation, subject matter, teaching sequence and utilization of student's feedback (Van den Akker, 1988; Ottevanger, 2001; CERG, 2007).

Lunetta et al (2007) attribute the persistent use of the laid down procedures to a lack of confidence and limited understanding of the science ideas on the part of the teacher. According to Osborne (1993), the role of science education is to construct in the student a deep understanding of a body of existing knowledge. Science is a creative process and should offer opportunity for the learner to create his/her own knowledge. Following the laid down procedures in Chemistry practical work does not offer such an opportunity. They do not also make the phenomena real and promote logical reasoning as targeted by science learning (Pogrow, 1993; Dillon, 2008). Teachers may gain confidence in the use of investigative teaching method when provided with a detailed guide on how to carry out the activities.

Teacher beliefs influence and drive science teachers' practice. It is suggested that science teachers need to consider the underlying belief they have about teaching and learning science inquiry and that they should be given opportunities to reframe and redefine their beliefs about inquiry instruction (Moeed, 2013). The materials prepared for this study were basically on the topic on acids and bases content but were designed to encourage teachers understand that their efforts in inquiry can be geared toward achievement of syllabus objectives.

Inadequate equipment and chemicals could make it difficult for a teacher to organise and carry out Chemistry practical (Orado, 2009; Nyang'ai, 2010). Instructional materials that offer suggestions on how simple materials can be improvised and provide options for use of locally available materials may therefore ease teachers' work in organising for investigative practical work.

A study by Dikmenli (2009) found that teachers ignored the development of scientific process skills and generally focused practical work on purposes relating to the verification of theoretical knowledge and laboratory techniques. These are based on students following a recipe procedure in order to try out a pre-determined outcome in the laboratory (Domin, 2007; Kang & Wallace, 2005; Ottander & Grelsson, 2006). This is generally reflected in the instructional materials that the teachers use to guide Chemistry practical work. Practical work should comprise scientific inquiry skills such as identifying problems, planning, predicting outcomes, conducting investigations, and formulating and communicating the results (Lunetta et al, 2007). Instructional materials that support this purpose may therefore be usefully adapted by teachers in their classroom practice.

Practical science learning puts a lot of emphasis on acquisition of skills. Some of these skills are cognitive in nature (process skills) while others relate to practical abilities (manipulative skills) (Kempa, 1986). Manipulative skills include ability to handle, arrange, pour or fix. Process skills deal with the process of procedure or experimentation. These include observing, classifying, measuring, communicating, questioning, interpreting, inferring and predicting (Dass, 2005; Twoli, 2006). Many teachers approach practical work as a means of lower order learning objectives such as names of equipment and use of standard procedures (Orado, 1999; Millar 2004). Millar (2004) and suggest that one of the most valuable things we can do in a practical lesson is to talk about the practical through teacher led discussions. Practical work should involve learners designing, predicting and also communicating results.

CDC-HKEAA (2007), observed that skills and processes that learners should gain from Chemistry practical work include; scientific thinking, scientific method, scientific investigations and problem solving, decision making, collaboration, information handling, communication and self-directed learning. Learners should be able to propose hypotheses and devise methods to test them. They develop plans and procedures to carry out investigations and make decisions based on evidence and arguments. They should also evaluate experimental methods and suggest possible improvements. This may however not be achieved using the recipe type procedures that learners read and follow without giving much thought to them.

Learners' involvement in planning out investigations and setting out procedures are key targets to achieving acquisition of such skills (CDC-HKEAA, 2007).

The exemplary instructional materials developed for the study were geared towards addressing the challenges that teachers face in an attempt to implement investigative work in secondary school chemistry. The materials were designed to support the teachers by assisting them in lesson preparation, subject matter, teaching sequence and utilization of student's feedback (Van den Akker 1988, Ottevanger, 2001; CERG, 2007).

2.5. Needs for Learner-Centred Chemistry Practical Work

Knowing the needs that teachers engaging in Chemistry practical work are likely to experience in their teaching is critical to the development of instructional materials that would potentially contribute to a change in their teaching practices. This is because teaching Chemistry practical work through investigative approaches demands a lot more from the teacher than teaching a traditional Chemistry lesson (The National Science Foundation, 2013).

Teachers need to develop a personal understanding of the need for investigative practical work in Chemistry. Science classroom experiences such as the one described in exemplary materials are not likely to happen unless teachers believe investigative work is important. Changing practices is not easy therefore teachers need to be convinced that their students will benefit. Indeed, research on professional development efforts has shown that program outcomes, and teacher change in particular, correlate with the level of individual teachers' participation and effort (Clarke, 1994). This study therefore involved teachers who were willing to try the approach.

Subject matter knowledge and pedagogical content knowledge are key variables that influence teachers' decisions in the classroom: Prior subject matter and background in a content area affect the ways in which teachers select and structure content for teaching, choose activities and assignments for students, and use textbook and other curriculum materials (The National Science Foundation, 2013; Krajcik et al, 2003). The materials will therefore contain detailed subject matter knowledge to assist teachers gain confidence in implementation of the lesson activities.

Research shows that most teachers, including prospective teachers, have strongly-held views/ beliefs about student and teacher's roles, desirable instructional approaches, students' science knowledge, how students learn and the purposes of schools (Sunzuma et al, 2012). Some view teaching as the direct transmission of knowledge from teacher to student and argue that learning takes place as long as the teacher provides clear explanations for the students to absorb. In contrast, the teaching practices recommended by the instructional materials are grounded in views of knowledge, learning and teaching informed by constructivism. This indicates that only the teachers who are willing to try a different approach in their classes could be involved. Teachers tend to depend on textbooks heavily. They feel responsible to teach contents and activities in the text-books (Kim & Chin, 2011). The materials prepared for this study were based on content of acids and bases where teachers can still deliver Form One textbook content and practice inquiry teaching in the activities.

The main challenge that the teacher may experience in investigative practical work is interpreting his/her students' thinking and responding appropriately (Yandila et al, 2003; Sunal & Haas, 2002). It is important for the teacher to have investigated a range of possible strategies and solutions to the open-ended tasks she/he would pose. Suggestions of these solutions and possible students' prior knowledge will be provided in the instructional materials.

It will be necessary for the teachers to become familiar with exemplary instructional materials and resources before they use them in class (Van den Akker, 1988). They will therefore be given time to read the materials and request for any clarifications. They may also suggest ways in which the materials may be improved to meet learners' needs. Emotions, both positive and negative, inevitably accompany efforts to change one's teaching practices (Ottevanger, 2001; Motswiri, 2004, Van den Akker, 1988). Some teachers may suddenly feel inadequate. Teachers who used the study materials in their classrooms were therefore informed that they were taking part in an attempt to design, develop and refine the materials and should not be worried about not doing it right. They were encouraged to provide feedback on areas where they feel the instructional materials did not support them adequately.

2.6. Pedagogy in Science Education and the 21st Century Pedagogy

Pedagogy is the process of presenting content in the context of learning strategies that connect with a cognitive process. Problem-based learning, process-oriented guided inquiry learning, and peer-led team learning are student-centered, active-learning pedagogies commonly used in science education (Eberlein et al, 2008). Planning and implementing a successful science lesson requires content knowledge, knowledge of inquiry and pedagogy knowledge. Pedagogical content knowledge is basically important for the creation of effective lesson plan for classroom instruction. Pedagogical content knowledge is an accumulation of common elements that incude: knowledge of subject matter, knowledge of students and possible pre-conceptions and misconceptions, knowledge of curricula and knowledge of general pedagogy.

The instructional materials used for this study were designed for class experiments. Classroom experiments are activities where a number of students work in groups on carefully designed guided inquiry questions. These are a form of what some scholars defined as engaged pedagogy (Eberlein et al, 2008). Engaged pedagogy refers to using teaching approaches that encourage student-student interactions in which the teacher takes on the role of facilitator as opposed to a source of knowledge. Typically, student learning is higher using these methods and students use more high-order thinking skills while learning material in depth.

Rapid changes in the world; including technological advancement, scientific innovation, increased globalization, shifting workforce demands, and pressures of economic competitiveness are redefining the broad skill sets that students need to be adequately prepared to participate in and contribute to today's society. New standards for what students should be able to do are replacing the basic skill competencies and knowledge expectations of the past (Bybee, 2010). To meet this challenge learning must be transformed in ways that will enable students to acquire creative thinking, flexible problem solving skills, collaborative and innovative skills they need to be successful in life. The 21st Century learning skills are important within the context of science education in accomplishing the necessary transformation (Pacific Policy Research Center, 2010).

The 21st Century critical learning and innovation skills include; communication and collaboration, critical thinking and problem solving as well as creativity and innovation (Bybee, 2010). Learning is a fundamentally social activity where individuals develop ability to work together effectively, assume shared responsibility for collaborative work, and value individual contributions made by each member in the group. Critical thinking and problem solving skills include the ability of individuals to a) reason effectively, b) ask pointed questions and solve problems, c) analyze and evaluate alternative points of view, and d) reflect critically on decisions and processes (Pacific Policy Research Center, 2010). The process of constructing procedures for the practical activities developed in this study was designed for this purpose. Leadership and responsibility skills also emphasized in the 21^{st} Century life and career skills, have a foundation in group activities done during practical work. Setting and meeting goals, prioritizing needs, managing time, working ethically, and collaborating and cooperating with other learners also indicate development of productivity and accountability skills. Other key features of 21st Century Pedagogy reflected in the teaching strategy proposed by the materials used in this study include; developing thinking skills, using problem solving as a teaching tool, collaborative nature of learning and fostering contextual learning. Though many educators tend to focus on use of technology, schools in developing countries which may not have sufficient new information technology machinery can make the best use of available resources to achieve these skills.

2.7. Scaffolding Instruction in Science Teaching

Instructional scaffolding is a learning process designed to promote a deeper level of learning. It entails the provision of sufficient support to promote learning when concepts and skills are being first introduced to students. In the classroom setting, scaffolds may include models, cues, prompts, hints, partial solutions, think-aloud modeling and direct instruction. It is a teaching strategy based on Lev Vygotsky's sociocultural theory and his concept of the zone of proximal development (Trowbridge et al, 2006). Scaffolds provided in science teaching are activities and tasks that: motivate learners interest in the task, Simplify the task to make it more manageable and achievable for a student, provide some direction in order to help the learner focus on achieving the goal and clearly define the expectations of the activity to be performed (National Research Council, 2004).

In the proposed investigative practical work model, the teacher guides learners through the activities mainly through questioning. Teachers may use questions as scaffolds to help students solve a problem or complete a task. By increasing the level of questioning or specificity, the student will be able to provide a correct response and comprehend the concept targeted. Thus, students are guided and supported through questioning and learning activities that serve as interactive bridges to get them to the next level (Trowbridge et al, 2006).

Instructional scaffolding in science inquiry mainly involves development of plans that lead students from what they know to a deep understanding of new concept or material and the execution of those plans, where the teacher supports the students at every step of the inquiry process. This was presented in all the stages of learning cycle used in the investigation conducted for this study. These stages being: engagement, exploration, explanation, elaboration and evaluation (Bybee et al, 2006). At engagement phase, the curriculum task accesses the learners' prior knowledge and helps them become engaged in a new concept through the use of short activities that promote curiosity and elicit prior knowledge. Learners are invited to express what they think and to raise their own questions. The activities made connections between past and present learning experiences, expose prior conceptions, and organize students' thinking toward the learning outcomes of current activities. This arouses the learner's interest in the concept.

Exploring was achieved through designing an investigation during which, student-to student interaction was encouraged as the teacher observes and listens to the students as they interact and asks probing questions to help students make sense of their experiences (Bybee, 2006). The concept is explicitly presented at this stage.

The explanation phase focuses students' attention on a particular aspect of their engagement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviors. This phase also provides opportunities for teachers to directly introduce a concept, process, or skill (Clark et al, 2000). In the investigative activities formulated, this was done through use of small group discussions as well as teacher led whole class discussions.

In elaboration, teachers challenge and extend students' conceptual understanding and skills. Students apply their understanding of the concept by conducting additional activities. This focuses students' attention on conceptual connections between new and former experiences. Conclusions from evidence and data, patterns and generalisations are made. Each group prepared a data table, showing their results and any relationships derived from the data and the results would be pooled together. Effective scaffolding leads students' investigation to conclusions and explanations.

The evaluation phase encourages students to assess their understanding and abilities and provides opportunities for teachers to evaluate student progress toward achieving the educational objectives (Bybee, 2006). The teacher observed as students demonstrated their understanding of the concepts and performance of skills through discussion over the results they obtained. Learners were provided with an opportunity to compare their ideas with those of others as the results were pooled together. Assignments were provided to help learners assess their understanding of the concept taught and extend knowledge on the subject.

2.8. Characteristics of Exemplary Materials

Curriculum materials developed through careful, extended work with diverse students and teachers and based on learner's knowledge form a tool that allows the teacher to do the best work with students (National Academy of Sciences, 1997; O'Donnell, 2007). Exemplary instructional materials usually include a rich collection of information to support learning experiences. The documents may include suggestions for planning lessons and orchestrating class discussions, examples of student work, and opportunities for teachers to learn more about the scientific concepts to be taught (The National Science Foundation, 2013).

The National Science Foundation (2013), Pogrow (1993), and National Academy of Sciences (1997), indicate that exemplary science instruction should; (a) Help students build on their prior knowledge, (b) Engage students in scientific inquiry, (c) Provide opportunities for reflection and problem solving. (d) Help students to actively construct knowledge and transfer it to new situations and (e) be based on research about how students learn. These features should be the foundation of instructional materials.

The National Science Foundation (2013), Millar (2009), O'Donnell (2007), Singer & Tuomi (2004), National Academy of Sciences (1997) and National Science Resources Center (1997) identified three components through which the effectiveness of curriculum materials can be judged. These are:

1. Content analysis which informs on instructional alignment with certain content standards (in the case of this study, KCSE syllabus). It also provides information on whether the material is scientifically accurate and developmentally appropriate.

2. Judgment of pedagogical appropriateness which informs on whether the materials can be used to support goals of learning science, provide effective instructional approach and focus on inquiry and activity as a basis of students' learning experiences.

3. Presentation of information and format/ organization and structure- this is based on clarity of information. It informs on whether the directions for implementing activities are clear and adequate and if the materials are free of bias.

These components were incorporated in the design of the instructional materials developed for this study to ensure their quality.

2.9. Instructional Design Models

An Instructional Design Model (IDM) provides procedural framework for the systematic production of instruction. These provide guidelines for the design and development of instructional materials. According to Gustafson and Branch (2002) instructional design models have five components. These are: analysis of the setting and learners needs; design of a set of specifications for an effective, efficient and relevant learner environment; development of learner and management materials and evaluation of the results of the development both formally and summatively. IDM therefore covers five phases: Analysis, design, development, implementation and evaluations. These are the phases that make up this study.

Some IDMs have been developed. The Universal Systems Model comprises of inputs, processes, and output/feedback mechanisms. Another model is the ADDIE which stands for the five steps; Analyse, Design, Develop, Implement and Evaluate. These steps are systematic where output of one step becomes the input of the next step. Another model is Rapid Prototyping by Tripp & Bichelmeyer (1990). The Rapid Prototyping approach adapted allows on-going review, evaluation and collaboration with teachers, students and subject experts as well as an iterative process through continual evaluation and improvement while the materials are being created. Utilization of the design with active participation of the learners leads to a design environment which makes it practical to synthesize and modify instructional artefacts quickly and leads to creativity and accelerated development. Errors can be detected earlier by iterations and corrected (Tripp & Bichelmeyer, 1990). Dick and Carey model is based on systems approach in designing instruction (Dick & Carey, 2005). It consists of phases of iterative design process that starts with identifying instructional goals and ends with summative evaluation.

Although models vary in their levels of specification and complexity, each is based on the typical processes of the five major phases of instructional systems design. These are analysis, design, development, implementation and evaluation. This study borrows from the models discussed. It mainly adapted from Dick & Carey model which incorporates most of the other models as shown on Figure 2.2.

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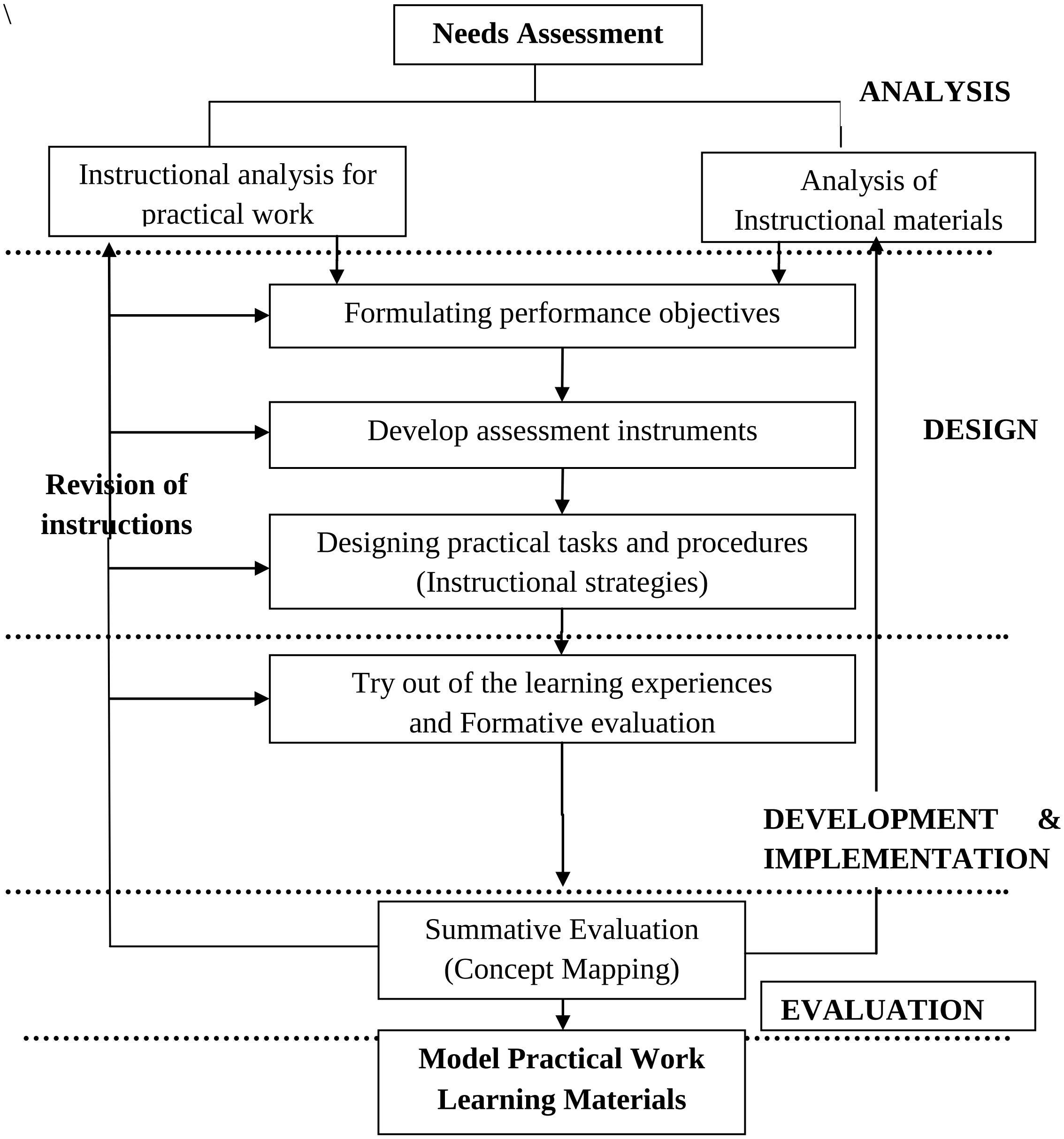


Figure 2.2: Instructional design model used in the study
Source: Adapted from Dick & Carey (2005)

Three pedagogical approaches are used within these models. (1) organizational strategies which deal with the way in which a lesson is arranged and sequenced, (2) Delivery strategies that deal with the way in which information is carried to the student and the selection of media and (3) Management strategies which involve the decisions that help the learner interact with the activities designed for learning (The National Science Foundation, 2013; Millar, 2009).

2.10. Organization of a Chemistry Practical Lesson

Practical work in science is varied in type and intention. They vary in aims, degree of freedom, level of openness of inquiry and type of laboratory task (Millar et al, 2002). Materials developed for this study was based on use of open guided inquiry using inductive approach with student generated procedures where outcome is integrated with related theory. Practical work of open-ended, investigative kind can develop students' knowledge of scientific enquiry (Millar, 2004; Trowbridge et al, 2004). Practical work is usually carried out in four main stages (Twoli, 2006; Omosewo, 2006); planning, implementation/activity, discussions and conclusions. The conclusions involve using responses from groups to discuss underlying concepts and principles. When these stages are well managed they can lead to conceptualization. Figure 2.3 summarises this development.

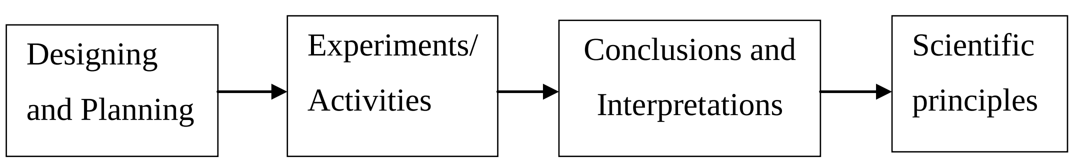


Figure 2.3: Development of understanding of scientific principles through practical lesson

The learning materials developed for this study seek to support teachers' management of these stages towards learner-centred teaching.

2.11. Concept Mapping in Chemistry Learning

Concept mapping is a technique used to show relationship between interrelated concepts placed in a hierarchy, linked by lines labelled with connecting words expressing propositions linking the concepts (Trowbridge & Wandersee, 1998; Twoli 2006, Aksela 2005). A concept map is a graphical tool that organizes, connects, and synthesizes information. Concept maps show concepts in circles or boxes and one can indicate relationships between concepts by connecting lines or linking words. According to Novak & Gowin (1984), concept maps represent organised knowledge which is dependent on both personal and social learning context. This organisation of knowledge may assist in providing effective learning and teaching and also help in answering the focus question. The knowledge maybe comprised of concepts that are meaningfully linked together and structured to provide patterns that assists learners in developing cognitive structures and developing creativity. Meaningful learning takes place when learners are able to recognise interrelationships between different segments of the concepts and being able to join the segments and create meaning. Figure 2.4 shows key steps in concept mapping as can be used in chemistry learning.

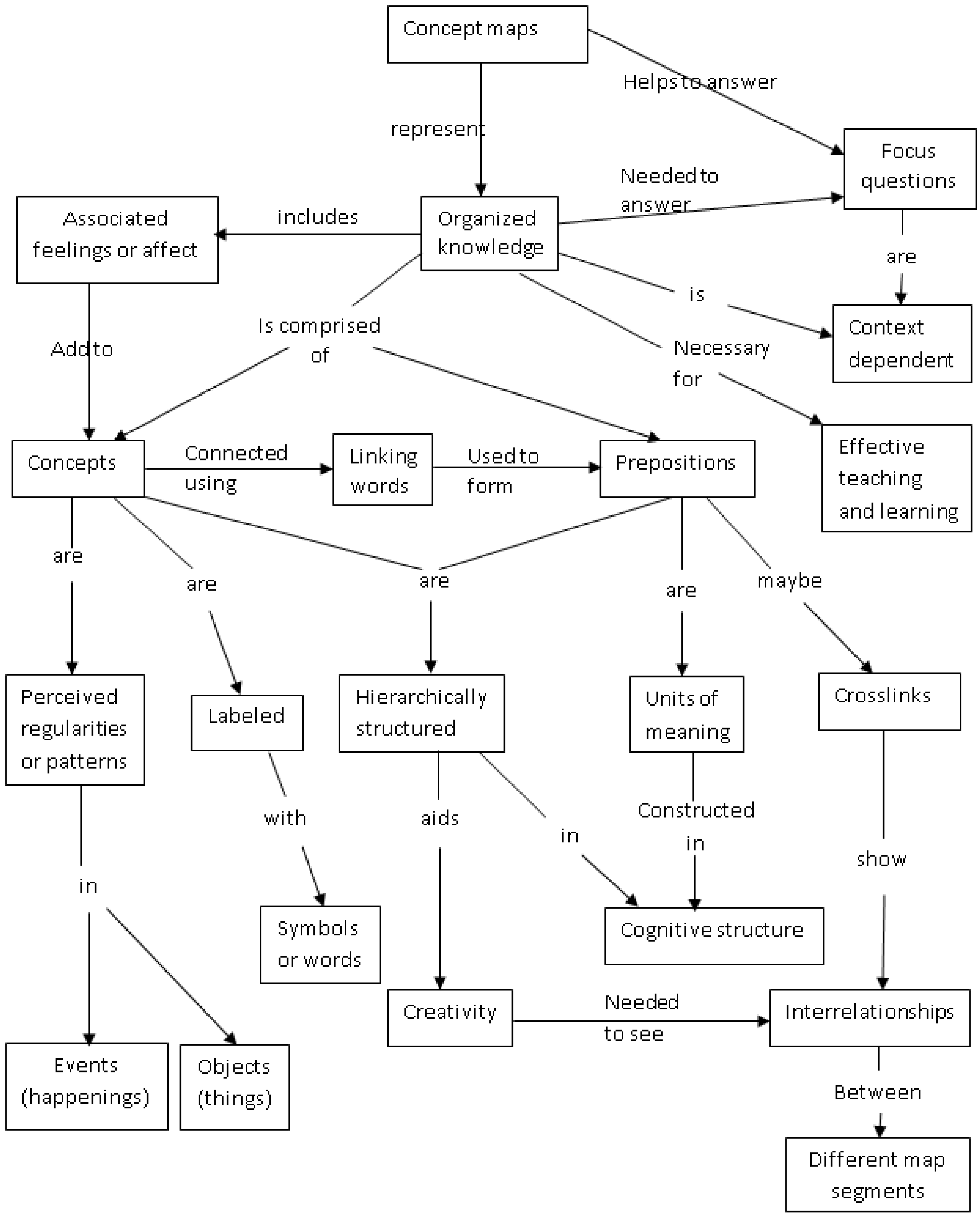


Figure 2.4: Concept mapping in Chemistry learning (Novak & Gowin, 1984)

Learning is meaningful when the student comprehends the relationship between what is being learned and other knowledge (Kilic & Cakmak 2013). Some important reasons attached to concept mapping include: (i) students can establish links between concepts rather than recalling concepts separately; (ii) It can be used effectively for revision after a topic; (iii) It develops the confidence level; (iv) provides clarity of the concept and (v) it is suitable for many different topics, instructional stage and grade level (Kilic & Cakmak, 2013). They further indicated four instructional uses to which concept maps can be put. They can be used as a method of learning, a teaching method, a curriculum and lesson planning method, or as an evaluation method of students' understanding. Aksela (2005) also agrees that concept maps can be used as an assessment tool to determine understanding of concepts learnt.

In this study, concept maps were used at the end of the practical lessons to help learners summarize results of their practical activities. Since Form 1 learners did not have much experience with use of concept maps they were provided with structured guide in which they filled in information on their understanding of the concepts and observations. They were used as an evaluation tool for students' concept understanding and skill development after using the instructional materials in learning.

2.12. Design Based Research Used in the Study

Design-Based Research (DBR) is one terminology used to describe a research methodology based on the influential works of Brown (1992) and Collins (1992). Some scholars also refer to this research design as developmental research design (Van den Akker & Plomp, 1993; Wang & Hannafin, 2005; Motswiri, 2004). Design research is expressed by Plomp & Nieveen (2007, p12) as;

> To design/develop an intervention (such as programs, teaching-learning strategies and materials, products and systems) with the aim of solving a complex educational problem and to advance our knowledge about the characteristics of these interventions and the processes to design and develop them.

Design based research is a systematic but flexible methodology aimed at improving educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually-sensitive design principles and theories (Wang & Hannafin, 2005; DBRC, 2003). DBR is grounded in both theory and the real-world context and aims at solving current real-world problems by designing and enacting interventions (DBRC, 2003). DBR emphasizes the participatory role of practitioners. Teachers and students can become re-designers by collaborating with researchers (Aksela, 2005). In DBR researchers integrate a variety of research methods and approaches from both qualitative and quantitative research paradigms, depending on the needs of the research (Wang & Hannafin, 2005).

DBR activities differ from typical research designs because they incorporate preliminary investigation. This includes searching for more accurate and explicit connections of that analysis with state-of-the-art knowledge from literature (Aksela, 2005). Some typical activities include: literature review; consultation of experts; analysis of available promising examples for related purposes and case studies of current practices to specify and better understand needs and problems in intended user contexts. Krajcik et al (2007) and Van den Akker & Plomp (1993), claim that the aim of DBR is not to elaborate and implement complete interventions, but to come to (successive) prototypes that increasingly meet the innovative aspirations and requirements. The process is often cyclic or spiral: analysis, design, evaluation and revision activities are iterated (repeated) until a satisfying balance between ideals and realization has been achieved (Ottevanger, 2013). Clear empirical evidence is delivered about the practicality and effectiveness of the intervention for the intended target group in real user settings (Brown, 1992; DBRC, 2003). In the field of learning sciences, research paradigms that simply examine learning processes as isolated variables within laboratory settings may lead to an incomplete understanding of their relevance in more naturalistic settings (Barab & Squire, 2004). Finally systematic documentation, analysis and reflection on the entire design, development, implementation process, evaluation and its outcomes are done.

Several studies in the science education have been carried out in African countries using DBR. McKenney & Reeves (2013), explored the possibilities of computer based support for science education materials developers in South Africa, Ottevanger (2001) investigated teacher support materials as a catalyst for science curriculum implementation in Namibia, Motswiri (2004) investigated how to support chemistry teachers in implementing formative assessment of investigative practical work in Botswana, Mfumiko (2006) examined how micro-scale experimentation can serve as a catalyst for improving the chemistry curriculum in secondary schools in Tanzania, Tecle (2006) explored the potential of a professional development scenario for supporting biology teachers in Eritrea. Januário (2008) investigated assessment practices in physics in secondary schools in Mozambique. All these studies provided positive outcomes of their intended development. This study provides an opportunity to explore this design in the local environment, Kenya.

2.13. Summary

The literature review indicates a lot of emphasis on learner-centred investigatory practical work. It is also clear that much of it has not been translated to classroom practice (Kisangi and Ateng', 2006). Practical work materials that present practical activities, mostly as 'hands-on' rather than 'minds-on', characterised by ready-made, step-by-step experimental procedures do not represent investigative practical work (Motswiri, 2004). It is however possible to achieve learner-centred classroom practices by involving students through investigative practical work (Brush & Saye, 2000). Some challenges to proper implementation of learner-centred chemistry practical work quoted by researchers (CERG, 2007; Orado, 2009; Hattingh & Rogan, 2007; Thiong'o, 1986; Nyang'ai; 2010) can be reduced if teachers are supplied with readily available support materials (CERG, 2007). Studies have shown that it is possible to support the use of innovative teaching strategies by teachers through using exemplary materials (Motswiri, 2004; Ottevanger, 2001; Van den Akker, 1988; Krajcik et al, 2003). Detailed teacher support materials can reduce teacher's preparation time, give details on learner activities and sequencing of learning hence making it easier for the teacher to adapt the teaching strategy.

Most research on chemistry practical work in Kenya has basically emphasized on analysing the quality of practical work (Thiong'o, 1986; Efumbi, 2002; Kamau, 2004; Inzahuli, 2007; Orado, 2009; Nyang'ai, 2010)). These researchers are in agreement that the quality of practical work in most Kenyan schools is low mainly because they are not investigative in nature. They have however not offered alternative teacher support solutions towards the suggested change of teaching strategy. Such support can come from a model of curriculum materials that would support learner- centred activities.

There is, therefore, need for comprehensive exemplary instructional materials that support the teacher in organising learner-centred practical activities within existing constraints at the school level.

CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

This chapter outlines the research design and methodology. It describes the actual process that was followed. It also outlines the location and population of the study and gives a description of data collection procedures, sampling, research instruments, data analysis procedures and logistical and ethical considerations. It also provides a description of procedures for the construction of instructional materials.

3.2. Research Design and Process

This study employed a Design-Based Research (DBR) design. DBR design was appropriate because it helped create and extend knowledge about developing, enacting, and sustaining innovative learning environments (DBRC, 2003). DBR has many advantages over experimental research; the research is carried out in real life setting where learning is done, it has multiple dependent variables, it characterises the situation with all its complexity it involves different participants in the design who bring in differing expertise instead of being subjects of study. It is a flexible design for revision in which tentative initial set is revised depending on success (Krajcik et al, 2007; DBRC, 2003). Based on constructivism theory of teaching and learning, practical work instructional materials that support investigative learner-centred teaching strategies were developed. The guidelines for the design and development of the instructional materials were based on instructional design model (IDM) which provide procedural framework for the systematic production of instructional materials. The five basic phases of IDM (shown in Figure 2.1) made up this study. These stages were:

1. Assessment of the practices and needs of Chemistry practical work in schools
2. Design and development of prototype Chemistry practical work instructional materials
3. Try out of the prototypes
4. Evaluation of the instructional materials
5. Refinement and redesign of the materials.

The research process involving the five stages is summarised in Figure 3.1.

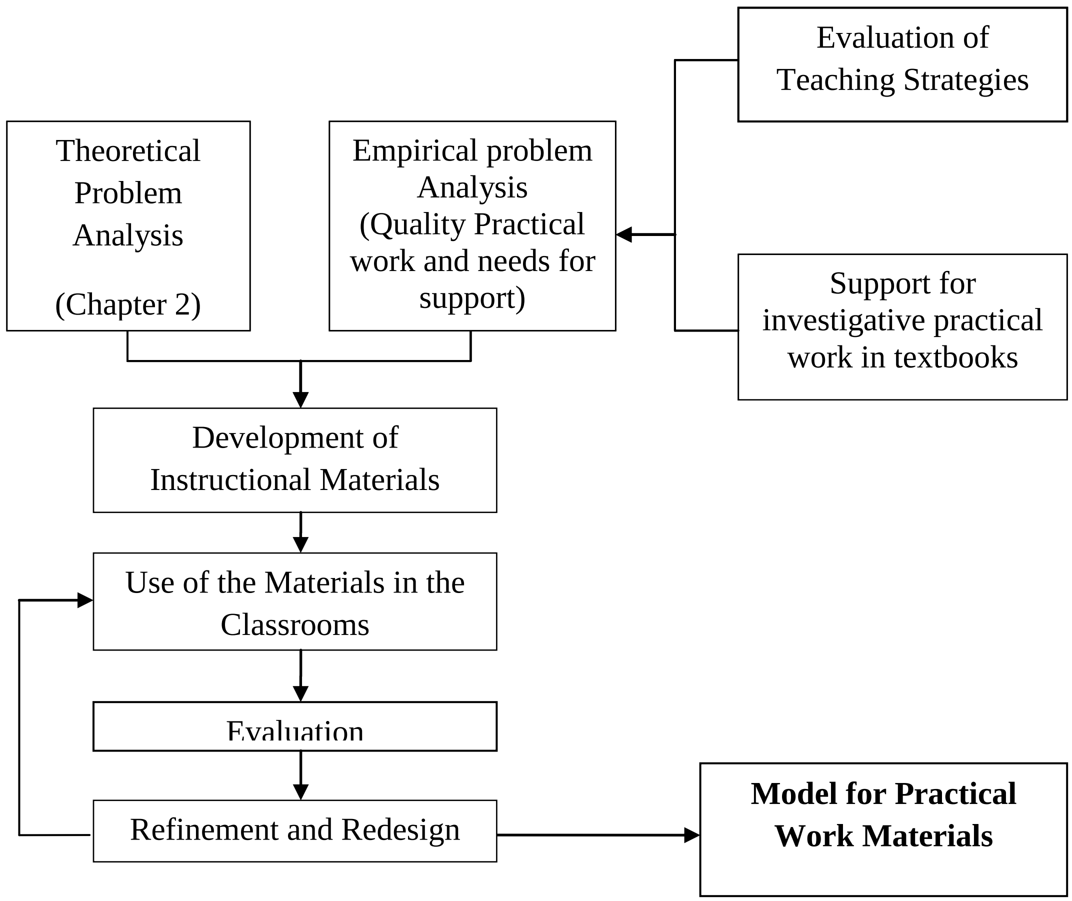


Figure 3.1: Research design and process of the study

Stage one involved a survey on the quality of practical work as carried out in schools as well as analysis of content in the textbooks that teachers used to guide them in the use of practical work in their classes. It also involved theoretical analysis from literature. This was important in providing information on the areas in need of support in order to achieve implementation of investigative nature of practical activities. It also helped in identifying appropriate content for the learners and use of content the teachers were used to teaching. The teachers were also able to provide their views on what they thought would provide the best learning for their students. This information and the state-of-art literature on the best learning methods were used to generate design specifications for the instructional materials constructed for the study. The materials were designed and developed through appraisals by Chemistry teachers and science education experts in stage two of the study. The outcome of the appraisals was used to refine and improve the materials.

The developed materials were tested by being tried out in the classroom situation to guide the teaching of Chemistry practical lessons. Feedback from these lessons was used to further refine the materials. The practicality and effectiveness of the refined materials was evaluated as they were used in class. During these lessons observations were made and data was collected using teacher logbooks, interviews and questionnaires. The outcome was used to further refine the materials leading to the final product of model practical work materials.

3.3. Location of the Study

The study was conducted in secondary schools in Kajiado County in Kenya. Kajiado County neighbours Nairobi; the capital city of Kenya on the South-West side. Kajiado was selected because of its proximity to the researchers' work station and a fairly good infrastructure. The study required use of materials in a normal classroom set-up for a number of lessons and actual observation of many lessons and a lot of interaction with the teachers involved. The proximity to the researcher's work station therefore enabled the researcher to maximally administer and manage research as well as reduce the cost of research. Kajiado is also a semi-arid area and thus with many challenges of availability of resources in some schools. Carrying out the study in this area can be important in exemplifying that simple apparatus may be used to achieve learner-centred practical teaching. The use of Kajiado County therefore increased chances that the materials could be applicable in the teaching of chemistry even in the disadvantaged situations observed in most Kenyan schools.

3.4. Target Population

The total population of 68 Chemistry teachers currently teaching form one Chemistry in the forty- two (42) public secondary schools in Kajiado County constituted the study population. All the forty-two schools teach Chemistry as a science subject in Form one. This is because all public schools in Kenya are required to teach the three science subjects (Chemistry, Physics and Biology) in Forms One and Two (MOE, 2012).

3.5. Sampling

The study being developmental in design was carried out in various stages. Different sampling methods and sample sizes were used depending on the nature of the study at each stage.

3.5.1. Sample size determination

For the empirical problem analysis (stage 1), a stratified random sample of the target population was chosen. In determining the sample size for this stage, the study adopted the formula and procedure for categorical data according to Cochran (1977) and Barlett et al (2001). The following formula was used to calculate the sample size:

$$n_0 = \frac{Z^2 p(1-p)}{e^2}$$

Where

n_0 = Required sample size

Z = Confidence level at 95% (standard value of 1.96)

p = Estimated response rate at 50% (which is 0.5).

e = Margin of error at 5% (standard value of 0.05).

Therefore, the sample size (**n_0**) was worked out as follows;

$$n_0 = \frac{1.96^2 \times 0.5 \times (1-0.5)}{0.05^2} = 384.16 \qquad \approx 384$$

Considering that the sample size at a confidence level of 95% and a margin of error at 5% is larger than the target population, the adjustment was done using finite population correction formula by Cochran's (1977) to arrive at the adjusted sample (***n***). The correction formula is;

$$n = \frac{n_0}{1 + n_0 / N}$$

Where,

$\boldsymbol{n}$ = Adjusted sample, $\boldsymbol{n_0}$ = Sample size, $\boldsymbol{N}$ = Target population

Therefore, $n = \frac{384}{1 + 384/68} = 57.77 \approx 58$

According to Cochran (1977) the sample actually obtained is smaller than the target sample. The rough estimate of the responses ranges between 45% and 55%. This range is worked as (50-5) and (50+5) percent respectively. This translates to range between (45% x 58) and (55% x 58). This range from 26 Chemistry teachers to 32 Chemistry teachers would be a sufficient sample for the survey for stage one of the study.

The study targeted response from teachers in each of the target schools that were sampled at random from the three main strata. The schools were stratified into Boys' schools, Girls' schools and Mixed schools using proportionate stratification. A representative sample of 58 Chemistry teachers as described in the Table 3.1 was targeted.

Table 3.1: Sample size for empirical study

Type of school	No. of public schools in the County	No. of teachers sampled	Percentage
Boys	8	11	19
Girls	9	12	21
Mixed	25	35	60
Total	**42**	**58**	**100**

Six schools were chosen from the random sample for Chemistry practical lesson observation. A total of six (6) lessons were observed. Two lessons were observed from each stratum. The teachers in the sample schools for lesson observation were those willing to allow the researcher to carry out lesson observation in their classes.

Three experienced teachers were also selected to appraise the materials. Purposive sampling was used to select the three qualified teachers with more than five years of experience in teaching Chemistry in secondary school who were requested to read and appraise the materials. Experienced teachers were selected purposively because it was necessary to get informed feedback to evaluate the consistency and validity of the instructional materials in the selected contexts. Two science education lecturers were also requested to appraise the materials and research instruments.

For the third stage (first try-out of materials in class), a sample of three teachers were selected depending on their willingness to participate and accessibility of their schools to the researcher for the purpose of lesson organisation and observations. This formed the pilot study.

In stage four, a purposive sample of five (5) teachers was selected. Purposive sampling was more useful in advancing understanding of the implementation process rather than a random selection of cases (Motswiri, 2004). Maximum variation purposive sampling was done to obtain an heterogenous group of teachers and schools for the study. Teachers with differences in the years of experience in the practice of teaching Chemistry were obtained. This was done because the materials for investigative practical work were designed to facilitate the teacher in carrying out instruction. Practicality as tested was therefore not influenced by the teacher experience. A small-scale, in-depth study of a limited number of teachers and students was considered relevant to gain deeper insight into the practicality of the materials. It was considered that the classroom practice of any Form 1 Chemistry teacher in Kenyan public schools offering KCSE Chemistry syllabus would be very closely similar. This satisfied the conditions for a purposively selected case (Trochim, 2006).

The materials consisted of six chemistry lessons that required teachers and learners engagement for more than one week. The lesson observations for the six lessons for each of the five teachers made up a total of thirty (30) lessons. This implies that a large sample for this part of the study would not have been easy to manage. This part of the study also involved full classes and therefore feedback from these groups was taken to be sufficient. Since the approach involved a lot of teacher engagement and full form one class, only those teachers who were willing to participate and had motivation to try out new ideas and to give critical feedback took part in the study. Table 3.2 shows the details of classes used in stage four of the study.

Table 3.2: Sample of learners used in stage four of the study

						TOTAL
Teacher Code	**J**	**K**	**L**	**M**	**N**	**5**
Number of students	13	24	30	35	42	**144**

The sample sizes used in each stage of the study was different. This summary is provided in Table 3.3.

Table 3.3: Sample size per stage of study

Stage	Nature of study	Sample size
1.	Survey	42 Chemistry Teachers
2.	Appraisal of materials	47 Pre-service Chemistry teacher trainees
		3 Teachers
		2 Science Education lecturers
3.	First try out	3 Teachers Chemistry teachers
4.	Evaluation of materials	5 Teachers (a total of 30 lessons)
		144 Form one students

The three teachers who participated in the try-out of the second level prototype and their schools were different from the teachers who participated in the evaluation of the third level prototype.

3.6. Research Instruments

The study incorporated features of Design-Based Research methodology, using various methods to develop exemplary learner-centred investigative practical work materials, evaluate their effectiveness when used in class and to guide refinement of the materials. The techniques, procedures and instruments used in data-gathering depended on the stage of the study. Details of each stage of study are outlined in section 3.1.

For empirical analysis of the problem in stage one, the quality of practical work carried out in secondary schools in Kajiado County was surveyed. This was done using questionnaire for teachers, document analysis schedule and lesson observation guide for lessons carried out. The second stage of the study involved development and initial appraisal of instructional strategies for investigative practical activities. These appraisals were guided by instructional materials' appraisal guide. The third stage involved pre-testing of the materials in actual classroom set-up while the fourth stage involved evaluation of the materials during their use with the learners. During stage three and four, teacher's logbook, interview schedule for teachers, lesson observation schedule, questionnaire for learners and concept maps from students were used. Table 3.4 provides a summary of the instruments used in each stage of the study.

Table 3.4: Study instruments

Stage	**Research instrument**	**Appendix**
1. Needs analysis	Questionnaire for Teachers: Document analysis schedule: Lesson observation schedule:	I II III
2. Design and Development of learning materials	Instructional materials' appraisal guide	IV
3. First try-out 4. Evaluation of the materials	Teacher's logbook Interview guide for teachers Lesson observation schedule Questionnaire for learners	V VI III VII

a) Questionnaires for Teachers (Appendix I)

The questionnaire was designed to gather information on the current practice in Chemistry practical work and gather teachers' views on ways to make practical work more learner-centred and investigative. The teachers' questionnaires consisted of three main sections. The first section contains an introduction to the questionnaire and requested personal background information about the respondents such as gender, school type and professional experience. The second section gathered information about the types of practical work that teachers use in their chemistry classrooms or preferred to use in their chemistry classrooms. The third section requests the teachers to furnish the researcher with information on the instructional materials they use to guide the chemistry practical work and their perception on the support they get from these materials in organising investigative practical activities. Although the majority of the questions were multiple choice or Likert type of items, the teachers were provided with an opportunity to express their opinion/views through exploring the opportunity of 'other' or 'specify' options. A few open ended questions were also included.

b) Document Analysis Schedule (Appendix II)

The instructional materials indicated by the teachers as the most commonly used in organising their chemistry practical lessons on the topic of acids and bases were analysed. Document analysis schedule was used to collect data on aspects/skills of chemistry learning emphasized by practical work in the books that teachers use. The organization of practical work in terms of opportunities available for carrying out investigations was also tabulated in the analysis schedule.

c) Lesson Observation Schedule (Appendix III)

The lessons were observed with an intention of finding out their level of incorporation of learner-centred investigative strategies. Such strategies have been defined in literature as well as in the analysis of needs for the support learner centred investigative practical work. The actions teachers were expected to show in the course of a learner-centred investigative practical lesson were listed and their observation during the lesson tabulated. The questions are formulated to determine the extent to which teachers' classroom practices reflect the suggested learner-centred teaching practice. This assisted the researcher in defining areas that may need improvement and support to attain the objectives of using learner-centred pedagogy.

d) Instructional Materials' Appraisal Guide (Appendix IV)

A structured guide was provided for the appraisers of the materials to note the areas that needed adjustment during the time they were reading the materials. The guides were also used as interview guide for an informal interview where the appraisers clarified various points noted in the guide. The appraisers were asked to clarify various points and suggestions that they had noted down in the appraisal guide and to provide their view about use of such materials in class. It assisted the researcher gather views of the appraisers concerning their perception on the validity of the materials, consistency of the proposed activities and probable practicability of the materials in classroom situations.

f) Teacher's Logbook (Appendix V)

This was a structured guide that assisted the teachers to note down their impressions about the lesson immediately the lesson was concluded. This was useful in capturing areas in which the materials were able to support teachers in the investigative practical work. The logbook was structured into three sections. Section one allows the teacher to record the experiences with the materials during lesson preparation, section two allowed the teacher to record experiences during the lesson implementation including the challenges they faced and suggest possible solutions while the last section allowed the teacher to comment on the structure and clarity of the materials.

g) Interview Guide for Teachers (Appendix VI)

Each of the five teachers carrying out the lessons was interviewed at the end of the lesson series. The guide had questions that guided the researcher in collecting information regarding teachers' perceptions about the clarity of the materials, complexity, congruence of the materials with their usual practice and perceived cost effectiveness of the lessons. These provided useful support for data recorded in the logbook as well as observation made in class. Interviews also helped the researcher to clarify points that the teachers noted in the logbook.

h) Questionnaire for Students (appendix VII)

This was structured as 15 Likert type items geared towards gathering learners' views concerning the effectiveness of the instructional strategies. It was considered necessary to gather information on the effectiveness of the materials from the learners as the consumers of the strategy. The questionnaire items had a scale of 5 ranging from strongly agree to strongly disagree. It also had a provision for the learners to note any challenges they could have faced in carrying out the investigations. It was initially developed and used as an interview guide but later changed to a questionnaire to allow more learners to participate in the evaluation.

3.7. Validity and Reliability of Instruments

The quality of research is described by validity and reliability of data. This study involved use of both qualitative and quantitative data. Guba & Lincoln (1981) stated that the nature of knowledge within the quantitative paradigm is different from the knowledge in qualitative paradigm. They noted that, within the quantitative paradigm, the criteria of quality are internal validity, external validity, reliability, and objectivity. On the other hand, they proposed four criteria for judging the soundness of qualitative research to ensure "trustworthiness" and credibility. These criteria were; credibility, transferability, dependability, and confirmability (Guba & Lincoln, 1981; Trochim, 2006). Validity and reliability of data both quantitative and qualitative data was therefore considered.

3.7.1. Validity and reliability of quantitative data

For the empirical problem analysis, questionnaires were developed on the basis of responses received from two experts from the university who evaluated them for content validity before they were used. Piloting was done to determine the clarity of question items in the questionnaires. This was to enable the researcher to check the suitability of the instruments to collect required data. Piloting was done in three schools. Questions that elicited ambiguous responses were adjusted accordingly. After piloting, the respondents were allocated random numbers. Using split-half method each type of instrument was split into two groups, those from even and those from odd numbered respondents. The reliability of the two was correlated by the Spearman-Brown split-half coefficient:

$$\alpha = 2r_{xy} / (1+r_{xy})$$

Where: r_{xy} is the reliability coefficient between two variables x (odd) and y (even). The reliability coefficient r_{xy} is determined by Pearson product- moment correlation formula;

$$r_{xy} = \frac{\Sigma xy - \frac{(\Sigma x)(\Sigma y)}{n}}{\sqrt{\left[\Sigma x - \frac{(\Sigma x)^2}{n}\right]\left[\Sigma y - \frac{(\Sigma y)^2}{n}\right]}}$$

Σx represents sum of scores of respondents of one (odd numbered) group, Σy represents sum of scores by the second (even numbered) group of respondents and n represents the number of respondents for each group.

For teachers' questionnaire the reliability of the Likert type items was found to be 0.814. These values are above the value 0.70 cited by Siegle (2010) as minimum reliability required for research purposes. The instruments were therefore considered to give reliable data.

3.7.2. Validity and reliability of qualitative data

For the other part of the study (stages 2-4), qualitative research methods were employed. The proposed criteria for judging the "trustworthiness" of qualitative research is credibility, transferability, dependability, and confirmability (Guba & Lincoln, 1981; Morse et al, 2002; Trochim, 2006).

According to Trochim, (2006) the credibility criterion involves establishing that the results of qualitative research are credible or believable from the perspective of the participant in the research. This was achieved through formative evaluation of the lessons as carried out in the classrooms and responses from the teachers and the learners. Transferability refers to the degree to which the results of qualitative research can be generalized or transferred to other contexts or settings (Trochim, 2006). The researcher enhanced transferability through a thorough description of the research context and the assumptions that were central to the research.

Dependability emphasizes the need describing the changes that occur in the setting and how these changes affected the way the researcher approached the study (Trochim, 2006). This can be achieved by various evaluation activities in the study being embedded in a cyclic approach of design and formative evaluation for the development of instructional materials (Ottevanger, 2013). The design of this study was iterative in nature with results of one stage informing the next stage. Confirmability refers to the degree to which the results could be confirmed or corroborated by others (Trochim, 2006). It is a measure of objectivity in qualitative research. In the light of confirmability, the researcher has documented the procedures for checking the data throughout the study. After the study, one can conduct a data audit that examines the data collection and analysis procedures and makes judgments about the potential for bias or distortion (Trochim, 2006).

Morse, et al (2002) also argues that the standards for the post hoc evaluation of qualitative inquiry (which can be cited at the end of a study) is to determine the extent to which the reviewers have confidence in the researcher's competence in conducting research following established norms but cannot be used as verification strategy. The verification strategies that can be used by the researcher in the process of inquiry so that reliability and validity are actively attained include; methodological coherence, appropriate sampling, iterative interaction between data collection and analysis, thinking theoretically, and theory development (Morse et al, 2002)

This study used Design Based Research design that uses mixed methodology (DBRC 2003) which helps the researcher to ensure: (a) ability to discover new perspectives (b) ability to examine complementary facets of a phenomenon, (c) triangulation (d) development and iteration (using methods sequentially, so that results from the first method inform the second method), and (e) expansion (Aksela, 2005). The characteristics of design research used in this study enhanced the ability to attain the needs of trustworthiness regarding methodological coherencies.

Validity of findings in design research is addressed by the partnerships and iteration, which results in increasing the alignment of theory, design, practice, and measurement over time (DBRC, 2003). This study was iterative in nature with the outcome of one process informing refinement of the materials for the next stage and repetition of the processes. The users of the materials evaluated them and suggested refinements that would make the materials better. Research results that are validated through the consequences of their use provide consequential evidence or validity (Barab & Squire, 2004). Reliability of design research findings and measures can be promoted through incorporating multiple data sources (DBRC, 2003). Multiple data sources were used throughout the study process.

Investigator responsiveness determines the reliability and validity of the study (Morse, et al 2002). In this study, the researcher carried out lesson observations and allowed for flexibility in the use of lesson materials. The researcher was able to note important features emerging from classroom activities that were not indicated in the observation guide and used them to refine the materials.

Ottevanger (2013) incorporated quality criteria based on relevance, consistency, practicality and effectiveness. In this study, relevance was attained through review of literature, content analysis of instructional materials, lesson observation to identify needs of investigative practical work, generation of design specifications for the materials and expert appraisal by chemistry teachers. Consistency was attained through expert appraisal and formative evaluation of prototypes. Practicality was determined by users during the try-out as well as during the final evaluation and user appraisals while effectiveness was assessed during classroom use of the materals.

According to Nieveen (1999) the reliability and validity of the instructional materials can be based on the three aspects of quality of exemplary materials suggested which are; validity, practicality and effectiveness. These basically formed the criteria against which the designed instructional materials were evaluated.

3.8. Data Collection Procedure

The study was made up of five distinct stages that used different methods and study instruments as appropriate for the particular stage. The use of DBR requires a detailed account on the study procedures (DBRC, 2003).

3.8.1. Stage 1: Needs analysis for Chemistry practical work

This stage consisted of theoretical problem analysis which involved literature review on characteristics of appropriate materials for learner-centred investigative learning. It also involved context analysis of current practice and needs for learner-centred Chemistry practical work. This stage involved empirical analysis of: (a) the teaching needs of Chemistry practical work (b) Instructional materials available for Chemistry practical work (material needs analysis) (c) Worksheets and textbooks to identify skills emphasized by practical work in the curriculum materials as well as presentation of practical activities in the materials (content needs analysis).

The study in this stage was carried out using questionnaires for teachers, teacher interviews, document analysis schedule and lesson observation of Chemistry practical lessons. Document analysis schedule was used for analysis of the textbooks commonly used by teachers for Chemistry practical work.

Questionnaires were delivered to Chemistry teachers in the sampled schools by the researcher. All the Chemistry teachers in those schools were requested to complete the questionnaires. These were completed and returned to the researcher. In some schools, the researcher waited for the questionnaires to be completed while in others the researcher organised to pick the completed questionnaires later. The researcher visited the schools for which lesson observation were carried out and requested the Chemistry teacher to allow for observation for practical their sessions. The researcher and the Chemistry teacher agreed on an appropriate time when the lesson observations could be conducted. From the questionnaires, the researcher identified the textbooks commonly used to guide practical work in schools. These were acquired and their content on practical work analysed using the document analysis schedule. The findings of this part of the study and theoretical insights from literature review provided ideas concerning the characteristics of instructional materials that were developed to support learner-centred investigative practical work.

3.8.2. Stage 2: Design and development of materials for practical work in Chemistry

Using data gathered in stage one, design specifications were formulated. These were design standards against which the final materials were evaluated. Some design specifications found in Ottevanger (2001), CDC-HKEAA (2007), Ottevanger (2013) and Motswiri (2004) were adapted to suit the requirements of this study. The characteristics of the materials were based on insights learned from literature review on constructivist based teaching methods and influenced by needs analysis of chemistry teaching in practical work. The materials were checked for quality during design and development. This was based on what literature indicates as basis for quality judgement for instructional materials. National Science Resources Centre (1997), National Academy of sciences (1998) and Rubdy (2003) outlines criteria for judging quality of instructional materials as based on pedagogical appropriateness, content quality and organization and structure. Nieveen (1999) suggests a framework for making the concept of quality in exemplary materials more transparent. The framework is based on three aspects of quality, including validity, practicality and effectiveness.

The researcher designed and developed instructional materials based on the design specifications with complete guidelines on how to start, carry out the lesson and conclude it. These materials consisted of both teacher support materials and learner's activity sheet. They were based on the objectives of KCSE Chemistry syllabus; and were adapted from available materials by changing the practical activities into investigative practical work problems to encourage learner-centred classroom practice through presenting scenarios and asking students to develop experimental plans to solve the problems. Since exemplary materials could not cover all content in KCSE syllabus, one content area was identified. This area was on *acids and bases*. A total of six practical lessons were designed (first prototype).

3.8.3. The practical lessons: Acids and Bases

The Chemistry topic on 'Acids and Bases' was chosen because it offered many opportunities for development of investigative practical work. Teachers in most secondary schools use the topic to involve students in some 'hands-on' practical work. It is a topic that requires simple apparatus that can even be easily improvised. Common household substances such as washing liquids, fruits and foods are acids or bases. This brings out the topic of acids and bases as a topic of interest to the learners. Acids and bases is a suitable topic for countering misconceptions usually inherent in preceding topics of the salt preparation and the strength of an acid when related to other concepts such concentration acids and bases (Motswiri, 2004).

In this lesson series, students were involved in planning and implementing their investigation plans by carrying out experiments. In the Chemistry syllabus, acids and bases are recognised by their observable behaviour. The properties of acids and bases are covered in six lesson series which are:

Lesson 1: Identifying acidic, basic and neutral solutions by use of indicators

Lesson 2: Making ones' own indicator from red cabbage

Lesson 3: Strength of acid/base and pH value

Lesson 4: Reaction of acids with metals

Lesson 5: Reaction of acids with carbonates (blackboard chalk used as common carbonate compound).

Lesson 6: Neutralisation reaction (related to relieving stomach acid by use of antacid drugs).

After the series of six lessons, the learners developed concept maps for the content section covered. Creating these maps is essential because it allows learners to identify clusters of content that interrelate, determine the key ideas and build an instructional sequence to foster smooth understanding of concepts (Krajcik et al, 2007).

3.8.4. Appraisal of the instructional materials

Experts in the science discipline conducted content reviews on the practical work materials developed (first level prototype) to ensure scientific accuracy. Forty seven teachers training on Chemistry teaching were asked to study the materials in the light of appropriate methods of teaching Chemistry and provide feedback on important characteristics for investigative practical work. Three teachers who had taught Chemistry for a number of years appraised the materials. Two science education experts from a university were also requested to appraise the materials and the study instruments. This led to redesign and improvement of the materials to develop the second level prototype that was used by teachers in the classroom.

3.8.5. Stage 3: Try out of the second prototype

The second prototype of Chemistry practical work learning materials materials developed in stage two were used by three teachers in class and provided feedback and assessment on different aspects of their practicality and effectiveness. This is the first try-out as pilot study that assisted the researcher to assess the suitability of materials for use in classes including adjustments required in timing and refinement of methods and design principles. This stage involved the use of the materials to teach and the testing of the research instruments. The teachers were briefly explained on what was contained in the materials and what was expected of them in the use of the materials. Logbook for teachers to record their views about each lesson, lesson observation and interviews for both teachers and learners were used. Feedback from this try-out was used to refine the materials further. Qualified teachers with at least two years of experience in teaching the subject were selected because there was need of informed feedback on practicality of the exemplary materials in the selected contexts. Feedback from the try out was used to review and redesign the instructional materials producing a third level of materials (third prototype).

3.8.6. Stage 4: Evaluation of the instructional materials

The third prototype was used in the classrooms by five teachers. This stage involved formative evaluation of the practicality and effectiveness of the instructional strategies in the materials in Chemistry classroom settings. The researcher used a variety of methods and instruments to collect data. These were lesson observation, teachers' logbook and interviews for teachers and questionnaire for the learners. Lesson observation was done as the lessons progressed, interviews were conducted at the end of the lesson series, and the teacher logbook was used to record findings of each lesson throughout the implementation of the lessons. Learners filled questionnaires and were asked to draw conclusions and relationships of the content learnt in the six lessons through concept maps.

3.8.7. Stage 5: Redesign and refinement

The last stage of the development of the exemplary instructional materials design involves refining the materials based on the feedback from classroom outcomes to produce the best model of instructional materials that can be used in learner-centred investigative practical Chemistry.

The challenge of creating quality instructional materials to support teachers and learners in scientific inquiry practices requires iterative design research (Brown, 1992; Edelson, 2002; DBRC, 2003; Krajcik et al, 2007). The iterative design effort in the study draws on multiple data sources. Each data source provided a unique perspective, as well as reinforces the importance of concerns identified from other data sources (Krajcik et al, 2007). Works of Thijs (1999), Ottevanger (2001), Motswiri (2004) and Krajcik et al (2007) demonstrate that cycles of principled revisions can improve the learning outcome of an instructional design. The design of the materials was therefore developed in prototypes where the outcome of one stage informed the next stage shown in Figure 3.2.

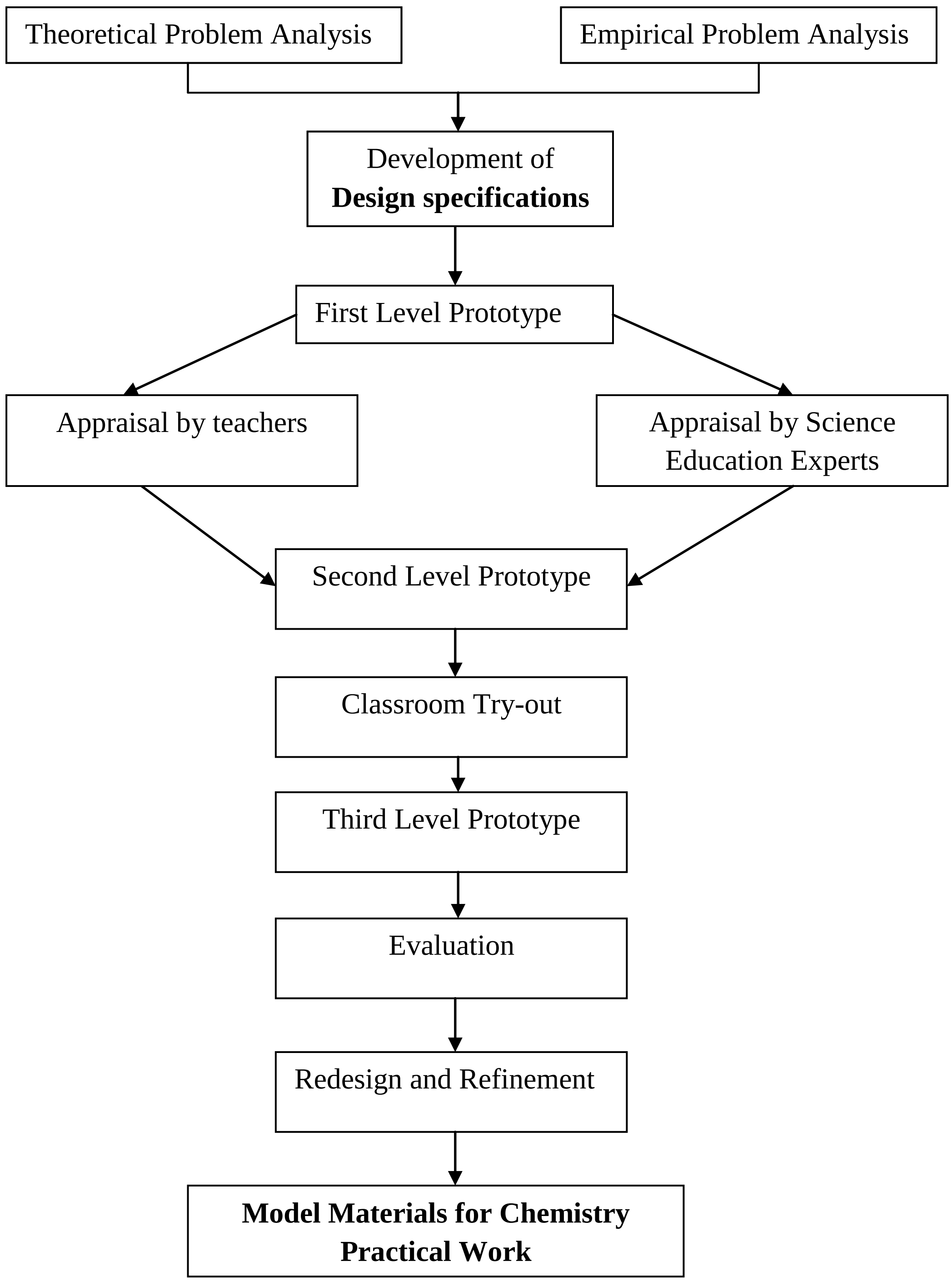


Figure 3.2: Development of instructional materials

The first level prototype was designed by the researcher guided by specifications of the instructional materials from theoretical and empirical review but subsequent versions of the materials were developed and formatively evaluated based on views of the experts and users. The final materials provided a model upon which investigative practical work in secondary school Chemistry can be based.

3.9. Data Analysis Procedures

Data collected through questionnaires was analysed quantitatively using descriptive statistics through Statistical Package for Social Sciences (SPSS) (Elliott & Wayne, 2007). Categorisation of questions and calculations of frequency distributions, means and percentages for various responses was done as guided by the research questions. Data was presented in appropriate tables, charts or graphs. The questionnaire items structured observing Likert–scale guidelines, were tallied and their frequencies calculated according to Likert Scale to show strengths of agreement or disagreement. Open-ended answers were classified into the content categories related to research questions. The answers to interview questions and logbooks was analysed by inductive content analysis (Denscombe, 2001). Classroom observations were analysed through summation of questions and categorization of responses.

3.10. Logistical and Ethical Considerations

Permission from the National Commission for Science, Technology and Innovation to carry out the research was sought. The County Education Officer, and County Commissioner (Kajiado County) were also informed of the intent to carry out research in the County. Head teachers from schools involved were consulted to allow research to be carried out in their schools. Consent from chemistry teachers who took part in the study was sought. An assurance of confidentiality was provided by the researcher. All the participants were informed about the nature of the study at the stage they were involved and the researcher guaranteed anonymity of individual participants. Participation was therefore voluntary.

3.11. Conclusion

This study involved analysing constructivist approaches to teaching and needs for learner-centred Chemistry learning, designing the instructional materials, developing materials through appraisals and trials, implementing and gathering feedback on their effectiveness in classroom situation and finally evaluating and refining materials hence coming up with instructional design model that would facilitate learner-centred teaching of Chemistry investigative practical work.

The prototypes consisted of six lesson materials including teacher guide and student work sheet based on the Form One Chemistry topic ‘acids, bases and indicators’ in the KCSE syllabus. Common household substances are acids or bases therefore the topic was of interest to the learners because it relates to their day to day activities. The development of prototypes used iterative design and formative evaluation with the outcome of an evaluation being used to build the next prototype which leads to with final product with empirical evidence of its practicality.

CHAPTER FOUR

PRESENTATION OF FINDINGS, INTERPRETATION AND DISCUSSION

4.1. Introduction

This chapter reports the findings, interpretations and discussion of the study findings. It describes finds on the needs for learner- centred investigative practical work in secondary school Chemistry. This is followed by design, development and appraisal of the prototypes of the practical work instructional materials intended to produce learner-centred teaching strategies for investigative practical work. It describes procedures for the development, appraisal, refinement and evaluation of the instructional materials, culminating in the development of a model that can be used in the construction of instructional materials that support teachers in using investigative practical activities in their classes.

4.2. Current Practices in the Teaching of Chemistry Practical Work

The aim of this phase of the study was to identify the current practices used by teachers in their Chemistry practical activities and to gather the views of Chemistry teachers about the status of secondary-level Chemistry practical work teaching and learning. The results of this phase provide the strategies that teachers employ in Chemistry practical work, and the support they needed in developing investigative practical activities in Chemistry. Data was collected using teacher’s questionnaire (Appendix I), document analysis schedule (Appendix II) and lesson observation schedule (Appendix III). The data from each of these sources was analysed and the results represented in the sections below.

The questionnaires administered to the teachers for the survey in phase one produced a response rate of 72.41% which is an adequate response rate for statistical reporting. Instructional Assessment Resources (2011) indicates that a response rate of 70% for questionnaires administered face to face or through mailing is good. This study satisfies this requirement because the study sample on which research was conducted was 58 teachers out of which 42 questionnaires were filled and returned.

4.2.1. Demographic data of teachers

Forty-two Chemistry teachers responded to the teachers' questionnaire. The first part of the questionnaire was intended to collect bio-data of the participants. This involved questions seeking to find out the qualifications, gender and experience of teachers. Table 4.1 shows the number by gender of the teachers that responded to the questionnaire items.

Table 4.1: Gender of the teachers involved in the stage 1 of the study

Gender	No. of Teachers	%
Female	19	45.24
Male	23	54.76
Total	**42**	**100.0**

The almost equal percentages of each gender indicate that the results of the study may not have been gender biased.

Chemistry teachers that responded to the study questionnaire were highly qualified and experienced in Chemistry teaching. The professional qualification of the teachers that participated in the survey is as shown in Table 4.2.

Table 4.2: Professional qualification of teachers

Professional qualification	**No. of Teachers**	**%**
M.Ed	2	4.8
B.Ed	**28**	**66.7**
B.Sc	8	19.0
B.Sc + PGDE	4	9.5
Total	42	100.0

Most of the teachers (71.5%) had at least a degree in education while 9.5% had Post Graduate Diploma in Education (PGDE). Therefore, a total of 81% of the teachers that responded to the questionnaire items were trained in the teaching of Chemistry. This implies that they were likely to have a good understanding of the strategies used in the teaching of Chemistry practical work and would therefore provide appropriate information regarding the teaching of the subject.

The teachers were also experienced in the teaching of Chemistry. Most of these teachers had some experience in teaching Chemistry as indicated on Table 4.3.

Table 4.3: Teaching experience of teachers

Teaching experience (Years)	No. of teachers	Percentage
0-4	14	33.3
5-9	6	14.3
10-14	10	23.8
15-20	4	9.5
Above 20	8	19.1
Total	42	100

It can be noted that 66.7 % of the teachers had taught Chemistry for at least 5 years with 52.4% having taught Chemistry for not less than ten years. The high qualification and long experience of teachers enabled them to provide wide and informed views regarding their practices in Chemistry practical work.

4.2.2. Types of Chemistry practical work used by teachers

The second section of the questionnaire was seeking to find out the instructional strategies, particularly the type of practical activities the teachers used and their views about the best practices in the teaching of Chemistry practical work. The teachers' responses were summarized in Table 4.4.

Table 4.4: Practical activities used by teachers in Chemistry

Method	**No. of teachers**	**%**
Demonstration	27	64.3
Group /Class experiments	9	21.4
Project	1	2.4
Individual student activities	5	11.9

N=42

The table shows that 64.3% of the teachers used demonstration activities in teaching practical work and only 21.4 % used group class experiments. All teachers indicated that they used some form of practical work in teaching Chemistry. This indicates that teachers attach a lot of value to the practical work in Chemistry teaching. This is in agreement with most practitioners who argue that good quality practical work can engage students, help them to develop important skills, help them to understand the process of scientific investigation, and develop their understanding of concepts (Millar, 2004; SCORE, 2009). Project work was not commonly used as only 2.4% indicated using it. This is, however, an approach that would assist learners in guiding their own learning experiences and improve individual learning.

The teachers were also asked to indicate the practical work activities they would prefer and thought would produce the best outcomes of Chemistry learning. The

Figure 4.1 shows that 82% of the teachers that believe use of class experiment activities would produce best results in the learning of Chemistry.

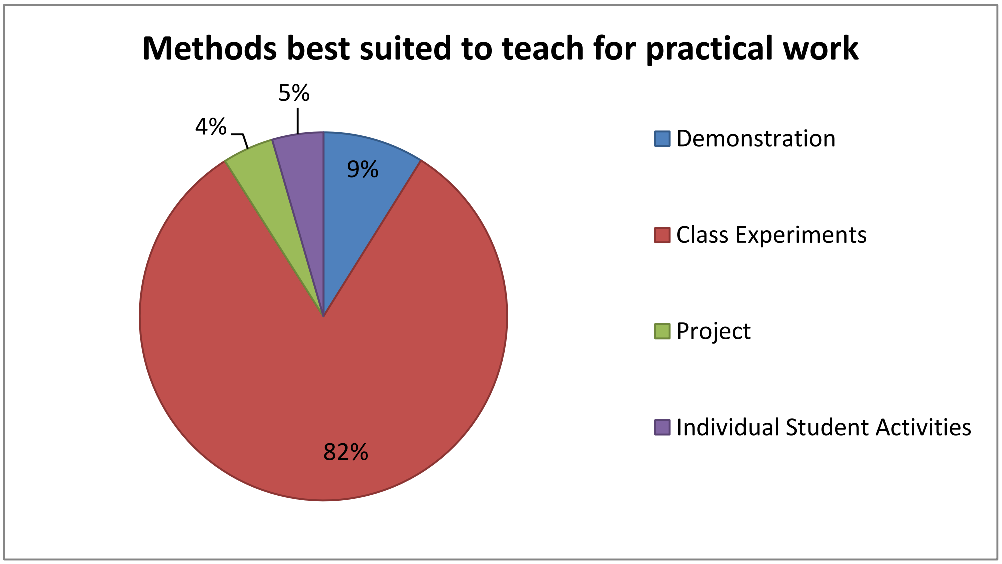


Figure 4.1: Methods of teaching practical work preferred by Chemistry teachers

Only 9% of the teachers thought that demonstration would produce the best results in Chemistry practical work. Most teachers (82%) indicated that use of classroom activities involving learners in groups would provide better learning and thus produce better results in Chemistry. This is because class experiments give learners an opportunity to handle the apparatus and develop various manipulative and process skills. It is, however, important to note that most of the teachers used demonstration method in their practice (as indicated in Table 4.4). This is a strong indication that they needed support in the implementation of class activities for practical investigations.

The researcher also sought to know the frequency with which teachers used various methods to carry out practical work. The percentage of each response was as in Table 4.5.

Table 4.5: Frequency with which each practical activities was used in Chemistry classrooms

Practical activity	**FREQUENCY (%)**					
	Never	**Once a term**	**Twice a term**	**Once a week**	**Twice a week**	**More often**
Group/ Class experiments	0	9.5	**42.9**	19.0	23.8	4.8
Teacher Demonstration	2.4	7.1	14.3	**47.6**	14.3	14.3
Project	**69.0**	26.2	4.8	0	0	0
Individual student activities	**35.7**	**35.7**	9.5	4.8	0	14.3
Average frequency	26.8	19.6	17.9	17.9	9.5	8.4

N=42

The table shows that the most commonly used type of practical work is through demonstration method as 47.6% Chemistry teachers used this method at least once a week. This is in agreement with the findings of Motswiri (2004), who noted that most teachers used to teach Chemistry through lecture method and when practical activities were carried out, they were done as teacher demonstrations. Though class experiments were rated as the best approach in the teaching of Chemistry, most teachers used it only twice in a term. Project work was rarely used with only 4.8% using it twice a term and 69.0% not using project work at all. Individual student activities were also not commonly used in Chemistry practical work teaching. The table indicates that on average, 26.8% of teachers never used any form of practical work in their Chemistry classrooms while 37.5% used practical work not more than twice a term. This could be mainly due to lack of resources and facilities (Orado, 2009; Nyang'ai, 2010), as well as lack of support of curriculum materials that could guide the teacher on improvisation of locally available materials for use in the Chemistry classroom.

The results were coded like Likert type items. Since the codes were meant to present frequency with which each method was used, the responses were coded such that the response never was zero, once a term was 1, twice a term was two, once a week was three, twice a week was four and more often was represented by five. The means of each response in percentage of use were calculated and the results presented in Figure 4.2.

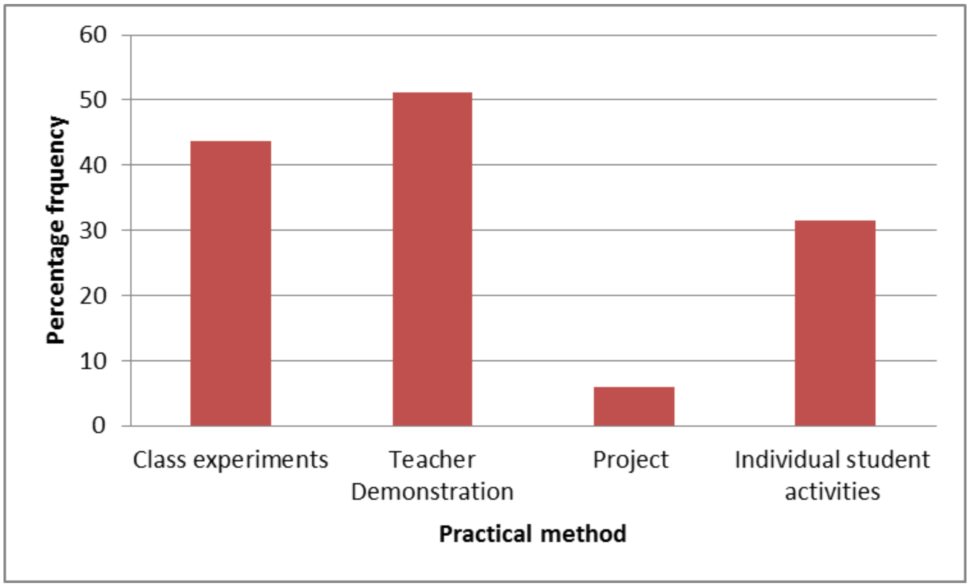


Figure 4.2: Average use of various approaches to practical work

The figure shows that teacher demonstration was the most frequently method used despite its limitations in development of manipulative and process skills in learners (Twoli, 2006). Other than making Chemistry learning abstract and uninteresting, teaching Chemistry without practical work does not enable the learners gain conceptual understanding of the content matter, manipulative and process skills essential in science learning as well as in the development of a nation (Chiapetta & Koballa, 2010; Trowbridge et al, 2004; Twoli, 2006). It does not also provide learners with a learning environment that encourages self-motivated and self-driven learning (McCombs & Whistler, 1997).

4.2.3. Reasons for using practical work in teaching chemistry

The researcher sought teachers' views on the purpose of practical work in Chemistry teaching. They were allowed to note down all their reasons for use of practical work. The responses were coded as a, b, c, d, e and f depending on the frequency of each response and summarized in Table 4.6.

Table 4.6: Reasons for using practical work in teaching chemistry

Code	**Reason for using practical work**	**No. of teachers**	**%**
a	To arouse interest in learners and motivate them	**40**	**95.2**
b	To verify facts/ theories or principles discussed in class.	**39**	**92.9**
c	To make learners understand a concept more readily	38	**90.5**
d	To make them relate Chemistry with life outside the classroom.	**32**	**76.2**
e	To keep learners engaged/busy.	**12**	**28.6**
f	To develop their investigative skills for everyday life	**10**	**23.8**
g	Because it is a requirement by the school/ department/ ministry	**6**	**14.3**

N=42

The teachers valued the use practical work to arouse interest in learners and motivate them to learn (95.2%), to verify facts/ theories or principles discussed in class (92.9%) and to make learners understand a concept easily (90.5%). This actually agreed with the importance of practical work from literature review (Hofstein, 2004; Millar, 2004; Achimugu, 2009; Twoli, 2006) (Chapter 2, section

2.2). Figure 4.3 shows relative importance attached to each reason of using practical work.

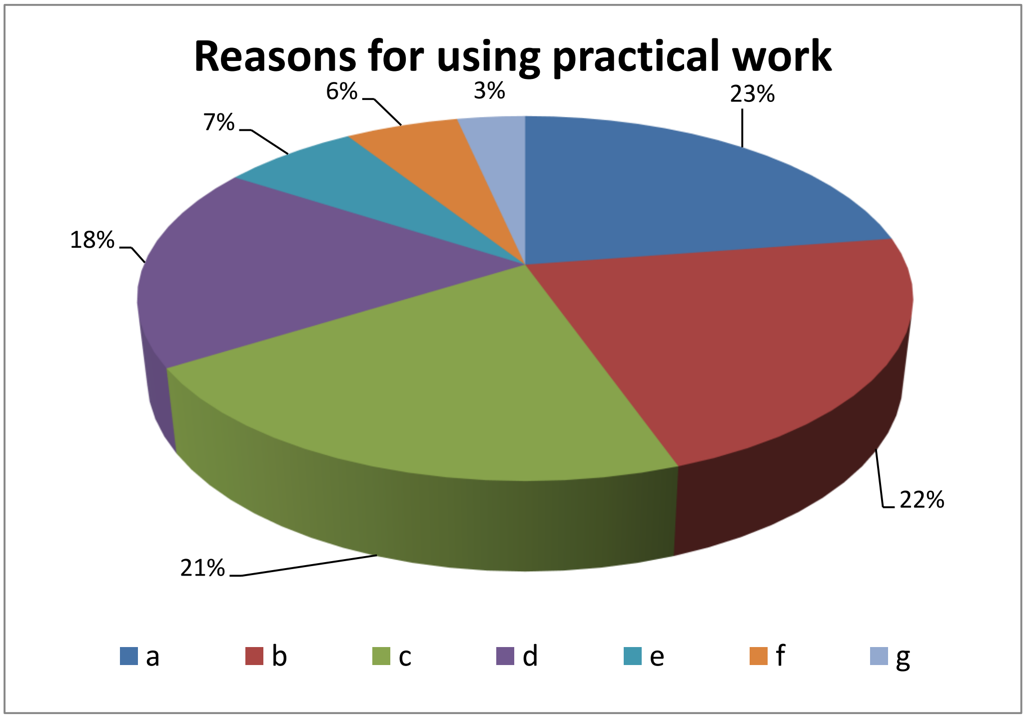


Figure 4.3: Reasons for using practical work in Chemistry teaching

The responses were taken to represent the relative value which teachers attach to the use of practical work. It is therefore possible to conclude that teachers do not attach a lot of importance to developing investigative skills for use in everyday life (6%). They however attach a lot of value to verification of facts/ theories or principles discussed in class. The type of practical work could also be affected by the fact that Kenyan curriculum is examination based and therefore teachers lay a lot of emphasis on areas and ways in which Chemistry would be tested at the end of the four year course. This could point to the reason as to why Chemistry practical work does not take the investigative approach.

4.2.4. Current classroom practice in Chemistry practical lessons

The teachers were also requested to indicate how they engaged the learners during Chemistry practical work. The responses were guided by 14 Likert type items which were divided into two sections. The first section sought to determine ways in which the learners were involved while the second section aimed at determining the level of engagement of learners in the practical activities. Responses to the question on how the teachers encouraged learners' engagement in practical work during their lessons were tabulated. The five items were in form of five scale likert type items which were coded and analysed in frequencies of occurrence. They were coded with strongly agree=5, agree=4, neutral=3, disagree=2, strongly disagree=1. Negative items in the questionnaire were changed to fit in the positive scale and the responses adjusted accordingly. Strongly agree and agree were combined to indicate agreement with the statement, while disagree and strongly disagree formed disagree. The results were as shown on Table 4.7.

Table 4.7: Involvement of learners in practical work

Learners are Involved in Practical Work Through:	Agree		Neutral		Disagree	
	No.	%	No.	%	No.	%
Being placed in groups	36	85.7	4	9.52	2	4.8
Being provided with detailed procedures to follow.	34	80.9	6	14.3	2	4.8
Designing experiments that relate to their lives' experiences.	24	57.1	4	9.5	14	33.3
Being allowed to design their practical experimental procedures.	8	19.1	14	33.3	20	47.6
Stimulating them to reflect on their prior knowledge.	40	95.2	2	4.8	0	0

N=42

The results indicate that 85.7% of the teachers were of the view that placing learners into groups and providing them with detailed procedures (80.9%) were ways of engaging learners in practical work. It is however important to note that merely placing learners in groups does not lead to practice of inquiry (Wachanga & Mwangi, 2004). Most teachers (80.9%) believe that providing learners with detailed procedures to follow leads to their engagement in learning. Educationists and researchers have however shown that students' following strictly set procedures to arrive at a predetermined outcome does not lead to meaningful learning in science (Woolnough & Allsop, 1985; Hodson, 1992; Pogrow, 1993; Osborne, 1993; Hubber & Moore, 2001; Trowbridge et al, 2004; Motswiri 2004;

Chiapetta & Koballa, 2010). Stimulating learners to reflect on their prior knowledge and design experiments would engage their minds on the activities to be carried out and thus improve science learning.

The frequency of use of learner involving practices in chemistry practical lessons was determined by use of eight questionnaire items. The eight items were coded as a, b, c, d, e, f, g and h and their percentage frequencies calculated. They were as shown in Table 4.8.

Table 4.8: Practices in Chemistry practical lessons

		Percentage frequency				
	Practice	Never	Seldom	Some times	Most times	Always
a	Working in groups	0	0	47.6	42.9	9.5
b	Use provided procedures	0	0	9.5	38.1	52.4
c	Designing experimental procedures	71.4	23.8	4.8	0	0
d	Carry out their own procedures	52.4	47.6	0	0	0
e	Design and carry out procedures interest learners	52.4	40.5	7.1	0	0
f	Question developed procedures	42.9	47.6	9.5	0	0
g	Carry out peer review of experiment	4.8	28.6	28.6	23.8	14.3
h	Write their laboratory reports	33.3	21.4	7.1	23.8	14.3

It was found that 71.4% of teachers never allowed the learners to develop their own procedures, or carry out procedures that interested them. Most teachers 47.6%

rarely allow learners to question the procedures they were given while a good number 42.9% never had learners questioning the procedures. The teachers instead provide learners with detailed step by step procedures that they followed as provided. This agrees with findings of a study by Motswiri (2004) where it was found that learners could carry out hands on activities while ideally their minds were not focused on the activity. This indicates that the learners may not actively engage their minds during the practical activity. This method has been referred to as providing ‘hands on’ and not ‘minds on’ activities (Hodson, 1992; Tobin et al, 1990; Chiapetta & Koballa, 2010). Figure 4.4 shows a comparison of the frequency of use common practices in chemistry practical lessons.

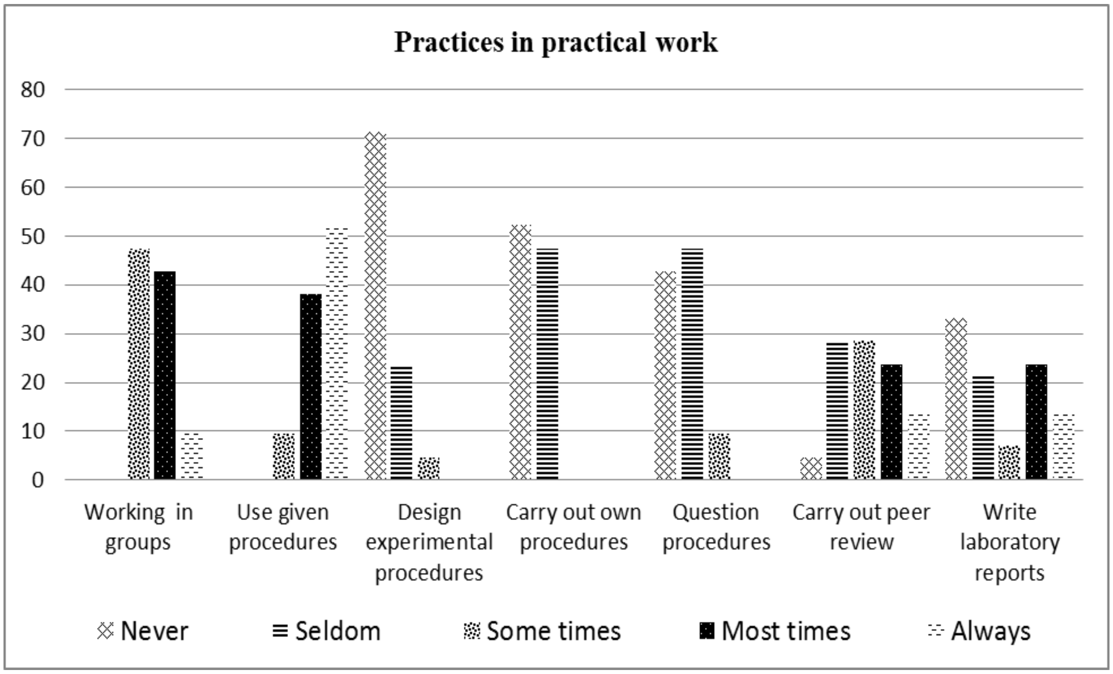


Figure 4.4: Practices in Chemistry practical lessons

Learners rarely designed procedures and carried them out. Working in groups was also not common in chemistry classrooms. This pointed to a need for support of teachers to implement these activities that they did not carry out in chemistry practical work.

4.3. Opportunities Provided by Curriculum Materials for Support of Investigative Practical Work in Chemistry

4.3.1. Instructional materials used in Chemistry practical work

In order to make informed decisions about the initial development of the features of instructional materials, it was necessary to explore the characteristics of the curriculum materials commonly used by teachers (Davis et al, 2014). Through the questionnaire for teachers, feedback was sought on the instructional materials that teachers used to guide their teaching of the Chemistry topic on acids and bases. The responses were then used to determine the appropriate materials whose content was to be analysed. The teachers also indicated the frequency of use of each of the materials. The results were as indicated on Table 4.9.

Table 4.9: Instructional materials used for Chemistry practical lessons in the topic on acids and bases

Instructional Material	Frequency of use				
	Always	Very Often	Often	Rarely	Never
Kenya Literature Bureau; Secondary Chemistry Book 1	14	22	6	0	0
(Muchiri and Maina) Principles of Chemistry pupils book 1	2	4	12	12	10
Longhorn Secondary Chemistry Form 1	6	8	12	4	2
Comprehensive Chemistry Book 1	2	0	22	12	2
N.M. Patel -Secondary chemistry book 1	0	0	6	22	2

N=42

The table shows that the most often used books were Kenya Literature Bureau (KLB) Secondary Chemistry Book 1, Principles of Chemistry pupils book 1, Longhorn Chemistry pupils book 1 and Comprehensive Chemistry book 1. Patel secondary chemistry book 1 was also in use though not as common as the others.

These were the books whose content was analysed. It was noted that teachers only used the mainstream Chemistry text books that are approved by KICD. They did not have laboratory manuals that they could use for practical work. This indicates need for special instructional material support for practical work in Chemistry teaching and learning.

4.3.2. Support provided by the curriculum materials for Chemistry practical work

The teachers were also requested to give information on the kind of support for learner-centred practical work they got from the instructional materials they used. This was done through use of 16 Likert type items where the teachers indicated their levels of agreement with the given statement. The results are in Table 4.10.

Table 4.10: Teachers' views on support for investigations provided in books

		Frequency %		
Characteristics of Chemistry practical work instructional materials		***Agree***	***Not sure***	***Disagree***
a	They provide clear objectives of the practical activity	90.5	4.8	4.8
b	The practical activities are related to learners' needs/ interests	28.6	38.1	33.3
c	Practical activities are based on learners real life settings to make them relate chemistry with life outside the classroom	42.9	9.5	47.6
d	They provide the expected results of the practical	81.0	14.3	4.8
e	They give sufficient background knowledge related to the practical activity	33.3	14.3	52.4
f	They provide detailed step by step experimental procedures	95.2	0	4.8
g	They give a list of apparatus required for practical	76.2	9.5	14.3
h	They provide grouping suggestions	23.9	19.0	57.1
i	Safety precautions are clearly indicated	66.7	23.8	9.5
j	They give opportunity for predictive guiding question	30.9	14.3	54.8
k	They give learners opportunity to develop their own practical procedures	14.3	35.7	50.0
l	They guide the teacher on probable questions from learners	26.2	14.3	59.5
m	They guide learners on writing a report	28.1	33.3	38.6
n	They have sufficient Assessment options	38.1	23.8	38.1
o	Allowance to look for alternatives to procedures given	19.0	11.9	69.1
p	Encourage thoughtful reflection on experience	38.1	26.2	35.7

The statements were coded with strongly agree=1, agree=2, not sure=3, disagree=4, strongly disagree=5. The negative items in the questionnaire were changed to provide the positive scale and the responses adjusted accordingly. To simplify the survey data further the five response categories were combined into two nominal categories. Strongly agree and agree formed agree, while not sure, disagree and strongly disagree formed disagree (Likert, 1932).

The instructional materials that teachers use in the teaching of Chemistry were indicated as having important qualities in guiding practical activities. The main quality being that they contain clear objectives of each practical outlined. It is important to note that the objectives should be used to guide all phases of the activity design (Reiser et al, 2003). It can however be noted that a mere 28.6% of the teachers agreed that practical activities in the instructional materials related to learners' needs and interests while only 42.9% of the teachers agreed that the activities are based on learners real life settings. According to Kesidou & Roseman (2002) meaningful learning can be achieved through sound pedagogy such as taking account of students' prior conceptions, providing first-hand experience with phenomena, providing a sense of purpose connected to the target science in each activity.

Most of the practical activities appeared to be geared towards confirmation of facts and ideas and therefore provide detailed step by step experimental procedures (agreed by 95.2%). Most of the teachers (81.0%) agreed that the expected results of the practical activity were clearly outlined and most learners work towards getting the results indicated in the book. Teachers indicated that the materials they use do not provide learners with an opportunity to develop their own procedures for practical activity, allow them to look for alternatives to procedures given or encourage thoughtful reflection on experience.

The teachers were also requested to give their opinion on how instructional materials can be improved to make them better able to support the teacher in organizing practical work. Some indicated that they should be enriched with more activities that learners are familiar with.

4.3.3. Extent of support provided by the Curriculum materials for investigative practical work

Content analyses of the curriculum materials (books) that chemistry teachers commonly use in the teaching of acid bases and indicators (as indicated in Table 4.9) was done with the aim of identifying the needs of Chemistry learning and the learning opportunities these materials offered. It was also necessary to find out the support that these materials offered Chemistry teachers in implementing learner-centred investigations in chemistry practical work. The books were analysed on aspects related to the concepts on which each of the six lessons developed for this study were based. The lessons developed for this study were based on the instructions in the curriculum materials the teachers were using by changing them to investigative form of activities. The six lesson areas were:

1) Identifying acidic and basic solution using an indicator.
2) Preparing simple acid base indicator from flower extracts.
3) Determining the strength of acid/base using pH scale.
4) Reaction of acids with metals.
5) Reaction of acids with carbonates.
6) Neutralization reactions.

The first section of the analysis was therefore based on learning aspects/domains noted for each of the six lesson areas with each aspect being allocated one point per lesson area. Each aspect therefore could have a maximum of six points (when the aspect was identified in all the six lesson areas) in each book analysed. A value of 6 shows that the book had emphasis on the particular aspect in all its six lesson areas while a value of 5 indicates that five lesson areas had shown emphasis on the aspect and so on. Table 4.11 shows the frequency of aspects of Chemistry learning emphasized by practical work in the books teachers use. The mean occurrence for each aspect from all the materials was calculated.

Table 4.11: Aspects emphasized by practical work in curriculum materials

	Aspect	**KLB**	**LHC**	**PC**	**CC**	**PSC**	**Mean**
1	Knowledge of facts	6	6	6	6	6	6.0
2	Understanding	6	6	4	5	3	4.8
3	Hypothesizing /predicting	0	0	0	1	0	0.2
4	Application of scientific facts	2	5	2	3	4	3.2
5	Creativity and imagination	0	2	0	1	2	1.0
6	Analysis, Synthesis and Evaluation	1	1	2	2	3	1.8
7	Observational skills	6	6	6	6	6	6.0
8	Manipulative skills	6	6	6	6	6	6.0
9	Data recording	6	3	6	4	2	4.2
10	Data interpretation	5	4	5	4	4	4.4
			Min =0		Max = 6		

Code Key

***KLB**- Secondary Chemistry Book 1 by Kenya Literature Bureau*

***PC**-Principles of Chemistry Book 1 by Muchiri & Maina.*

***LHC**-Longhorn Secondary Chemistry Form 1 by Ngaruiya, G., Kimaru, J. & Mburu, P.*

***CC**- Comprehensive Chemistry Book 1*

***PSC**- Secondary Chemistry; Form 1 by Patel, N.M.*

The analysis showed that the books had put a lot of emphasis on lower order learning levels such as knowledge of facts (mean of 6) and understanding (mean of 4.8) while higher order learning such as analysis, synthesis and evaluation did not receive as much emphasis (mean 1.8). The analysis and synthesis aspects noted were in the questions at the end of the topic. The skills emphased were manipulation and observation skills (6). This was in agreement what other researches on Chemistry practical work in Kenya had noted (Orado, 2009; Nyang'ai, 2010). The materials were lacking in emphasis of important skills of predicting/hypothesizing (mean 0.2), creativity and imagination (1), as well as application of scientific facts (3.2). The small amount of application noted was placed at the end of the topic as uses of acids and bases but did not indicate their direct relationship to the practical activities that the learners were involved in. Creativity was only noted in the books that offered project work at the end of the topic. Some of the project work was organized in such a way that the learners activities were directed minimizing the amount of creativity they could employ.

To strengthen the teachers' views given in the questionnaire, the materials were analysed to find out various opportunities they offered for carrying out investigations. These were analysed by viewing each of the six basic experiments in the topic and noting down whether or not the opportunity was provided. The number of times each opportunity was noted out of the six experiments was then indicated for each curriculum material and the mean and its percentage calculated. The analysis was similar to that of the section above. The results were as shown on Table 4.12.

Table 4.12: Opportunities for investigation on acids and bases in the Chemistry books

Opportunities for carrying out		Instructional material/book						
		KLB	LHC	PSC	CC	PC	Mean	%
a	Clear objective of the practical activity	6	3	3	4	6	4.4	73.3
b	Background information related to the practical activity	2	1	2	2	2	1.8	30.0
c	List of apparatus required	0	3	2	3	6	2.8	46.7
d	Grouping suggestions	0	0	0	0	0	0	0.0
e	Safety precautions	1	0	0	0	0	0.25	4.2
f	Provide a guiding question	1	0	0	0	0	0.2	3.3
g	Gives step-by-step practical procedures	6	6	6	6	6	6	100
h	Reference to prior knowledge	1	2	2	2	2	1.8	30.0
i	Teacher guide on probable questions from learners	0	0	0	0	0	0	0.0
j	Guide on pooling results and support arguments	0	0	0	0	0	0	0.0
k	Providing a relevant phenomena	1	1	2	1	2	1.4	23.3
l	Opportunity to develop procedures or look for alternatives to given procedures	0	0	0	0	0	0	0.0
m	Assessment opportunities	3	5	3	4	3	3.6	60.0
		Min =0 Max = 6						

Code key: as used in table 4.11

The results show that most of the books that teachers use (73.3%) do provide objectives of the activity which was commonly written as a statement of what the learners were seeking to find. The objectives are important in focusing the learner towards the intended goal (Ottevanger, 2013). Very little information was provided in background information (30%) which was mainly written at the beginning of the topic in such a way that learners could not easily identify its relationship with the activities they were to carry out later. It was found that for most of the activities the teacher would have to read through the procedures to find out the list of apparatus and reagents necessary for a particular activity. Only less than half of the activities were provided with a list of the apparatus (46.7%).

The books seemed to be oblivious of the fact that it would be important for learners to work in groups. The teacher was not guided on how to manage learners' activities during learning. Very little reference was made to learners' prior knowledge (30.0%) and the activities outlined did not focus on what was common to the learners/relevant phenomena (23.3%). The 30% indicated as observed on prior knowledge of the learners was only in the assessment questions at the end of the topic. This indicates that the materials do not emphasize on constructivism in learning science (Brooks, & Brooks, 1999; Hidir & Gultekin, 2007). The structure of the activities involved provision of step-by-step procedures for all practical activities and did not accord learners an opportunity to develop procedures or look for alternatives to the procedures given.

All the materials had assessment opportunities at the end of the topic. However, because the assessment for all the activities in the topic was covered together at the end of the topic, it was found that some lesson areas were not covered by the assessment provided.

Learners were not accorded opportunities to engage in scientific arguments and support the outcome of their experiments. These results point to the fact that the emphasis in the instructional materials available does not provide sufficient guide to scientific practices and higher order thinking. Similar weaknesses concerning instructional materials have been noted by other researchers (Thijs, 1999; Stoffelsma & Kwetu, 2004; Ottevanger, 2001; Motswiri, 2004; Krajcik et al, 2003).

4.3.4. Lesson Observation

Analyzing the curriculum materials using the identified areas of learning as well as literature review guided the researcher to develop lesson observation schedule for use in observing both lessons taught using the available materials that are currently used as well as the materials created for this study. The lesson observation schedule was thus customized to include prompts for characterizing the key steps within the lesson to show whether or not activities were carried out to achieve learner-centred learning and to cover the aspects of learning Chemistry.

The lesson observation schedule included the three sections of a Chemistry lesson plan namely; lesson introduction, lesson development and lesson conclusion (Twoli, 2006). Each section had described expected actions related to learner-centred activities based on constructivism and a place to mark whether the action was observed or not (see Appendix III). There was also space for comments that assisted the researcher in identifying and describing the learners' engagement in the lesson and the teacher's apparent level of comfort and areas that were challenging. The resulting data informed the incorporation of theoretically grounded educative features in instructional materials for this study.

Six Chemistry practical lessons were observed. From lesson observations, it was noted that all the teachers were able to provide learners with the objectives of the lesson and organize learners in groups, though the groups were mainly large comprising of more than five learners. In four of the lessons, the apparatus were well distributed in an orderly manner and were correctly used. However in two classes, the learners picked the apparatus from the demonstration bench. The process was however not well organized because the learners were not provided with a list of the apparatus they needed for the activity and therefore spent time looking around. For example, the solutions to be tested were to be shared by all groups yet some learners picked the solutions and kept them to themselves. A lot of time wasting as some learners moved from group to group looking for particular solutions. In two lessons, the teachers spent time preparing some of the solutions as the learners carried out the activities and thus could not supervise the activities.

In all the lessons observed, the teacher gave a detailed step by step procedure for the learners to follow and the learners followed these procedures without question. In four out of the six lessons observed, the teachers did not provide background information or even ask learners to reflect on their own ideas. In the other two lessons, the teacher gave brief descriptions of the lessons. In three of the six lessons, the teacher simply discussed the concept demonstrated by the practical activity without involving learners' views and consolidating their results. In the other two lessons, the teacher asked the learners to say their findings but did not ask them to support their argument or to receive others views regarding the answers given. In one lesson the teacher simply allowed learners to copy the conclusion as written in the text books they were using.

It was also noted that the teachers had a few challenges in content knowledge. One of the teachers was not able to tell the learner whether the methylated spirit (ethanol) and sugar solution used at home is basic or acidic. They learners were also not provided with an opportunity to find out for themselves. All these were indicators of the fact that though chemistry practical activities were being carried out in schools, they did not take the investigative form. This was in agreement with findings the of Motswiri (2004) and Kracjik et al (2007)

4.4. Challenges Faced by Teachers in Conducting Learner Centred Practical Work

The teachers were faced with various challenges in their endeavor to implement learner-centred investigative practical work in Chemistry learning. During lesson observations, the teachers were found to conduct practical work that was not reflecting investigative nature. They also indicated that class experiments were the best method for teaching practical work yet they mostly used teacher demonstration method. Some of the challenges they faced in trying to conduct investigative practical activities include:

1. Lack of confidence and limited understanding of the science content on the part of the teacher. Understanding of the Chemistry content gives the teacher confidence and this does influence and drive science teachers' practice. The teachers therefore needed support in detailed content matter of the practical activities.
2. Inadequate resources and time to prepare for the activities and to carry out investigations. There was need for support in improvisation of materials and provision of detailed requirements for the activity to ease teachers' preparation for the practical session.
3. Lack of support in the development of investigative abilities such as prediction, questioning, hypothesizing, designing experiments and scientific arguments. With the step by step recipe-type of instructions learners simply

carried out activities without giving much thought to them. This could be due to a lot of emphasis on manipulative skills and observational skills. A detailed teacher guide on lesson organization and implementation could assist teachers in implementing learner centred investigative activities (Ottevanger, 2001 Motswiri, 2004).

4. Lack of understanding of the learners' prior knowledge and misconceptions held by the learner. Prior knowledge seemed to be ignored in the chemistry practical work and yet it's a key pillar in constructivism teaching and learning.
5. Lack of collaboration and peer review during practical activities. The activities as laid out in the curriculum materials used in schools do not encourage learners to enquire from each other and challenge each other's thinking since all activities are well outlined. Allowing learners to do predictions as well as design their own experiments allows for varied views of the phenomena and provides learners with an opportunity for scientific arguments.
6. Insufficient support for development of ability to make inferences and conclusions from experimental observation. The learners and the teacher tend to carry out experiments to verify what they already learnt and simply follow the conclusions indicated in the curriculum materials they are using.

7. Practical activities are not commonly based on learners' real life settings which can make it difficult for them to relate Chemistry with life outside the classroom. This could lead to lack of interest in the learning of Chemistry which in turn affects chemistry performance (Nyang'ai, 2010)

Due to these challenges in the implementation of Chemistry practical lessons, students' meaningful learning is not supported. There is a lot of rote learning and Chemistry is often boring to students (Aksela, 2005). The learners are not able to relate chemistry to their day-to-day experiences and appreciate its role in the community. The evidence gathered from empirical and literature review demonstrated the importance of providing support for investigative practical work through instructional materials that would assist the teachers to overcome these challenges.

4.5. Design and Development of the Instructional Materials for investigative practical work in Chemistry

The instructional materials developed in this study were specifically designed to assist teachers overcome the challenges they faced in implementing investigative practical activities in their classrooms and thus improve learning outcomes. Through content analysis of the instructional materials that teachers commonly use to teach the topic on acids, bases and indicators, the researcher identified the needs of the science learning and the learning opportunities they offered to the learners.

Analysis of responses from teachers and lesson observations were also used to identify areas where teachers needed support in teaching Chemistry through practical work. These analyses, coupled with literature review, informed the design of curriculum materials used in the study. Five areas of learning against which curriculum materials can be designed were identified. Davis et al (2014) referred to them as five lenses. These areas are science content, scientific practices, literacy practices, participation structures, and assessment.

4.5.1. Design Specifications for the Instructional Materials

The design specifications were formulated as informed by the empirical review and by what the literature says about best practices with regard to how teachers can support students in engaging in specific practices in science learning. Design specifications are important in guiding the development of instructional materials (Motswiri, 2004).

The design specifications developed for the instructional materials used in this study characterize five key features: content support features, support for scientific practices, support for scientific literacy, support for teaching strategies for participation and support for assessment of student's learning outcome. A description of each of these features as used in the design specification of the instructional materials is provided below.

Science content is central in learning. Scholars have recognised the central importance of content supports for teachers in educative curriculum materials (Davis et al, 2014; Davis & Krajcik, 2005; Kesidou & Roseman, 2002). Actual content for each lesson developed was therefore provided in the teacher guide including background information and lesson notes. The content was based on the topic of acids and bases.

According to Reiser, et al (2003), **Scientific practices** are achieved through motivating and contextualizing the inquiry. This involves; asking scientific questions, making or revisiting predictions, designing or setting up investigations, collecting data, making observations, recording, organizing and analyzing data and observations, representing and interpreting data, constructing evidence-based explanations, making inferences, sharing ideas and making scientific arguments (Davis et al, 2014). The context for the inquiry is created through the use of a driving question, a rich, open-ended question that connects with authentic interests and curiosities students have about the world (Reiser, et al, 2003)). Contextualizing inquiry also involves use of common day experience to help students apply their scientific understandings to the real world (Reiser, et al, 2003). Learners engage in various scientific practices as a key to understanding their experiences and answering the driving question which they find motivating. The scientific practices used in developing the instructional materials included; use of driving question, relating to everyday experiences, predicting outcomes, designing experimental procedures, making and recording observations as well as explaining the observations made.

Scientific literacy practices involves using scientific language, and engaging in scientific arguments and discourses of the content areas (Davis et al, 2014; Reiser, et al, 2003). The instructional materials made provide multiple opportunities for students to predict, observe, and explain their ideas about scientific phenomena in oral and written discourse.

Participation structures involve use of various strategies that support learners in inquiry practices some of which they may not be familiar with (Davis et al, 2014). This includes; collaboration and discourse in whole group discussions, teacher led or student led, small group peer-assisted learning, student led as well as teacher and student led discussions through communicating scientific procedures and explanations of observations. The instructional materials also guided teachers to scaffold learning by sequencing, modeling, coaching, and giving feedback. Scaffolded learning materials reduce complexity and highlight concepts and inquiry strategies (Reiser, et al, 2003). The materials guided teachers to discover and use students' prior knowledge by understanding them through use of prediction activities. These prior conceptions serve as foundations for building new understandings.

Assessment opportunities: Anticipating students' ideas is an important form of support emphasized in the literature (Ball & Cohen, 1996; Kesidou & Roseman, 2002). Having assessment materials present in educative curriculum materials supports teachers' practice (Grossman and Thompson, 2004). Some assessment practices incorporated in the instructional materials for this study include; notebooks pre-activity and post-activity reflections, and written responses to prompts; verbal communication in whole group and small group discussions during predictions, observations, recording data, planning investigations, structuring results, drawing conclusions, giving evidence-based explanations and presentations. The teacher was provided with suggested feedback that he/she might use in responding to student questions. At the end of the lesson series, concept maps were also used.

Similar design specifications are found in Ottevanger (2001), Reiser, et al (2003), Motswiri (2004), CDC-HKEAA (2007), Ottevanger (2013) and Davis et al (2014) and were adapted to suit the requirements of this study. Given best practices recommended in the literature, the design features of the materials included recommendations and guidance about how teachers can implement and adapt the recommendations (Davis & Krajcik, 2005). An overview of the design specifications used to develop the first prototype instructional materials is presented in Table 4.13.

Table 4.13: Design specifications for the instructional materials

Design specification feature supported	Characterization of teacher support provided for the feature
Content support (subject knowledge)	Core content to be learnt- concepts and skills • Background information- provides a description of what the lesson looks like and what is expected. • Objectives of the lesson (based on the KCSE Chemistry syllabus) and structuring content around learning goals. • Topic (acids, bases and indicators) notes on actual content • providing solutions to problems that may develop during the lesson such as possible student questions and answers – to reduce uncertainty
Scientific Practices	Suggested guide on ways to facilitate learning through: • making predictions by asking scientific questions, • specific activities for designing procedures and setting up investigations • collecting data, making observations and recording data, • organizing, representing, interpreting and analyzing data and observations • constructing evidence-based explanations and sharing ideas • revisiting predictions, controlling variables, • listing apparatus required-makes planning for the lesson easier.
Scientific Literacy Practices	• using scientific language, and engaging in scientific arguments and discourses during predicting , observing, and inferencing • guide on consolidation of data and pooling results
Teaching Strategies for Participation Practices	Suggestions for sequencing of activities by giving a detailed teacher guide on; • Grouping students and using groups to promote effective learning. • Understanding and use of prior knowledge • Suggestions on how to hand out apparatus and materials • Timing of each activity in the investigation • Group discussions- both teacher led and student led • The role of the teacher in supporting investigations
Assessment of Student's Learning Outcome	Concrete suggestions for the role of the teacher in carrying out assessment during and after the lesson in areas involving; • Brainstorming, verbal communication in whole group and small group discussions • scientific practices such as predictions, observations, recording data, planning investigations, structuring results, drawing conclusions, • evidence-based explanations and student presentations • Suggestions for homework and use of concept maps

The researcher consulted the syllabus and the commonly used curriculum materials and developed the first prototype instructional materials consisting of six practical lessons on acids and bases. The materials designed were tailored to reflect the needs in each of the five areas. The materials contained a lot of procedural specifications in terms of content support scientific practices, scientific literacy practices, lesson preparation, teaching strategies for participation practices and assessment of student's learning outcomes.

The Chemistry content in the instructional materials constructed was similar to the content in the curriculum materials teachers commonly used. The instructional materials borrowed from strengths of the materials the teachers used (Davis et al, 2014), and were structured to help teachers overcome the challenges they faced. The design of the activities was therefore changed from the step by step structure and converted into problem solving investigations composed of activities to meet the specifications of the design shown in Table 4.13. The materials also emphasized specific strategies for supporting students in constructing evidence-based explanations (Davis et al, 2014). They also contained reminders of areas where the teacher should engage learners in scientific practice or scientific discourse.

4.5.2. The Designed Lessons

Instruction materials for a total of six lessons were designed. The instructional materials contained a teacher guide that had procedural details for lesson implementation and a student sheet. The six lessons were designed from the topic on acids, bases and indicators in the Form one chemistry syllabus. Six lessons were achieved through an effort to cover the six practical areas emphasized in this topic. Lesson 2 was taking a double period which was covered in 80 minutes while all the other lessons were single period lessons within duration of 40 minutes. The six lessons were:

Lesson 1: **Identifying acidic, basic and neutral solutions using indicators** - this was a 40 minute introductory lesson that offered learners hands-on experience in testing common household solutions to determine whether they are acidic, basic or neutral using litmus indicator.

Lesson 2: **Make your own indicator from red cabbage-** the lesson involved the learner preparing their own indicator from red cabbage juice and using the indicator to identify solutions that are acidic or basic. The concept of some acids/bases being stronger than others based on colour change of red cabbage indicator was introduced.

Lesson 3: Strength of acid/base and the pH scale- learners were required to extend the knowledge on strength of the acid or base by learning to allocate and interpret numerical values of pH scale to colour changes of the universal indicator.

Lesson 4: Why do acids wear out metals- the lesson involved discovering the property of acids that involve reaction of metals with acid solution producing hydrogen gas. The learners design an experiment to find out how acids react with metals. They also test the gas evolved.

Lesson 5: What is blackboard chalk made of? - The lesson involved testing another property of acids: reaction with carbonates. Chalk was used because it is a very common object in the classroom. Chalk is mainly calcium carbonate and its reaction with an acid releasing carbon (IV) oxide exemplifies reaction of acids and carbonates.

Lesson 6: Relieving stomach acid: Antacid remedies - The lesson involved investigating common antacid tablets as remedy to common stomach acid problems. The learners react commonly used antacid tablets with hydrochloric acid solution (which is the acid found in the stomach) and used an indicator to show neutralization of the acid takes place. This was chosen because learners' experiences with stomach acid problems were common and there is frequent use of common antacid tablets and different herbal medicines to relieve stomach acid problems. This could also assist students in relating Chemistry learning to careers such as medicine and analytical Chemistry.

4.5.3. Judging the quality of the Instructional Materials

During the development of the instructional materials, the appropriateness of the materials was checked. Various sources of criteria judgments were considered (Rubdy, 2003; The National Academy of Sciences, 1998; National Science Resources Center, 1997), and basic ideas for determining quality of instructional materials picked and incorporated into the design of the materials. According to National Science Education Standards (NSES) the selection criteria should be consistent with the goals, embody the critical tenets of accurate science content, effective teaching strategies, and appropriate assessment techniques (The National Academy of Sciences 1998). Rubdy (2003) suggests a framework including psychological validity (learners' needs, goals and pedagogical requirements); pedagogical validity (teacher's skills abilities, theories and beliefs); process and content validity (the thinking underlying the materials, writer's presentation of the content and the approach to teaching and learning).

Three sets of criteria from NSES as outlined by National Science Resources Center (1997) and National Academy of Sciences (1998) were adapted and used in review of the instructional materials. The first set concerns **pedagogical appropriateness**, which encompasses strategies for building conceptual understanding, teaching science as inquiry, and applying effective instructional strategies. The second set concerns **science content**, striving to answer questions of content accuracy and appropriateness and the third deals with the **presentation and format** of the written materials. The questions the researcher tried to answer regarding each of these sets are outlined in Table 4.14, 4.15 and 4.16. The construction of the materials was based on these standards.

Table 4.14: Criteria for judging Pedagogical Appropriateness

a	Do the materials focus on concrete experiences with science phenomena?
b	Do the materials contribute to the development of scientific reasoning and problem-solving skills?
c	Do the materials build conceptual understanding over several lessons through a logical sequence of related activities?
d	Does the material include a balance of student-directed and teacher-facilitated activities as well as discussion?
e	Do the students have opportunities to work collaboratively in group activities and alone?
f	Does the material provide opportunities for students to gather and defend their own evidence and express their results in a variety of ways?
g	Does the material encourage collaboration and reflection?
h	Does the learning presented have relevance to the students' day-to-day experiences?
i	Are instructions for using laboratory equipment and materials clear and adequate?
j	Are lists of materials for each activity provided?

Table 4.15: Criteria for judging content

a.	Is the content consistent with the KCSE syllabus?
b.	Is the treatment of content developmentally appropriate (for the Form One learners)?
c.	Is the content scientifically accurate, correct and significant?
d.	Is the content free of bias?
e.	Does the background address content to be taught and common misconceptions?
f.	Is scientific language used appropriate for the learners?
g.	Does the content emphasize scientific inquiry?
h.	Is the science represented in the material related to their prior knowledge and the society?
i.	Do the materials stimulate students' interest and relate science learning to daily life?

Table 4.16: Criteria for judging presentation format/ organization and structure

a.	Do the materials actively engage the students to promote their understanding of the subject matter?
b.	Will the students develop a depth of understanding of the content of the standard through use of the materials?
c.	Do the materials provide effective strategies for assessments to evaluate progress?
d.	Do the materials provide for in-depth, inquiry-based investigations of major scientific concepts?
e.	Do the materials incorporates appropriate instructional technology
f.	Are the directions for implementing activities clear?
g.	Are the suggestions for instructional delivery in the teacher's guide adequate?
h.	Are the materials free of cultural, racial, economic, age, and gender bias?
i.	Are lists of materials for each activity provided, including suggestions for improvisation?
j.	Are instructions for using laboratory equipment and materials clear and adequate?

Source: National Science Resources Center (1997)

Quality criteria for curricular products can also be judged on; relevance, consistency, practicality, and effectiveness (Nieveen 1999; Thijs, 1999; Motswiri, 2004; Ottevanger, 2013). In this study these quality criteria were used to judge the quality of the instructional materials. Relevance implies need for the intervention and its design to be based on state-of-the art (scientific) knowledge (Ottevanger, 2013). This was ensured through context analysis of learning needs, theoretical base of appropriate teaching strategies, generation of design specifications of appropriate instructional materials for supporting investigations and inclusion of expert practitioner views in review and redesign of the materials. Consistency is experienced when the structure of the curriculum is logical and cohesive (Ottevanger, 2013). This was ensured through formulation of design specifications checked by experts and development of materials that go through stages of expert appraisals. Practicality is the ability of the material to be usable in the settings for which it has been designed (Nieveen 1999). In this study practicality was ensured through appraisal of materials by Chemistry teachers and actual use of materials in the classroom situation. Using the intervention to result in desired outcomes provides for its effectiveness (Nieveen, 1999; Motswiri 2004). In this study, effectiveness is determined through use of the materials in the actual classroom situation and carrying out an evaluation of their use.

4.5.4. Appraisal of the First Prototype

Forty seven teachers on pre-service teacher training programme in the teaching of secondary school Chemistry in one of the leading universities in Kenya, were given the instructional materials constructed for this study and their views on the quality of the materials sought. This was done through use of ten questionnaire items consisting of both closed and open-ended type of questions (Appendix IV). One key aspect the researcher sought to find is if the materials reflected content that should be taught at KCSE level. The analysis showed that 91.5% agreed that materials reflected the KCSE syllabus. The 8.5 % argued that the suggested use of red cabbage indicator was inappropriate because they felt that it was not readily available. The materials were therefore adjusted to offer suggestions for alternatives to the red cabbage. A high percentage (82.9%) of the respondents indicated that the role of the teacher and the learner were clearly outlined with the key role of the teacher being facilitation of the learning process while the learner is an active participant to the learning process.

Asked if the materials could be practically used in the classroom situation, 91.5% agreed that the materials could be practically used in their Chemistry classes with reasons being that the apparatus required were simple and easy to use, the activities relate to the learners daily life and that the lesson objectives were clearly guiding. Some 68.1% 0f the teachers were of the opinion that learners would like the new approach of teaching because of the high involvement in various activities and also being given a chance to design their own work. However 31.9% indicated that learners would find the approach challenging because it requires critical thinking, but they were optimistic that they would get used to the new approach. Particularly, lesson two was noted to introduce a totally new concept of the pH scale in a way that could lead to confusion and difficulties in conceptualization. This concept was later moved from lesson two to lesson three and introduced more systematically. The teachers were of the views that the teacher guide would adequately support the teacher in lesson planning, sourcing for the materials in good time, as well as maximally involving learners in all lesson activities. They also indicated that since learners would be fully engaged in each part of lesson development, class control would be enhanced. The teacher guide helped the teacher to understand what was expected of them and was guiding them in every step by specifying what they should do. Other responses included that the materials would lead to increased learner participation and help learners develop independent thinking skills.

The respondents also suggested several adjustments on the time allocated especially for the discussion, and the practical activities. The time allocation was adjusted to reflect more applicable schedules. Suggestions on improvisations were made such as using transparent plastic containers in the place of test tubes and use of other coloured vegetables in the place of red cabbage. They also felt that safety precautions in the teacher guide should also be included in the learner guide. It was also found necessary to add more solutions to be tested for lesson two.

4.5.5. Appraisal of the instructional materials by experienced Chemistry teachers

After the initial adjustments to include views of the forty seven teacher trainees, the materials were given to three experienced Chemistry teachers to appraise them. They were asked to review the instructional materials and give feedback to the researcher related to the validity of the materials based on the syllabus they used and also the consistency between the lesson activities. They were guided using a questionnaire similar to the one used by the forty seven teachers which was coupled with individual interviews in a bid to understand their views of the quality of the materials.

Two male teachers and one female teacher were involved in this part of the study. All the three teachers had taught Chemistry for a long duration and one of them was a national trainer of the SMASSE science teacher in-service training. This means that the teachers had taught the topic on bases and acids many times. They also were willing to analyse the materials when they were approached by the researcher to assist. The codes P, Q and R, are used to represent the teacher's names. These teachers were given sufficient time to read through all the guides for the six lessons and provide their feedback. One of the teachers took two weeks while the other two stayed with the materials for three weeks. This was mainly due to their busy schedule in their schools.

The three teachers were in agreement that the materials reflected the expectations of the KCSE syllabus. Basing the instructional materials on the KCSE Chemistry syllabus was also seen to make the materials relevant and essential for teachers to use. They agreed that the materials would be instrumental in guiding the teacher through discussions during the lesson and in acquiring information on their prior knowledge. They indicated that the teacher guide was useful in assisting the teacher understand his/her role during the lesson. Teacher Q actually noted that the teacher is well guided in what he/she should do during the activities stating that "the materials can be used to guide in organizing learners in groups"

Two of the teachers felt that the researcher needed to allocate more time for the introduction and plenary discussion since this was a new approach that learners were not used to. This was more critical especially for the first two lessons. This led to adjustment of time for introduction of lesson one from five to seven minutes. The three teachers agreed that the role of the teacher was clearly given in the teacher guide. They also felt that the materials could be used in a classroom setting; however they expressed fears of the process of time limitation. During the interview teacher P was of the idea that it would be good to use this approach since the learners would be fully engaged and also learn to reason on their own, but also expressed fears that it might not be possible to cover the syllabus if this approach was used throughout the four years.

Teacher Q expressed fears that large class sizes and limited facilities could pose great limitation to the use of this method. Teacher R also noted that there was a lot of teacher supervision required for the method to be effective. They were all in agreement that the approach is actually learner-centred. Teacher P and Q suggested that the materials should include a few summary questions at the end of the activity to test the concept learnt. This was added as an attachment to the teacher guide. The teachers agreed that developing the exemplary materials from materials teachers already used would enhance the teacher's confidence in using the materials, because teachers would have some knowledge about the practical activities to be carried out.

4.5.6. Appraisal by Science Education experts

Two science education experts from the university with experience in Science Education also appraised the materials and the research instruments. The aim of the appraisal was to find out if there was consistency between the instructional materials and the instruments and between the suggested design specifications and the conclusions of literature on constructivist learning context and design. The appraisers concluded that the design specifications were consistent with constructivism knowledge and the context information. They agreed that the instruments were in line with the procedural specifications in the teacher guide and had the potential to collect the intended data. They also suggested that it should be made clear why it would be necessary for the teachers engage in investigative practical work through the suggested approach. Though the researcher discussed the use of the materials with the teachers who used them in their classes, it was found necessary to provide a written overview of the approach to the teachers. This led to the development of a one page note introducing the intention of the materials to the teachers.

These refinements of the initial materials which were based on appraisal by forty seven Chemistry teacher trainees, three experienced Chemistry teachers and the two Science Education experts improved the confidence in the quality of the design. A second prototype building on implications from the first prototype of instructional materials was made for use in the third phase of the study.

4.6. Try Out of the Second Prototype

The second prototype was made up of six lessons consisting of both teacher guide and student activities. The six lessons were the same as outlined in Section 4.5.2 with the structure and details within the instructional materials having been refined according to the outcome of the appraisals. This prototype was tried out with Chemistry three teachers who had not taken part in the earlier appraisals. The purpose of the try out was to explore the practicality of the materials. This try out was also a pilot for testing procedures and instruments for the field test of the third prototype. The three teachers used the materials in their class and provided feedback and assessment on practicality and different aspects of their effectiveness.

The three Chemistry teachers were approached and asked to take part in the pilot study. They were explained in detail the requirements of the study and the approach to be used. The teachers were willing to try out the new approach and give critical feedback.

The three teachers coded as teacher A, B and C that took part in the pilot study were qualified teachers and had experience in teaching Chemistry. They were also teachers who were teaching the Form one classes in their schools. This was appropriate because learners were not subjected to a new teacher or new environment which could possibly affect their responses. The three teachers carried out the activities with their Form one classes during their scheduled chemistry lessons. Table 4.17 summarizes information about the pilot study sample of teachers and their classes.

Table 4.17: Pilot study sample

Teacher Code	Gender	Number of students	Lessons taught
A	Male	42	1, 2, 3 & 4
B	Male	24	2, 5 & 6
C	Female	14	3, 4 & 5, 6

Using the materials in class was necessitated by need to find out if teachers and learners could be able to implement them as intended by the designer. During the try out, the researcher used a variety of methods and instruments to collect data. These included lesson observation using lesson observation schedule (Appendix III); teacher responses though teacher's logbook (Appendix V) as well as interview guided by interview schedule (Appendix VI); and students' interview guided by an interview schedule.

The try out was done in one learning week for each teacher. According to the Kenyan curriculum, secondary schools are allocated four Chemistry lessons per week in Form One classes. Each of the teachers was therefore able to teach only four out of the six lessons prepared. The teachers were given the instructional materials prepared to read and choose the lessons they would prefer to carry out in their classes. Teacher A taught lesson 1,2,3 & 4, while teacher B taught lesson 2,5 & 6 and teacher C taught lesson 3, 4, 5 and 6. This ensured that all the six lesson materials were used in the teaching. Lesson observation was carried out as guided by the lesson observation schedule (Appendix III).

4.6.1. Results of the observation of the practical lesson

The practicality of the lessons was evaluated though lesson observations carried out by the researcher. This was based on description of practicality as a measure of the materials' quality, indicated by clarity, congruence, complexity and cost when viewed in the context of the teachers' practice (Motswiri, 2004; Ottevanger, 2001). The focus was on finding out if the teacher was able to follow the teacher guide on guiding learners through essential aspects of investigative practical work**.** The observation schedule in this study was adapted from other research studies (van den Akker, 1988; Ottevanger, 2001; Motswiri, 2004) and developed to suit the design specifications, as described in section 4.5.1. It was structured as a set of statements about the intended teachers' actions during lessons (van den Akker & Voogt, 1994). The observation schedule had data of the teacher lesson number and number of learners in class. This was followed by statements that indicated actions that the teacher was expected to show in the course of a learner- centred investigation. The introduction section of the lesson consisted of 7 statements while the lesson development had 18 statements and conclusion had 7 statements as shown in below. Statements of actions listed in the observation schedule were:

Actions for lesson introduction

1. Discusses background of the problem
2. Discusses the objectives of the lesson
3. Teacher helps learners clarify the question to be answered by the activity
4. Teacher informs learners how participation will be carried out.
5. Stimulates learners to reflect on their prior knowledge
6. Distributes problem sheets and/or Lists apparatus
7. Discusses stages of investigation i.e. informs learners about the timing of the various activities in the investigation (e.g., planning, post planning discussion, experimenting)

Actions for lesson development

1. Uses small groups of 2-4 learners
2. Encourages students' approach (Teacher allows learners room to choose their own approach)
3. Guides by question/answer method not 'telling'
4. Encourages group collaboration
5. Monitors experimental set-ups: goes round groups checking as they work.
6. Ensures collection of apparatus is orderly
7. Guides learners to generate procedures
8. Asks students (groups) to specify assumptions
9. Attunes instruction to learner's ideas.
10. Encourages self-time management
11. Stops learners at appropriate times to review various lesson activities.
12. Encourages active involvement of learners in the activities by demonstrating and supporting thinking processes in learners.
13. Encourages peer assessment (allow learners to ask each other questions)
14. Facilitates peer plan review (provide alternatives or advice with reasons why we think the plan is not workable or safe)

15. Encourages students to ask questions seeking clarification on their work.
16. Teacher makes sure learners use materials/ equipment correctly to execute the activity
17. Teacher allows learners to draw own conclusions and pool results together
18. Encourages and guides students to discuss possible experimental discrepancies in the results by asking the students to reflect on the activities

Actions for lesson conclusion

1. Teacher gives feedback summarising by highlighting major points of the investigation
2 Teacher guides students to make conclusions based on data collected from the experiments they carried out.
3 Asks for students' opinion when responding to class questions.
4 Reminds students to draw conclusions that relate to their specified assumptions made earlier.
5 Ensures clear up before next lesson is done in an orderly manner
6 Gives students homework (e.g., in the science textbook) to prepare for the next lesson.
7 Encourages learners to write a laboratory report of the activity carried out.

A tick (√) was used to indicate if action was observed and a cross (x) if action was not observed. There was also space for the observer to record comments regarding the actions or to note any salient features or practices with a view of improving the instructional materials. The frequency of ticks was analysed and presented as percentages of actions performed by the teacher during the lesson which indicates whether the intentions of the developer of the materials have been put into practice or not. The percentages presented on Table 4.18 were for all the lessons that each teacher conducted. A dash (-) was used for the lesson that was not taught by the particular teacher.

Table 4.18: Lesson observation for the try out

Section	Lesson Number	Frequency Observed for Teacher (%)			Average frequency (%)
		A	B	C	
Introduction of the lesson *(7 Items)*	**1**	71.4	-	-	71.4
	2	85.7	85.7	-	85.7
	3	85.7	-	71.4	78.6
	4	100	-	85.7	92.9
	5	-	85.7	-	85.5
	6	-	57.1	100	78.6
Lesson development *(18 Items)*	**1**	62.5	-	-	62.5
	2	83.3	61.1	-	72.2
	3	94.4	-	64.7	79.6
	4	92.9	-	83.3	88.1
	5	-	88.8	-	88.8
	6	-	55.6	94.4	75.0
Lesson conclusion *(7 Items)*	**1**	57.2	-	-	57.2
	2	100	83.3	-	91.7
	3	85.7	-	85.7	85.7
	4	83.3	-	100	91.7
	5	-	83.3	-	83.3
	6	-	57.1	100	78.6

A lot of interaction was observed; however, since this was the first time learners were involved in developing their own procedures for an experiment more time was used in planning than expected. Groups of learners were involved well in discussions and consolidation of the results. Teacher A appeared not fully confident with carrying out activities in the first lesson but was able to handle subsequent lessons more easily. Teacher B had already introduced the topic on acids and bases and chose lesson 2, 5 and 6 because he had not covered that area. He however appeared not to have familiarised himself well with the teacher guide for lesson 6 before the start of the lesson and therefore had problems following the guiding statements which is reflected by low percentages of observed actions (57.1% in introduction, 55.6% in lesson development and 57.1% in lesson conclusion). This indicates the importance of teachers getting familiar with supporting materials for teaching. Teacher C had also introduced learners to the topic. She however carried out three lessons that had not been taught and showed high percentages of teacher guided actions especially for lesson 6. The averages of percentage of expected teacher actions for each section of the lesson were as shown in Figure 4.5.

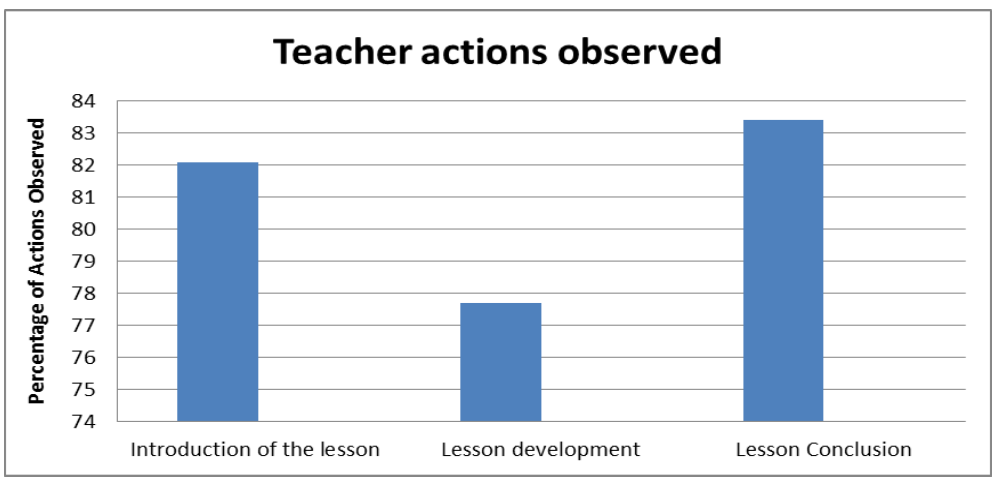


Figure 4.5: Teacher actions observed in the try out

The figure shows that 82.1% of teacher actions expected during the introduction of the lesson were observed while 77.7% of actions expected during lesson development and 83.4% of actions expected during lesson conclusion were observed. This was taken as an indication that teachers were able to follow the teacher guide provided to implement investigative practical work. Teachers used open ended questions to allow learners to think more critically.

During lesson introduction, the teachers were able to discuss background of the concept to be learnt through the practical activity, the objectives of the investigation and to give guiding questions that would provoke learners' reflection as well as enable the teacher to know the prior knowledge of the learners. What was found missing in most of the lessons during introduction stage is the discussion of stages of the investigations and guide on timing for each stage. The teachers however informed the learners of each stage as it appeared in the teacher guide. The teachers preferred writing the list of apparatus on the board for the learners to copy. The researcher found this consuming a lot of the teachers' time and this prompted the development of list of apparatus attached to the student sheet as the materials were developed for the next try out.

During lesson development, teachers were able to group learners easily. Teacher A formed groups of 5 students with two groups having 6 students. This was due to limitations of apparatus and the large class size (42 students). The teachers guided learners to predicting and developing procedures though teacher A and C were observed as straining not to give answers to the predictions as well as not to provide procedures. All the teachers were able to go round the working groups to ensure proper use of apparatus and to support the learners thinking. The lessons were adequately summarized and conclusions made. The assignments were however hurriedly given and clean-up was not done appropriately except for lesson one and three. The teachers preferred to do the clean- up at a later time. It was noted that the drugs used in lesson 6 required adequate grinding and mixing in water which reduced visible effervescence. This was indicated as an important note in the teacher guide.

4.6.2. Teacher interview

Teacher interviews were carried out after the lesson series as guided by interview schedule (Appendix VI). Notes were taken and voice recording done. The responses were categorised according to content analysis themes based on conceptualizing validity and practicality of the materials (Motswiri, 2004; Ottevanger, 2001; Nieveen, 1999). This mainly captured teachers' perceptions regarding the following themes:

- Support for the teacher in guiding learners through investigative practical work: this involved finding out if the materials were helpful in supporting them for tasks they were expected to carry out. It also included their views on support for the content matter.

- Clarity of the instructions in the materials in guiding the teacher: this involved finding out if the materials expressed clearly what the teacher was expected to do and were thus understood by the users.
- Complexity of the approach: this indicated how the teachers perceived the complexity of the approach. This was conceptualised in terms of the consistency between what teachers find easy or difficult and what they find interesting or discouraging and the scope of the change.
- Congruence: did teachers find the materials consistent with the perceptions of their usual practice? This included the extent to which they see possibilities and opportunities to conduct the investigative practical work activities as proposed by the exemplary materials.
- Cost associated with the approach- the teachers' perception of the cost of adopting the suggested practices conceptualized as the consistency between the teacher's personal investment in operationalizing the innovation and the output of the investments (positive reactions from students). This also involved their perception on the cost of resources involved; including improvisations.

The teachers expressed views that the materials were useful in supporting preparation and implementation of investigative practical work. The main area of support echoed by all the three teachers was that of planning for resources for the investigation. Teacher A said "*the materials were very useful in assisting prepare* *for the lesson as the resources required were well outlined and I was able to acquire them in good time."* This was in agreement with the empirical phase of the study where teachers indicated that the materials would provide adequate guidance on resource acquisition. Other than this, two teachers indicated that the background information provided in the materials gave them a firm basis for the practical investigation. Teacher A claimed that the background "*was very informative*" while teacher B argued that it gave him *"confidence in carrying out the investigation especially for lesson 2 and 6."* They all agreed that the stepwise support for every activity to be carried out in class reduced their stress and time for planning on how to carry out investigations. Teacher C commented that if all instructional materials guided them in the same manner teaching Chemistry would be more enjoyable and refreshing. Their comments on content support were that the materials had adequate content for the level of the learner. Teacher B said "*at least I did not need to carry other books containing similar content"* and teacher A added "*the notes included in the materials gave all the information I would have required for the topi*c" while teacher C simply said "*Yes the content was sufficient."* Teacher B and C, however, added that the materials should increase the number of questions suggested for assignment to increase learners practice on the learnt content.

The teachers also agreed that the materials reflected the KCSE syllabus with good application that related to the learners experiences. This agreement, compounded with content analysis and evaluation of the materials gave the researcher confidence in content validity of the materials.

Concerning clarity of the instructions in the materials, the teachers were of the view that the materials were easy to understand and the guidelines were clear. Teacher A said "*these materials have been written in simple language and are similar to what we have been using in our classes*" teacher C added to the fact that the materials were similar to what they use *"but the approach is more interesting.*" This indicated that teachers had no problems understanding the expectations of the teacher guide.

Teachers perceived the complexity of the materials to be manageable and within their level of understanding. Teacher B and C indicated that if time and the resources would allow, the method would be good for their learners because they would be both mentally and physically active during chemistry practical lessons. Teacher A commented that "*if all chemistry content was outlined as done in these materials I would have no problem in adopting and changing the teaching practice."*

On congruence, the teachers found the approach very different from their common practices in the chemistry classrooms. "*Our learners are used to being given detailed step by step procedures, they are not used to doing their own thinking*" said teacher A. Teacher B said, *"the learners were indeed shocked when I told* *them that I will not provide procedures for the practical."* He also added, *"I do not use this approach in class but I think it is good to involve learners in the thinking."* The challenge pointed out was mainly in changing the thinking of learners from following strictly laid down procedures to constructing their own procedures. All the teachers agreed that by the second and third experiment the learners had started enjoying the approach. The teachers were of the idea that the approach would be very appropriate for the teaching of Chemistry and all other sciences because it would get learners mentally involved in the learning process.

As for the perceived cost, the teachers perceived the activities as doable in their normal classrooms. They indicated that most of the requirements of the experiments were easy to obtain and use in their classes. Teacher C commented "*the only difference is the approach; the materials are easy to obtain or improvise."* Teacher A however felt that the approach would be easier if his class was smaller. He noted *"the teacher is very much involved especially if the class is this big, but I think the effort is worthwhile"* The teachers also indicated that the approach led to better participation in group activities. It was also noted earlier that teachers were of the opinion that learners liked the approach. Even so, they all felt that the approach is much slower than their usual practical sessions and if used exclusively, the syllabus may not be completed in time.

4.6.3. Teacher logbook

The teachers recorded the observations of the implementation of each lesson in a teacher logbook (appendix V). The logbook was meant to provide feedback that would support the data from lesson observations as well as teacher interviews. It is important to note that the teacher interviews were conducted at the end of the lesson series and the teacher could easily have forgotten the fine details of the happenings of each lesson carried out. The logbook was filled immediately after the lesson thus capturing every fine detail of the happenings during the investigation. It also provided the researcher with the teachers' views on the lesson implementation which were independent of the researcher's views that were reflected in the observation schedule.

The logbook was a guided structure for the teacher to record his/her experiences with the instructional materials when carrying out the investigations. This enabled the teacher to record experiences during lesson preparation and even implementation. They were able to record the challenges and the benefits from the materials as well as include additional comments on possible ways in which the materials could be improved.

Data from the teachers logbook was analysed through inductive data analysis as responses were categorized according to areas of quality described earlier as validity, practicality and effectiveness (Nieveen, 1999). It was therefore analysed in a similar way to the interview as the researcher grouped the responses according to the themes of supporting investigations, clarity of the guide, complexity, congruence and cost associated with the approach.

All the three teachers considered the materials as containing appropriate content for Form one learners as related to the KCSE syllabus. They also considered the objectives as relating to those in the syllabus and related to the learners daily experiences. They also indicated that the objectives were covered at the end of the lesson. This was an indication of the effectiveness of the instructional materials.

The teachers were asked to indicate whether they found the instructions easy to understand and if they clearly indicated what the teacher was expected was expected to do. The two questions seeking to describe the clarity of the materials got positive answers from all the three teachers. They all indicated that it was clear what the teacher was expected to do. Teacher A stated "*all steps to be taken during the activities are clearly indicated."* As an indicator to clarity of the materials the teachers were also asked to describe their role during the lesson. The descriptions provided by the teachers included that they were to act as guide and facilitators to learning. This indicated that teachers were able to understand their role as guided by the instructional materials.

Several statements in the logbook guided the researcher in gathering information on the teachers' perception regarding support to investigative practical work. The teachers indicated the teacher guide was useful in guiding them though the activities and in consolidating resources for use in the investigation. Teacher A and B indicated that the materials reduced time required for lesson preparation while teacher C was of the opinion that preparation time was increased due to the fact that one had to read and understand the material thoroughly. The three teachers agreed that the information in the materials they used was sufficient to guide them through the lesson but required more assignments for the learners at the end of the lesson. They also indicated that the materials actually supported learner involvement through guiding the teacher for lesson plan and organization of the lesson. The areas of support quoted included provision of background information, list of apparatus, expected results of the experiments as well as content notes. All the three teachers indicated that the objectives of each of their lessons were achieved. This was an indication of the effectiveness of the materials.

Two questions were geared towards understanding the congruence of the materials. Just as indicated during the interviews, the teachers felt that the approach was different from their normal practices but still came out as a better approach regarding learner involvement and chemistry practical work investigations.

The teachers indicated that the materials were easy to understand and use in their classes. They however identified some challenges in the use of the materials. Teacher A identified the challenge of a large class considering the amount of supervision required for the investigations. The challenge of getting learners to understand why they should formulate their own procedures especially for the first lesson was experienced by all the teachers. However as mentioned earlier, the learners got used to the method and said that it made them learn more deeply. Teacher B and C indicated that there was a challenge of time to carry out the activities as suggested considering the large amount of content that should be covered in the Chemistry syllabus. Teacher C was of the opinion that the learners should be exposed to more of this approach and get used to it.

The cost of using the method as earlier described was established by what teachers considered worthwhile. All the teachers perceived the activities as involving but useful because they were learner centred. Teacher A however indicated that the use of such materials could translate into a burden of resources for the schools.

4.6.4. Student Interview

The appropriateness and effectiveness of the instructional materials can be judged from the perspective of the learner who is presumed to be naive and uninformed rather than from teacher's perspective (Ottevanger, 2013). In this study learners were actively involved in the group discussions and investigative activities. After the lesson activities, group interviews were carried out with five students from each class. The students who responded to the interviews were randomly selected by the teacher. The interview was guided by a structured student interview schedule (latter converted to questionnaire Appendix VII). The interview questions were formulated with an aim of describing the effectiveness of the instructional materials as perceived by the learners. The interviews were however short lasting between 15 and 20 minutes. This was carried out to evaluate their experience with the materials and the approach to practical work. Notes were taken during the interviews and their views grouped according to experience areas answering the questions:

- Did they find the lessons interesting?
- Were they able to learn the concept and did they find the method more useful/meaningful to learning?
- How was their participation?

The learners indicated that they found the approach being more challenging than what they are used to. One of the learners said, "*We are used to following instructions given by the teacher, we found it difficult to prepare our own procedures at first."* They however found the approach engaging and the learning more meaningful than the approach they commonly used in their classes. All the learners were in agreement that the approach allowed everyone to participate in the activity and to think about what they were doing. They enjoyed managing their own activities which made one student state; "*we were able to discover some things on our own."* They also indicated that the manner in which they learnt the concepts was interesting and memorable. One learner recounted *"the changes of colour in the red cabbage were fantastic. I must try that at home."*

4.6.5. Conclusions of the evaluation and the development of third prototype

The evaluation of the second prototype was carried out through lesson observation, teacher interview, teachers' logbook and student interview. From the evaluations through lesson observations, the materials were perceived to guide teachers in the implementation of investigative practical work. It was however noted that emphasis on the importance of informing learners of particular stages of development and their involvement and timing was not realized. This led to an emphasis on this being included in the introduction note to the teachers. To reduce the time teachers were observed to spend writing the list of apparatus on the blackboard, the list was included in the students' activity sheet. The questions suggested for assignment at the end of each lesson was increased. A separate sheet was made for the additional assignment and for exercise (lesson 5). To improve on time management, the apparatus list and prediction exercise guide (for lesson 5) were attached to the students' sheet or given at an appropriate time as advised by the teacher guide. This was to avoid distracting the learners when they were carrying out a different exercise. It was noted that introductions were not given enough time to engage the learners in sufficient question and answer sessions that would result in clarification of the intended activities. For lesson one, two and six, time for introduction was adjusted upward to allow sufficient development of base for the practical activity.

Similar to the findings of Motswiri, (2004) teachers were perceived not to have had problems with the exemplary materials in terms of its clarity and complexity. They also perceived the exemplary materials to be incongruent with their usual classroom practice, but indicated that the approach was more learner centred.

Teachers indicated both in the logbook and in the interview that the materials had adequate content support for the level of the learner. The results also indicated that the materials were perceived to support learner involvement through guiding the teacher for lesson planning and organization of the lesson. The statement of actions in the lesson observation (outlined in section 4.6.1) were refined in terminology and the number of action statements outlined in lesson development reduced from 18 to 16 by merging two statements that were discovered to describe the same statement and removing one statement that did not clearly indicate the expected action. Statements of actions for lesson conclusion were reduced from 7 to 6 by removing the statement on the teacher guiding learners to write a report. This was because KCSE Chemistry syllabus does not directly emphasize on report writing and thus teachers had not introduced their Form one learners to Chemistry report writing. The learners however wrote down notes as the lesson discussions progressed.

The learners were seen to be actively involved and also indicated in the interviews that they learnt the concepts and enjoyed the activities. The learners' interview schedule was changed to a questionnaire that contained both Likert type items and structured questions for the learners to respond to. This was necessitated by consideration of time involved in the study which made it difficult to have comprehensive interview with the learners as well as need to get views from more learners. Since the next stage of the study required teachers to carry out a total of six lessons which involved a lot of their usual learning time, it was found difficult to get more time with learners for interviews immediately after the lesson series. It was considered that interviews conducted more than a week after the lesson series would not provide accurate information regarding their views on the lessons.

4.7. Evaluation of the Third Prototype

The instructional materials that were redesigned and refined after the try out of the second prototype made up the third prototype which was used in the second try out/ field test. This is the stage in which the evaluation of the materials was done. The instructional materials consisted of the teacher guide and student materials that composed six lessons which were the same as described in section 4.2.2. The teacher guide was the main document because the aim of the study was to support teachers in implementing investigations in chemistry practical work.

The analysis of the third prototype was to evaluate the instructional support provided by the materials. The key criteria for this evaluation was guided by determination of practicality and effectiveness of the materials in actual classrooms as represented in the design principles that guide the investigative practical work (Krajcik, 2003). Practicality was evaluated as measure of the materials' quality, which was indicated by support, clarity, congruence, complexity, and cost as perceived by the teacher using it in the context of his or her practice (as discussed in section 4.6.2). The evaluation was guided by the following questions:

1) Were the investigative activities in the lessons implemented as intended by the researcher?
2) Did teachers find the materials helpful in supporting them carry out investigative practical work?
3) Were the materials effective in supporting investigative practical work in Chemistry learning?

Question 1 was answered by data collected through lesson observation of various items regarding how teachers implemented the lessons and how the students carried out the activities (Motswiri, 2004; Aksela, 2005). Lesson observation guide was used to guide and record observations made during the practical activity. The researcher observed all the lessons and was able to take note of salient features of the investigations even if they were not covered by the observation guide.

Question 2 was answered by teachers' responses to interview questions and logbook regarding their perception on how the materials supported them for investigation, the clarity of the materials, and congruence of the materials with their usual practice, complexity and the cost of adopting the practices suggested in the instructional materials.

The effectiveness of the materials (question 3) was determined by responses from all the participants in the research. Teacher interviews and logbooks provided the views of teachers regarding the effectiveness of the materials; lesson observations provided the effectiveness as observed by the researcher while questionnaire for students and concept maps provided feedback from the learners. The teachers provided feedback concerning their perceived achievement of lesson objectives and the overall outcome of the lesson while the learners provided feedback on their perception of the lessons carried and responded to the concept maps.

4.7.1. Sample involved in the evaluation

The evaluation was carried out in a case study approach using a small number of teachers to achieve an in-depth study of the problem. Five teachers and their usual Form one Chemistry classes were used. A small-scale in-depth study of a limited number of teachers was considered relevant to gain a deeper insight into the dynamics of the implementation process, rather than a large-scale approach where probably more superficial information would be gathered (Motswiri, 2004). The study was intensive in nature and there was need for deeper understanding of the practicality of the instructional materials compounded with need for lesson observation of all the lessons. Each of these five teachers carried out investigative activities in the six lessons of the study, therefore a total of thirty lessons were observed. The identity of teachers involved in the study was coded as J, K, L, M and N. general information about the teachers and the classes involved in the study is summarized in Table 4.19.

Table 4.19: General information on the sample of Chemistry teachers involved in the evaluation

Teacher	Qualification	Gender	Teaching experience (Years)	Number of students
J	B.Ed. (Sc.)	Female	4	13
K	B.Sc. + PGDE	Male	6	24
L	B. Ed. (Sc.)	Male	22	30
M	B.Ed. (Sc.)	Male	18	35
N	B.Ed.(Sc.)+ M.Ed.	Female	13	42

Data was collected using five instruments: lesson observation schedule (Appendix III), teacher logbook (Appendix V), teacher interview scheme (Appendix VI), student questionnaire (Appendix VII) and learners' concept maps (Appendix VIII)

4.7.2. Lesson observation

The researcher visited schools for lesson observations during the lessons which were fitted within the usual Form One Chemistry lessons as indicated in the timetable. The lesson observation schedule was similar to the one used in the tryout of the second prototype. It was made up of action statements, where each statement indicated actions that the teacher was expected to show in the course of the investigation following guidance from the teacher guide. The schedule had a total of 29 statements. The introduction of the lesson consisted of 7 statements while the development had 16 statements and conclusion had 6 statements. A tick (√) was used to indicate if action was observed and (x) action was not observed. There was also space for the observer to record comments regarding each action or to note any other relevant action. The teacher action statements were as shown in Table 4.20, 4.21 and 4.22.

Table 4.20: Action statements in the observation schedule for lesson introduction

Teacher actions		**Observed** (√) **Not observed** (x)	**Comments**
1.	Discusses background of the problem		
2.	Discusses objectives of the lesson		
3.	Helps learners clarify the question to be answered by the activity		
4.	Informs learners how they will participate		
5.	Stimulates learners to reflect on their prior knowledge		
6.	Distributes problem sheets and/or Lists apparatus		
7.	Discusses stages of investigation and the timing of the various activities in the investigation.		

Table 4.21: Action statements in the observation schedule for lesson development

Teacher Actions for		Observed (√) **Not observed** (x)	**Comments**
1.	Uses small groups of 2-4		
2.	Encourages students' approach (Teacher allows learners room to choose their own approach)		
3.	Guides by question/answer method not 'telling'		
4.	Encourages group collaboration		
5.	Monitors experimental set-ups: goes round groups checking as they work.		
6.	Ensures collection of apparatus is orderly		
7.	Guides learners to generate procedures		
8.	Asks students (groups) to specify assumptions they made		
9.	Attunes instruction to learner's ideas.		
10.	Encourages self-time management and stops learners at appropriate times to review various lesson activities.		
11.	Encourages active involvement of learners in the activities by supporting thinking processes in learners.		
12.	Facilitates peer plan review (provide alternatives or advice with reasons why we think the plan is not workable or safe)		
13.	Encourages students to ask questions seeking clarification on their work.		
14.	Ensures that learners use materials/ equipment correctly to execute the activity		
15.	Guides learners in drawing their own conclusions and pooling results together.		
16.	Encourages and guides students to discuss possible experimental discrepancies in the results by asking the students to reflect on the activities.		

Table 4.22: Action statements in the observation schedule for lesson introduction

Teacher actions for lesson conclusion		**Observed** (√) **Not observed** (x)	**Comments**
1.	Teacher provides feedback by highlighting major points of the investigation.		
2	Guides students to make conclusions based on data collected from the experiments they carried out.		
3	Asks for students' opinion when responding to class questions.		
4	Reminds students to draw conclusions that relate to their specified assumptions made earlier.		
5	Ensures clean-up before next lesson is done in an orderly manner		
6	Gives students homework (e.g., in the science textbook) to prepare for the next lesson.		

Data from the lesson observations was analysed from the completed observation schedules. The frequency of ticks (√) for each action was tarried and converted into percentages of actions performed by the teacher during the lesson. These percentages were taken to be an indication of achievement of the developers' intentions in the design of the materials. The percentages were as presented on Table 4.23 for all the lessons that were conducted. The percentage indicated is a tally for all statements in the section indicated.

Table 4.23: Observed actions during the Chemistry practical lesson

Section	Lesson Number	Frequency Observed for Teacher (%)					Average frequency (%)
		J	K	L	M	N	
Introduction of the lesson *(7 statements)*	**1**	71.4	57.1	43.8	71.4	57.1	**60.16**
	2	85.7	71.4	85.7	100.0	57.1	**79.98**
	3	85.7	100.0	100.0	85.7	85.7	**91.42**
	4	71.4	85.7	100.0	71.4	71.4	**79.98**
	5	100.0	85.7	85.7	85.7	85.7	**88.56**
	6	85.7	100.0	85.7	85.7	100.0	**91.42**
	Mean %	**83.32**	**83.32**	**83.48**	**83.32**	**76.17**	**81.92**
Lesson development *(16 statements)*	**1**	81.3	68.8	62.5	75.0	68.5	**71.22**
	2	93.8	81.3	87.6	75.0	93.8	**86.30**
	3	87.6	93.8	87.6	81.3	81.3	**86.32**
	4	100.0	75.0	93.8	68.8	87.6	**85.04**
	5	93.8	87.6	62.5	68.8	81.3	**78.80**
	6	87.6	93.8	75.0	81.3	56.3	**78.80**
	Mean %	**90.68**	**83.38**	**78.17**	**75.03**	**78.13**	**81.08**
Lesson conclusion *(6 statements)*	**1**	66.7	66.7	66.7	50.0	66.7	**63.36**
	2	66.7	71.4	83.3	66.7	83.3	**74.28**
	3	83.33	83.3	100.0	83.3	100.0	**93.32**
	4	100.0	83.3	83.3	71.4	83.3	**84.26**
	5	83.3	100.0	83.3	83.3	100.0	**89.98**
	6	83.3	66.7	66.7	83.3	83.3	**76.66**
	Mean%	**80.56**	**78.57**	**80.55**	**73.00**	**86.10**	**79.75**

The average percentage of observed teacher actions in lesson one for all the teachers was found to be lowest in comparison to all the other lessons (60.16%) for introduction of the lesson, (71.22%) for lesson development and (63.36%) for the conclusion. This could be due to the fact that the teachers were also not familiar with the approach of teaching the researcher was introducing. The percentages of actions observed in the other lessons were higher. In the introduction phase, most actions expected from the teachers were observed giving the average percentage of 81.92%. In the introduction stage of the lesson, most teachers did not discuss the stages of investigation by informing learners about the timing of the various activities in the investigation. Most teachers were informing learners about the time allowed for each activity as it started. In a number of lessons, the teachers did not clearly inform the learners how they were expected to participate at the beginning of the lesson.

After the introduction, the learners were allowed time for planning during which they came up with an appropriate procedure for the activity. In the first and second lesson most learners found it difficult to generate the procedure, though the plan was quite simple. This could be associated with the fact that they were used to being provided with step by step procedures in all the experiments they carried out. In most lessons they spent the first few minutes wondering what to do and when the teacher enquired what they were waiting for, they indicated that they still expected to be given a procedure. Some groups were able to formulate the plans before the others but had to wait for the others. This was because the learners were in Form one and therefore had to be guided more than the senior learners. Once the planning was done the teachers carried out a discussion of the plan. This discussion was meant to allow learners understand and agree on appropriate procedures, and thus reduce the time required for the experimentation stage. Emphasis on safety precautions was done during this discussion. Once procedures were agreed upon, the learners were allowed to carry out the experiments in their groups. During this session, the teachers were engaged in moving from group to group ensuring that the learners were doing the right thing, answering their questions and encouraging their thinking. It was more difficult for the teachers with large classes and hence many groups of learners. Grouping learners as suggested in the teacher guide seemed to pose difficulties to some teachers due to limited resources and large class sizes. Teacher N found it difficult to set up apparatus for small groups and therefore had to increase the number of students per group to 5 or 6 instead of suggested two to four. Most lessons required a good number of test tubes which limited the number of groups a teacher could set. Teacher M formed 7 groups of five students each. This was also necessitated by limitation of space in the laboratory. Generally, most (81.08%) of the expected teacher actions were observed during the lesson development.

There was a challenge of time in a number of lesson conclusions. This was mainly due to use of more time than allocated for the planning and lesson activities. Most teachers did the conclusion in a rush. Some teachers used a few minutes of the next lesson for the conclusion of their lessons and others left the clean-up to be done during lesson breaks latter in the day. This was most serious in the first and the second lesson but was improved as the lessons progressed. Most teachers however found the lesson notes provided in the guide as very useful in the conclusion of the lesson.

From the Table 4.23, it is observed that an average of 81.92% of expected teacher actions were observed in the introduction phase of the lessons, 81.08% expected teacher actions were observed in the lesson development phase and 79.75% actions were observed in the conclusion stage. These high percentages were taken to be an indication that the materials were used as intended by the developer and were also clear in communicating the expectations of the teacher and the learners.

Apart from teacher actions recorded in the observation schedule, there were some other important observations pointing to the fact that learners enjoyed carrying out the investigations. Lesson two seemed to excite learners as they discovered they can make and use an indicator at home without the requirement of laboratory chemicals. The basis of learning developed in lesson two was used for lesson three and most teachers attested to the method having made it easier for them in introducing the abstract idea of the pH scale. Lesson 4 led to great excitement when the learners discovered the hydrogen burning with a pop sound. They actually wanted to repeat the experiment many more times. Lesson six took longer than expected for most teachers especially when it came to discussion stage because learners were eager to know if they can test various substances they used at home as antacid remedies in the same way they did for the two drugs provided.

The researcher had to acquire red cabbage for all the teachers. The red cabbage was readily available in the local supermarkets and grocery stores but the process of requisition of the materials seemed long and most of the teachers could not find time to go to the stores to buy the cabbage. The researcher therefore offered to buy it for them. The researcher also bought lemon and vinegar for three of the teachers to use in the investigations.

During lesson implementation it was noted that some teachers experienced problems with distribution of the apparatus. When the apparatus were distributed before the discussion, some learners seemed fascinated by them and this led to less concentration on the discussion. This mainly happened to those learners who did not have much exposure to the apparatus. For this reason, other than teacher K, all the other teachers would only provide the learners with a list of apparatus for planning and allow them to pick apparatus when they started the investigations. Teacher L would not distribute the apparatus before discussion because the laboratory was small in size and learners would be distracted by them. The numbers of solutions being tested in lessons 1-3 were many and could not be supplied per group. This was due to insufficient number of beakers and also to reduce chances of contaminating one solution with the other. The solutions were therefore arranged on the demonstration bench and learners picked one solution at a time in their test tubes. The type of water used to make the solutions seemed to affect the indicator colours especially that of red cabbage juice. The teachers were therefore advised to use distilled water in making the solutions.

As noted by (Twoli, 2006), teacher characteristics also affected quality of lesson implementation. Some teachers were of the opinion that the lessons were too demanding. One of the teachers decided to engage the full class in the discussion for the development of procedures in lesson 5 and 6 while another teacher almost provided the learners with outright directions on what they were expected to do in lesson 5. Learners who had little exposure to the simple apparatus used in the experiments also took a bit of time to adjust to their uses. Some learners appeared unable to use droppers while one of the learners loudly wondered if the glass beaker will heat the red cabbage (lesson 2) to boiling without breaking.

4.7.3. Evaluation using teacher logbook

The teachers were provided with a logbook (Appendix V) to assist them note down their observations regarding lesson preparation and observation of each lesson they carried out. Data from the logbook was used to support the data from observation schedule as well as that from teacher interviews carried out after the lesson series. The responses to the open ended questions in the logbook were analysed by use of inductive content Analysis (Kawulich, 2004; Elo & Kynga, 2008). The answers were classified into main categories of evaluation of the validity, practicality and effectiveness of the materials applied in real classroom situation. The subcategories as earlier mentioned are support, clarity, complexity and usability, congruence and cost (Motswiri, 2004; Aksela, 2005; Ottevanger, 2001).

The analysis of teacher logbook showed that all teachers used the teacher guide to identify the materials required for the investigation as well as to guide the activities throughout the lesson. Four out of the five teachers that carried out the lessons agreed that materials reduced the time required for lesson preparation because it clearly outlined the resources required and provided for the lesson notes. However teacher N indicated that the assistance was not much since the experiments were very demanding on the teacher attention which required the teacher to be very familiar with the experiment before exposing it to the learners.

All the teachers agreed that the information provided in the teacher guide was sufficient in directing the process of the lesson. All the five teachers indicated that they found it easy to follow the directions given in the instructional materials. These were indications of the teachers' perceptions regarding clarity and complexity of the instructional materials.

The teachers also indicated that there were several challenges during preparation and implementation of the lessons. Teacher J had to spend a lot of time preparing for investigations since the school had not employed a laboratory technician. This coupled with her large workload was overwhelming. Limited resources and large class size were also noted as challenges during preparation. As noted during lesson observation, some teachers were not able to set up learners in small groups. Large class size was indicated as posing problems in grouping and monitoring of activities by both teacher M and N.

Three teachers also indicated that the process was too engaging since the teacher had to guide groups through questioning to develop the procedures. This confirmed what was observed in the lessons were some of the teachers decided to engage the full class in development of procedures instead of using group work as advised by the teacher guide. Another challenge that the teachers indicated was time factor. They expressed the feeling that more time should be provided for the learners to utilize the approach. Teacher K, M and N indicated that time was not sufficient especially for lesson 1, 3, 5 and 6.

All the teachers indicated that they experienced a problem with learners adjusting to the practice of developing their own procedures while they were used to being provided with step by step procedures for all their practical activities. They however agreed that if learners were to be exposed to this approach for a long time, they would adjust and engage in more thoughtful processes. The teachers suggested increased practice as a solution to the challenges they faced with the materials.

According to the teachers the objectives for all the lessons were achieved. This implies that the materials were effective in their classes and were able to offer support for the implementation of investigative practical work. They all indicated that the instructions in the teacher guide were easy to follow and clearly indicated the role of the teacher and the learner in a learner-centred investigation.

On congruence, the teachers indicated that the practice was very different from what they commonly used in class but also indicated that the investigations would be easier to carry out when supported by such materials. They also indicated that the materials were appropriate for use with Form one secondary school Chemistry learners.

In terms of the teachers' perception on cost related to adopting the approach, three teachers K, L, and N indicated that though there was high demand for resources, the benefits of learner-centred learning experiences in science would include more involvement of learners in the activities, better understanding of concepts and relating Chemistry learning to their own experiences. Teacher K and M indicated that they believed improved performance would be attained if such learning would be used. Teacher J indicated that the materials had a very high demand on the teachers time and energy but she still believed this type of learning would assist learners understand the concepts in Chemistry more easily. One of the teachers indicated that the method had high demand on resources and schools were not in a position to sustain this type of learning approach. The other three teachers however noted that the materials were available and all it required was change in teaching approach as well as innovativeness.

4.7.4. The teacher interviews

Teachers were interviewed after the lesson series. The interviews were meant to provide the researcher with more details on the teachers' perception on the support they were able to get from the instructional materials for the investigative practical work. Interviews were also helpful in providing the researcher with details of the teachers views regarding the effectiveness of the lessons carried out using the instructional materials. Data from the interviews acted as support to the data from the logbook as well as the lesson observation. Interviews also helped the researcher clarify answers that were not clear from the logbooks. The interviews were short considering most of the information had been captured in the logbook. They were audio taped with permission from the participants. Responses from teacher interviews were analysed by categorization of responses to gather information regarding practicality, validity and effectiveness of the materials. The classification of responses was similar to the one used for the logbook which included support for investigative practical work, clarity of instructions, complexity and usability, congruence and cost (Aksela, 2005; Motswiri 2004; Ottevanger, 2001).

All the teachers were of the view that the materials were able to support them in implementing learner centred investigative activities. They all indicated that the materials helped them identify and collect resources for the experiments. Teacher M said that the step by step teacher guide assisted the teacher in organizing the flow of the lesson. The benefits of the instructional materials mentioned were similar to those mentioned in the logbook. The teachers mentioned that the activities kept the learners minds engaged and thus increased their participation and understanding. Teacher K said "I *was made to understand what I should do and therefore kept the learners busy with activities and discussions"* teacher M also said *"if chemistry books and manuals were written in this form, no one would find it difficult to carry out investigations"* teacher N however, noted that preparing and implementing such activities with large classes was not easy. *"It would be an appropriate method if my class had about 20 learners."* The teachers also noted the challenge of time due to their busy schedule and the workload. Lack of time to go to the market to buy the red cabbage and the lemons was given as an example. The resources were also limited but the teachers implied that for the topic on acids and bases they could manage the resources available and improvise a few apparatus.

On clarity all the five teachers said that the teacher guide was easy to follow and use. They also indicated that the materials had sufficient information for any teacher willing to implement the approach. Teacher J noted that while using such materials "*even an untrained teacher can guide a chemistry practical lesson successfully."* The materials were clear on the role of the teacher as guide to the learning process.

In terms of complexity the teachers felt that there was need for the teacher to carefully study through the materials before presenting them to the learners to avoid confusing the learners. They indicated that the materials were constructed according to the level of the learners. They also said that the format and presentation of the materials were good and easy to follow. Teacher J said the instructional materials were complete in themselves and that there was no need for supporting notes from other books.

The challenge was mainly on time requirement. "*The investigations require more time than the simple demonstrations we are used to*" said teacher L. The need to complete the syllabus in time and nature of national examination were also cited as drawbacks to the investigative approach in teaching. This was emphasized by teacher K who said "we *have a lot to cover in the chemistry syllabus and the school administration always wants to know how much the teacher has covered in a week".* The other challenge brought up by L, M and N was large class size and a big workload. Teacher N commented that the approach was good and "*were it not for the size of my class and the workload, I would adapt the approach for my other Chemistry classes*". Teacher N cited time required for preparation given her class size and work load "I *would like to implement this method in all my classes but my workload may not allow for that.*" Groups for large classes were many and difficult to manage. The other challenge that came up was the learners' naivety in the exercise. Teachers said that learners lacked confidence in developing their own procedures for practical work. The teachers felt that some groups took too long to plan which consumed much learning time. They however indicated that this could improve if the learners were constantly exposed to the method.

The teachers were of the view that the materials were consistent with the secondary school Chemistry syllabus. They acknowledged that the syllabus suggested learner centred learning and investigative aspect of Chemistry practical work. However, they found the approach suggested in the instructional materials incongruent with their usual practice but they were in agreement that the method would lead to better understanding of the content matter. Teacher J said "*I have never thought of asking learners to formulate their procedures, it however would involve learners more"* and teacher K even joked "*if you* (the researcher) *could develop such materials for form four Chemistry, I would be the first one to buy them."*

All teachers expressed a concern on the cost of implementing the practices as suggested in the instructional materials. Cost concerns were mainly referring to resources, time and teacher's energy. Resources may be deterring in long term use of investigations in Chemistry classrooms. Teacher J cited that they had only one laboratory and no laboratory assistant yet such lessons required that the teacher organizes for the lesson materials before time for the lesson. Teacher J was of the view that though the method seemed to be more appealing to the learners, using it would cost valuable time. All the teachers however said it would be worthwhile to spend time on such learning that would produce meaningful learning in Chemistry and science in general. The teachers further attested to the fact that learners seemed to remember (in the review of previous lesson) what they had learnt through this approach more readily than they remembered when they were taught using the conventional methods. This was taken to be an indicator of effectiveness of the materials.

4.7.5. The student questionnaire

After the lesson series, the students were given a questionnaire to fill. The questionnaire (Appendix VII) was designed to gather information on the learners' experiences with the instructional materials that would be used to determine how effective the materials were as perceived by the learners. The questionnaire captured views on whether learning using the instructional materials was interesting, how they viewed their participation in the investigations and how they viewed the understanding of content taught.

All the 144 learners involved in the study were supplied with the questionnaires.136 questionnaires were returned as some of the learners were sent home for school fees before they returned their questionnaires. The questionnaire contained 15 Likert type items with five response choices ranging from strongly agree to strongly disagree. There was also an open question requiring the learner to note down any challenges faced during the investigations. The questionnaires were analyzed by calculating percentages of responses for each statement. The response agree and strongly agree were taken to indicate agreement with the given statement while disagree and strongly disagree were taken to be disagreement with the statement. The results were as indicated in Table 4.24.

Table 4.24: Learners' views on investigations carried out

Statement		Agree %	Not sure %	Disagree %
a	I enjoyed the practical activities we carried out	85.3	4.4	10.2
b	I was able to participate actively during the lessons	97.1	2.2	0.7
c	All my group members actively participated during the lessons	94.1	3.7	2.2
d	The was teacher supporting our discussions instead of telling us what to do	89	3.7	7.3
e	The lessons were interesting	83.8	7.4	8.8
f	I enjoyed developing the procedures for the practical	83.8	5.2	11.0
g	Setting procedures for practical work is difficult	22.1	29.4	48.5
h	Developing procedures made me think of what I was doing	97.1	2.9	0.0
i	Developing procedures and using them made me understand about acids and bases	79.4	6.6	14
j	The method of learning was **not** motivating	15.4	7.4	77.2
k	The lessons were clear on what we were required to do	73.5	14.7	11.8
l	I was always longing for the next lesson to see what the teacher would bring.	97.1	2.2	0.7
m	The experiments were easy to carry out	61.7	9.6	28.7
n	There should be more investigations in Chemistry	84.6	2.9	12.5
o	Doing practical work by setting our own procedures makes practical work easier and more satisfying.	88.2	7.4	4.4

The responses of items in the questionnaire were further grouped according to categorically similar items to bring out quality of the materials in terms of practicality and effectiveness as perceived by the learners (Nieveen 1999; Morse et al, 2002). Ability of materials to support learning was indicated by statements d, g and m, clarity of materials was indicated by factor k, while the other items indicated effectiveness of the materials based on; learners enjoyment (a,e, f and l); motivation to learning (j, n and o); participation in lesson activities (b and c) and conceptualization (h and I). Figure 4.6 shows summary percentages of each of these categories.

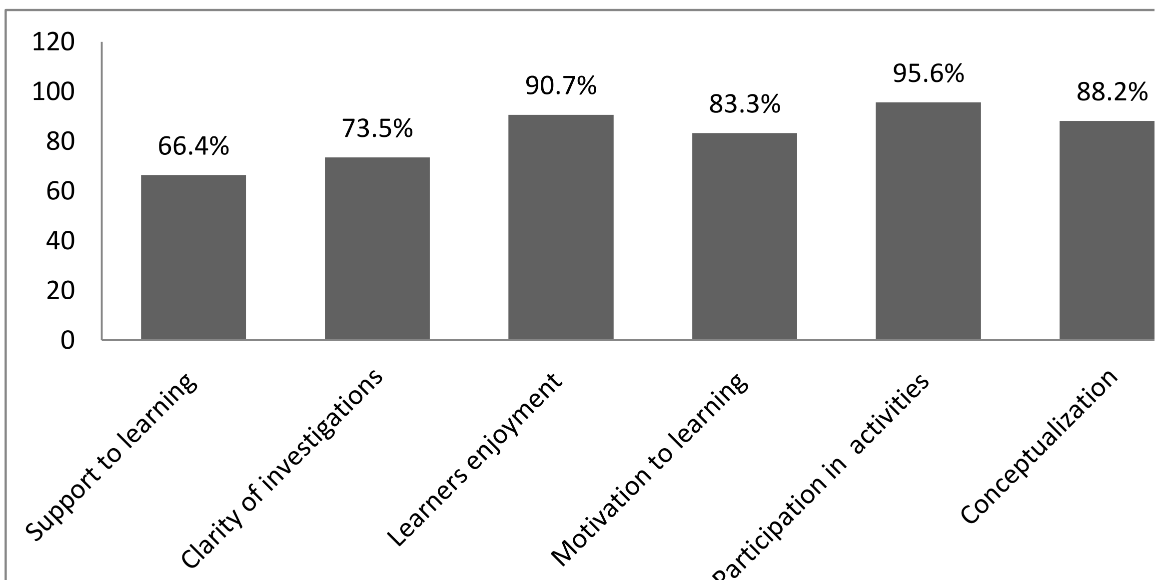


Figure 4.6: Learners' views on the investigative practical work carried out

The average percentage indicating ability of materials to support learner centred investigations (statements d, g and m) was found to be 66.4%. Most learners 73.5% indicated that the lessons were presented clearly and they understood what was expected of them. Learners indicated that they liked engaging in investigative work and perceived the activities to have been interesting. The average percentage of responses indicating learners enjoyed the activities was very high (83.8%), with the highest percentage (97.1%) being for those who indicated that they longed to see what investigation the teacher would bring in the next lesson. On average 95.6% indicated they and their colleagues in their groups were actively involved in the investigation. This indicates that they perceived their role during the lesson as active learners.

The responses also showed that most students (77.2%) perceived the structure of the practical activities as motivating and helpful to them in carrying out the investigations. The responses also showed that students perceived the approach of teaching as motivating and helpful to them in understanding what they were doing. The responses that agreed to the statement 'doing practical work by setting our own procedures makes practical work easier and more satisfying' was quite high (88.2%). Students perceived the exemplary materials helpful to their learning because they felt their understanding of the concept was improved (88.2%). They perceived that they were able to learn because the developing their own procedures made them think about what they were doing and this could have been useful in helping them understand the concept of acids and bases.

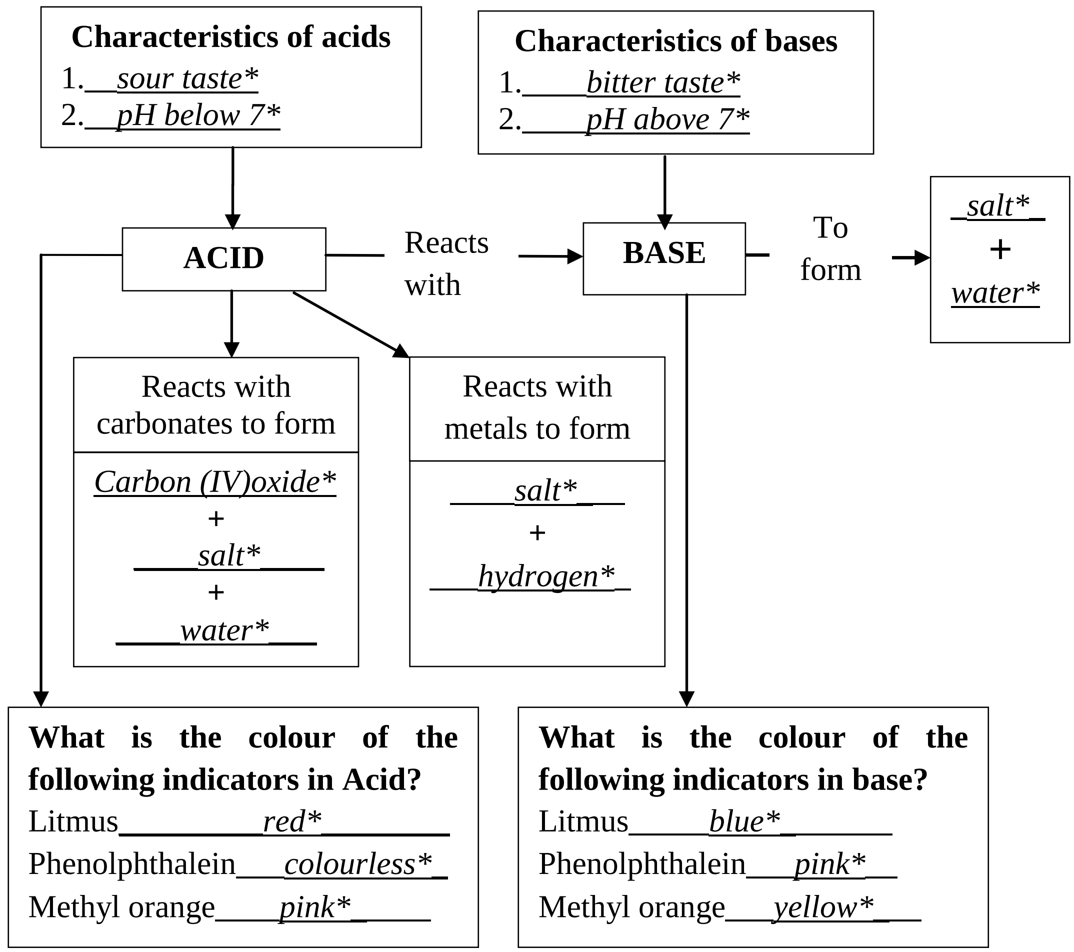
4.7.6. The Use of Concept Maps

After the leaners had been taken through instruction in the six lessons, they were given an opportunity to summarise, organize and present the learnt content through concept maps. Concept maps are two-dimensional representations of interrelated concepts placed in a hierarchy, linked by lines labeled with connecting words expressing propositions linking the concepts (Trowbridge & Wandersee, 1998). Graphic organizers, such as concept maps, are a graphical way to organize information and thoughts for understanding (Trowbridge & Wandersee, 1998):

In this study, concept maps were intended to help students summarize results of their investigations which can be seen as a demonstration of their understanding of the concept. The learners were provided with two sketch guides (figure 4.9 and figure 4.10) from which they developed the concept maps.

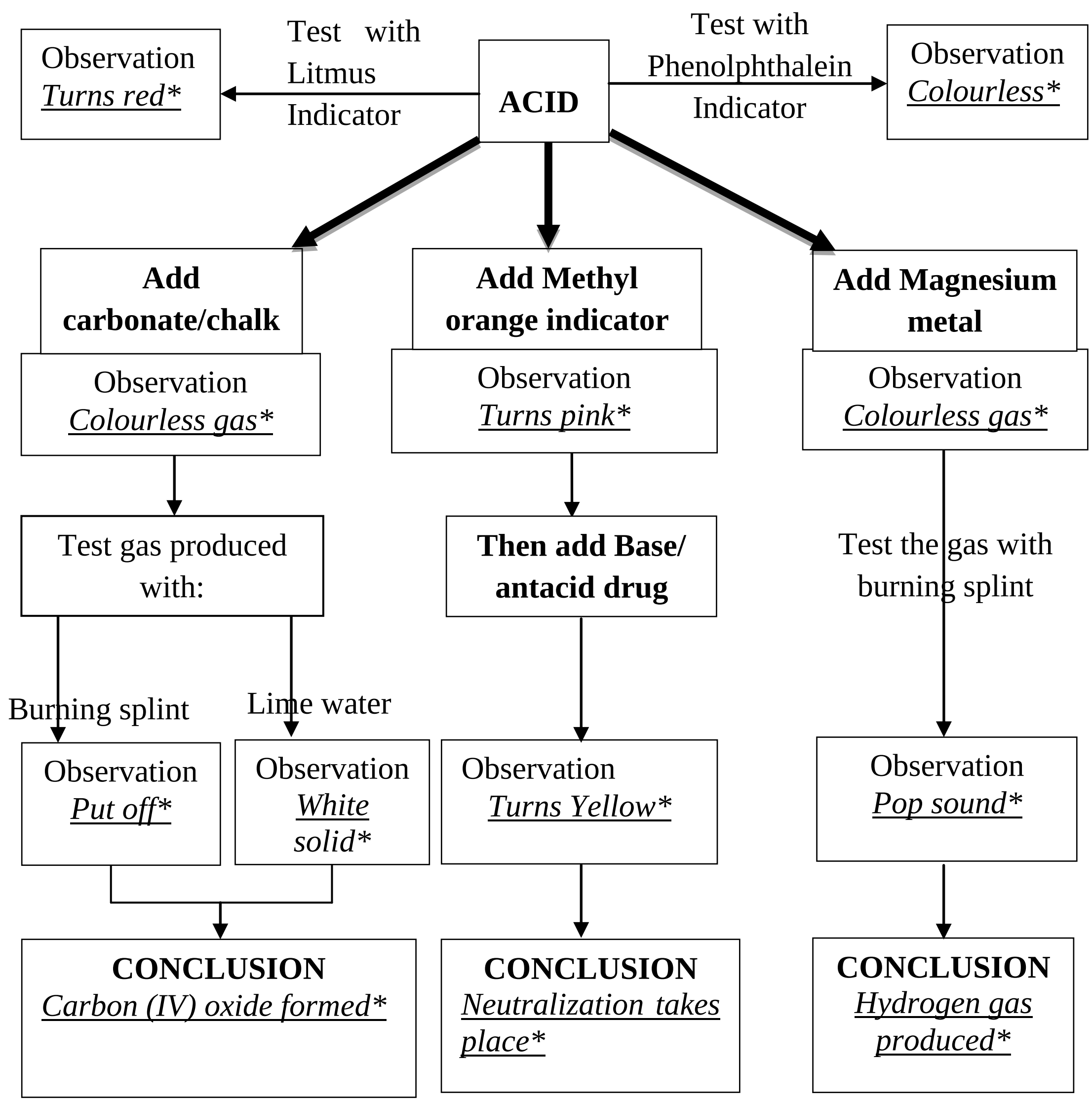
The guide was provided because the learners were in their first year of secondary education (Form One) and had very little exposure on developing concept maps. It would therefore have been difficult for them to develop the maps without guidance. The concept maps were simple because they were to be used by form one learners who did not have a lot of background knowledge in concept mapping. They were intended to gather information regarding conceptualization of the topic on acids and bases both in terms of knowledge and skills. Concept-mapping tasks prompt students to articulate their thoughts, elaborate the meaning of concepts, and construct conceptual understanding (Aksela, 2005). Concept mapping could be a key for developing strong performance assessments on how students are applying concepts and to observe the deep understanding that students are gaining (Kilic & Cakmak, 2013). The type of maps used in this study is the systems concept map which organizes information in a format. Fill-in concept mapping was used where the teacher constructs a concept map and then removes the concept labels and allows learners to fill them (Novak & Wandersee, 1990). The learners therefore, use critical thinking skills along with problem solving skills (Kilic & Cakmak, 2013).

The first concept map, guided by the structure shown on Figure 4.7 was to assist the learner articulate the understanding of concepts acquired during the lessons while the second concept map guided by the structure on Figure 4.8 was to assist the learner demonstrate the skills acquired during the learning.



*Areas left unfilled for the learners to fill

Figure 4.7: Concept map demonstrating understanding of concepts on acids and bases



*Areas left unfilled for the learners to fill

Figure 4.8: Concept map demonstrating understanding of skills acquired

The sketch of the concept maps were filled up by the learners and analysed by the researcher. The aim was to find out if learners were able to understand various areas of learning that they were exposed to using the instructional materials. Each learner filled both concept maps. A random sample of 60 concept maps was analysed. The concept maps were therefore in pairs from the same individuals based on content knowledge and on observations made during the practical activities. The responses were marked and graded (in percentage) and the means were calculated. The results from the concept map on the concepts produced a mean of 89.8% while that of skills produced a mean of 71.3%. These results were considered to indicate the effectiveness of the instructional materials in learning.

From the high mean values of the results, it was taken that the use of the instructional materials was effective in improving conceptualization of content mater and developing basic observational skills. A t-test for paired samples was calculated to determine whether the instructional materials were supporting conceptualization of Chemistry content. This was mainly because the lessons were activity centred on investigative practical work while the Kenyan education system is examination centred and formative assessments is not used for determining the final performance of the learner at KCSE level. It was important to find out if there was significant improvement in content conceptualization over skill acquisition in investigative practical work supported by the instructional materials used in the study. A t-test was carried out for 30 pairs of concept maps analysed. The t-test results were $t(29) = 2.572$, $p < .02$ and $> .01$. The indication of the results was that with consistent use of teacher support instructional materials for chemistry investigative practical work, conceptualization of chemistry content and thus performance in chemistry could be significantly improved.

4.8. The Development of Secondary Chemistry Investigative Practical Work (SCIPW) Model

The theory of constructivism in learning underpins the development of instructional strategies for investigative practical work in secondary school Chemistry. The focus of constructivism learning theory is to involve the learner in knowledge construction and skill development. The model for the development of instructional materials for teaching secondary school Chemistry practical work through investigations developed in this study is referred to as **Secondary Chemistry Investigative Practical Work (SCIPW) model**. In a constructivist learning environment (forming the theoretical foundation of the proposed SCIPW model), the teachers play the role of a guide and helps students to connect their prior knowledge with new information.

Models are important in the processes of curriculum and instructional design as they assist in the development of systematic instructional design. Gustafon & Branch (2002) argue that instructional models provide conceptual and communication tools for visualizing directly and managing process for creating high quality instruction toward a consistent scope and sequence of content and instruction. Models play an important role in designing courses because it guides the designer to complete the process in a step by step manner and offers tools for determining appropriate outcomes, collecting data, analyzing data, selecting media, conducting assessment and implementing and revising results (Gustafon & Branch, 2002; Smith and Ragan, 2004).

The major goal of this model is to guide through the process of developing instructional strategies that support teachers in the implementation of learner centred investigative practical work in secondary school Chemistry. It serves as conceptual framework for organizing and sequencing a set of instructional activities to build meaningful student learning. Design based research (DBR) was used mainly because DBR is a goal-oriented process where the goal of design is solving problems, meeting needs, improving situations, or creating something new or useful (Friedman, 2003). The applied process involved five steps which are; analysis, design, development, implementation, and evaluation of instructional materials (Smith and Ragan, 1999). Secondary Chemistry Investigative Practical Work (SCIPW) model was basically constructed through some key stages identified by the study. The first stage is the ‘mainstream’ which is regarded as the backbone of the overall model.

4.8.1. Stage one of SCIPW model: The Mainstream

The mainstream model involves a close analysis of the content of Chemistry practical work currently used in secondary schools. This guides in the design of instructional strategies and activities for investigative practical work. The designed activities went through various, appraisals, trials, evaluation and refining as well as redesign in a cyclic process (Dick & Carey 2005) producing exemplary instructional materials for Chemistry practical work. Figure 4.9 shows the mainstream model.

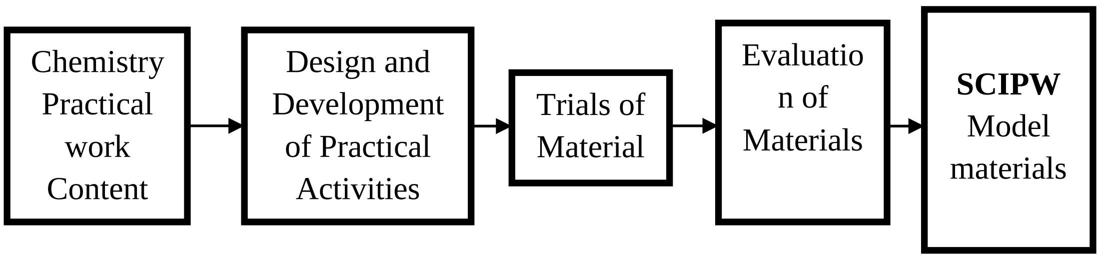


Figure 4.9: The Secondary Chemistry Investigative Practical Work (SCIPW) mainstream model

The content of the instructional materials should reflect facilitation of activities that engage the learners cognitively. Constructivism involves active participation and personal applications in learning. The learning process must be concerned with the experiences and contexts that facilitate meaningful learning. Constructivist learning environment enables the learner to reflect their own thoughts and become autonomous (Friedman, 2003). During the instructional activities, students try to get their own experience of things which motivates them to involve actively in the process. During the first lesson of the study (which was on identification of acids and bases) learners were asked to predict common household solutions that were basic or acidic. Arguments on whether substances like common salt (sodium chloride solution), baking powder and wood ash were basic or acidic and how that can be determined arose. This motivated them to find out the truth with an aim of supporting their predictions.

Design and development of such materials demand a careful consideration of needs for chemistry learning. To ensure materials are usable in secondary school set up, they go through appraisals as well as trials in classroom set up which leads to review, improvement and redesign to attain the practical work materials model.

4.8.2. Stage two of SCIPW Model: Identifying Chemistry practical work content

The content of instructional materials (mainly textbooks) that teachers were using in schools to guide learners through Chemistry practical work were analysed with an aim of finding out the nature of content as well as support for investigative practical work available in the materials. This was done through document analysis schedule. The utilization of such materials in the classroom was also sought through lesson observations of teacher practices as informed by the instructional materials they used.

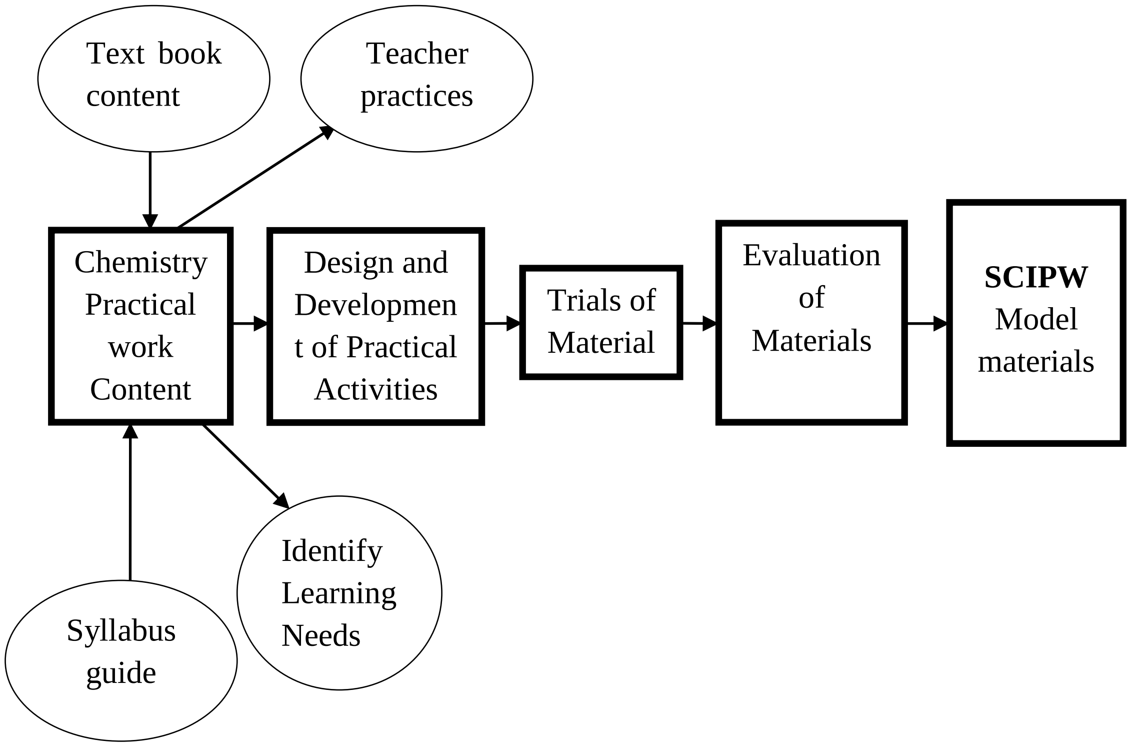


Figure 4.10: Stage 2 of SCIPW model: Identifying chemistry practical work content

The syllabus provides a guide on appropriate content for the level of learners. The content recommended by the syllabus was found in the text books analysed. The text books, however, were found to contain practical work content presented in a cookbook style where all the procedures were provided and for most of them expected outcome outlined. Such provides in instructional materials do not support learners thinking skills (Kidman, 2012; Krajcik et al, 2003). They tend to encourage learners to simply learn how to follow instructions. Similar observations were made by Abrahams & Millar (2008) who argued that practical work was generally effective in getting students to do what is intended with physical objects, but much less effective in getting them to use the intended scientific ideas to guide their actions and reflect upon the data they collect. The textbooks did not also provide much support for investigative activities. The only support found in most textbooks was provision of objectives observed in 73.3% of the materials. Other support features for investigative practical work were found in low percentages such as; providing relevant phenomena (23.3%), reference to prior knowledge (30%) and provision of background information related to the practical activity (30%). Opportunities such as guiding on learner participation in formulation of procedures to use in the activity, guide on pooling of results together and probable learner questions were completely lacking.

The books were also found to emphasize aspects related to lower levels of science learning domains such as knowledge and understanding and basic scientific skills such as observational and manipulative skills. Little emphasis was found in application of scientific facts, analyzing synthesis and evaluation as well as predicting, data interpretation, imagination and creativity. Similar weaknesses concerning instructional materials have been noted by other researchers (Thijs, 1999; Stoffelsma & Kwetu, 2004; Ottevanger, 2001; Motswiri, 2004; Krajcik et al, 2003). Such weaknesses in instructional materials could hinder the use of constructivism in the classroom set up. Lesson observations showed that teachers were not conducting lessons in learner-centred strategies. The teachers provided step by step guide on the activities they carried out which the learners followed without question. In most cases the results were not consolidated and learners were not given opportunities for scientific reasoning and arguments.

The syllabus and textbooks make a useful starting point when constructing instructional materials for investigative practical work because it ensures the content selected is appropriate for learners and what the teachers are conversant with. This analysis of content provided the researcher with an identification of content needs in the learning of investigative practical work. Teachers' attitude towards the instructional materials greatly determines teacher practices and thus the success of instruction in the classroom situation. Most teachers were found to follow the practical work as outlined in the textbook without alterations. This practice indicates the importance of constructing instructional materials based on the current teacher practice with a change in the approach to instruction. The instructional materials developed in this model were designed to support teachers in including such areas of learning as found missing in the books. The content of these books was used to develop activities that were changed from step by step directions to investigative activities in the materials that were designed. These materials were developed in prototypes that were taken through trials in classes and finally the model prototype was produced.

4.8.3. Stage three of SCIPW model: Design and development of instructional activities

Design and development of practical activities in the instructional materials started with development of design specifications. Design specifications for the instructional materials were informed by theoretical orientation (what literature presents as best practice for learner-centred investigative practical work) and feedback from empirical analysis (textbook content, teachers' views and actual teacher practice in the classroom). Theoretical orientation provided the designer with what is considered as best practice in constructivist learning environment (Smith & Ragan, 1999; Brooks & Brooks 1993; Hidir & Gultekin, 2007; Kirschner et al, 2006 Jonassen, 1999) and design specifications for developing materials used in similar studies (Ottevanger, 2001; Thijs, 1999; Reiser et al, 2003; Motswiri, 2004; Davis & Krajcik, 2005; CDC-HKEAA, 2007; Ottevanger, 2013; Davis et al, 2014). Designing the instructional materials also involved a consideration of the challenges identified in the books used by teachers to support teaching of practical work (obtained from document analysis schedule and teachers' views in teacher questionnaires) as well as observed classroom practices during practical work lessons (from lesson observation). Teachers' views of what they considered best practices in chemistry practical work were also gathered through the teacher questionnaires. It was found that teachers use practical work to teach textbook knowledge. This nature of recipe-based practical work is not sufficient to develop students scientific thinking referred to by Kim & Chin (2011) as ‘habits of mind’. It was observed that learners were restricted to the use of procedures given and did not even question them. During class activities involving practical work, learners were keen on following procedures and could be heard asking each other to read out the next ‘step’ in the procedure provided. When finished with the activity they would sit and wait for the teacher to tell them what they should do next. They were found to be reluctant to discuss their findings among themselves. This could indicate that such practical work may not be appropriate for the development of intellectual abilities of learners.

Through content analyses of the textbooks content, learning demands for the topic on acids and bases were identified and the learning the opportunities they offered students. The feedback from empirical and theoretical analysis as well as formulation of design specifications ensured relevance of the designed materials in the learning situation (Ottevanger, 2013). Availability of resources in the local set-up was considered in the design and suggestions for improvisations provided in the instructional materials. Activities were designed such that available resources could be used to enhance Chemistry and science learning in general. New teaching approaches were infused in the design of the practical work activities.

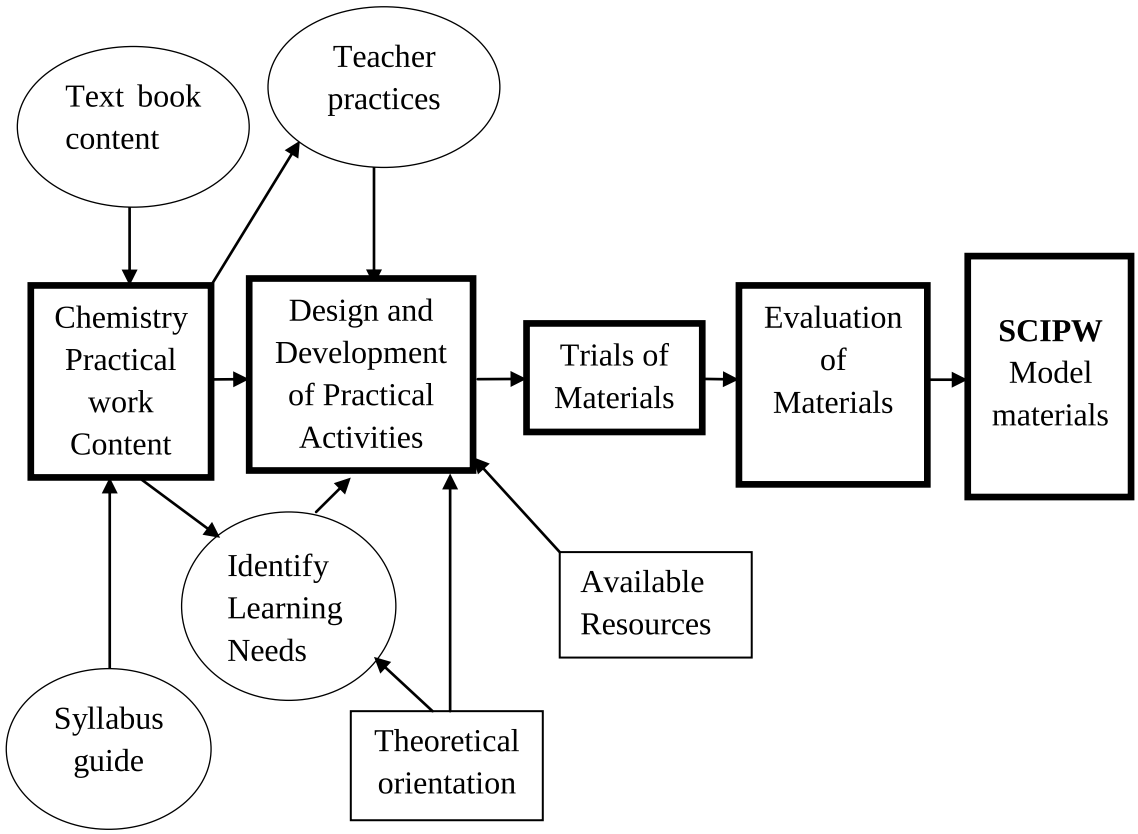


Figure 4.11: Stage 3 of SCIPW Model: Design and development of instructional activities

Five areas of science practical work learning against which instructional materials were designed identified as science content, scientific practices, literacy practices, participation structures and assessment (Davis et al, 2014). Design specifications were formulated with detailed characterization of each of the five areas of learning. The first prototype of instructional materials was then designed. These materials included the teacher guide (which was the main document) and a brief student guide. The main focus of the teacher guide was to support the teacher in guiding learners through conducting practical activities in an investigative way. The role of the teacher was presented as to design meaningful experiences in learning environments while that of the learner was to join discussions and collaboration activities. Designed meaningful experiences were to motivate students to construct new knowledge in their long term memory (Isman, 2011).

The quality of instructional materials at this stage should be carefully checked. Three sets of criteria for judging appropriateness of instructional materials used were; pedagogical appropriateness, science content and presentation format (The National Academy of Sciences, 1998; Rubdy, 2003). It was also considered necessary to have the instructional materials appraised by the teachers who are the users of such materials in the classroom. The process was iterative, with the outcome of one appraisal informing the refinement of the materials. a good number of teachers on pre-service training in chemistry teaching were found important in the appraisal of the materials. This was boosted by the fact that a high percentage (91.5%) of the teachers indicated that the materials reflected the KCSE syllabus and were usable in chemistry classrooms. Most of the teachers (68.1%) agreed that learners would cope with the approach of teaching suggested in the materials. They suggested various adjustments on time allocation for classroom activities, provision of suggestions for improvisations and alternatives and inclusion of safety precautions. These suggestions were used in the review and redesign of the instructional materials.

To reinforce this important stage, teachers with long experience in the teaching of Chemistry at secondary school level also appraised the materials. From their recommendations, more adjustments were done on the timings of the practical activities and more guidance on teacher activities especially on assessment provided. To cap it all, two science education experts lecturing at the university appraised the materials and research instruments that were used in the study. These appraisals also offered quality check on relevance and consistency of the instructional materials. The instructional materials were redesigned leading to the development of the third prototype.

4.8.4. Stage Four of SCIPW Model: Trials of Materials

The third prototype was tried out in a classroom set-up. In this step, teachers tried out the planned instruction with the students. This was aimed at testing the practicality of the materials in a classroom set-up. Ottevanger (2013) describes practicality as the usability of the intervention in the settings for which it has been designed. The main goal of this stage is to find out which areas are working and which stages are not working. Isman (2011) argues that problems in instructional design are identified during testing of prototypes. During the tryout a consideration of resources available for use in schools was made. Some adjustments for improvisation and grouping learners for practical activities were made. The lessons were planned and prepared for by the teacher. The teachers used teacher guide to assist guide in the lesson implementation. Time available for teaching was a major consideration at this stage. During the lesson activities lesson observation was done by the researcher. It was observed that teachers were able to follow the teacher guide in the classroom set-up but the effectiveness of the lesson depended on teacher practice and time management by the teacher.

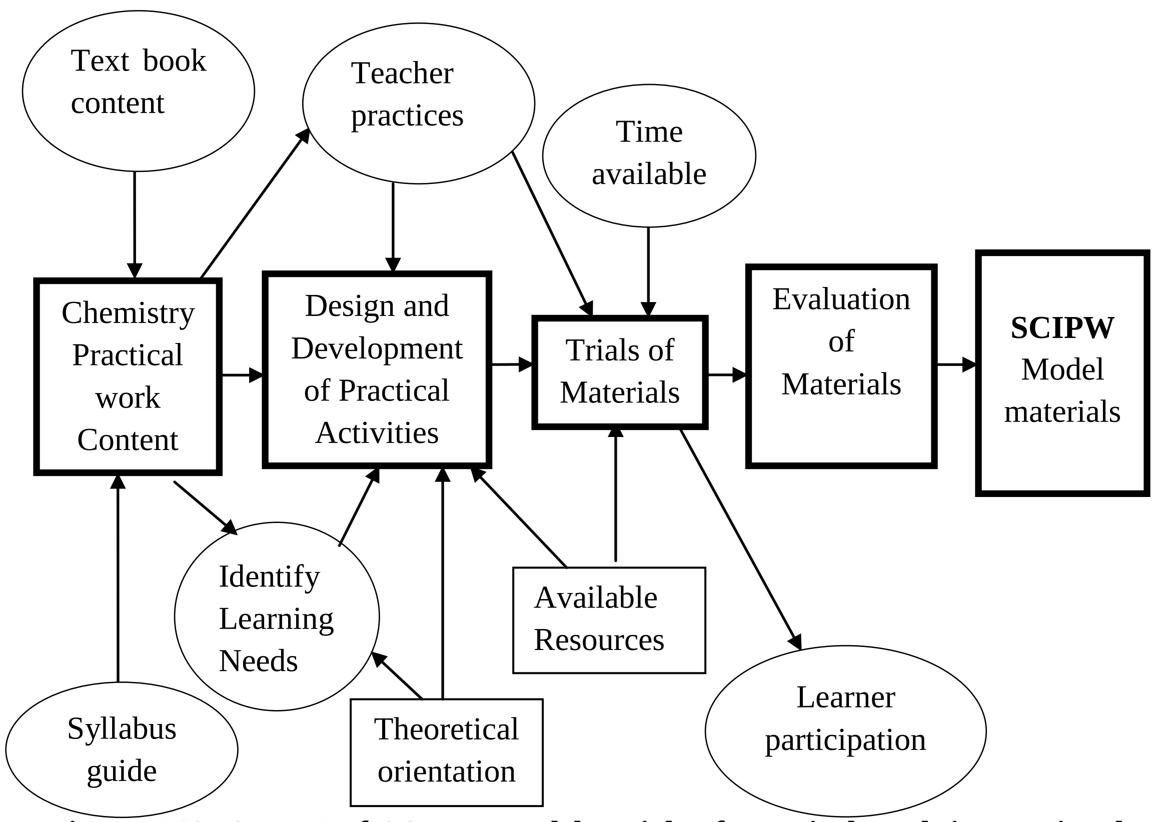


Figure 4.12: Stage 4 of SCIPW Model: Trials of practical work instructional materials

Observation of the practical activities carried out showed that teachers were able to understand and utilize the instructional materials appropriately. Analysis of lesson observations showed that 81.06% of expected teacher actions in an investigative practical work set-up were observed. Grouping of learners was, however, affected by lack of sufficient resources and time for improvisation as well as large class sizes considering the intense guidance required from the teacher. A logbook was used to gather information regarding teacher experiences during planning and implementation of the lessons. Teacher interview at the end of the lesson series provided clarification of areas they mentioned in the logbook and their experiences in class.

Student interviews were used to gather information about effectiveness as perceived by the learners. The observations and views were used in the redesign of the materials producing another prototype for evaluation in stage five.

4.8.5. Stage Five: The SCIPW model

The materials were further refined after the first try-out and used by other teachers in their Form One classes. This was the evaluation of the materials in real classroom use. Huitt et al (2009) discusses three levels of analysis to evaluate how well a method works in achieving instructional outcomes. These were; effectiveness, efficiency, and appeal. Effectiveness requires that appropriate indicators of learning be identified to objectively measure the learning outcomes.

Efficiency requires an optimal use of resources such as time and money to obtain a desired result. Level of appeal relates to the degree to which learners enjoy the instruction (Huitt et al, 2009). Nieveen (1999) identified these levels as practicality and effectiveness. Practicality (efficiency) was based on: the ability of the instructional materials to support teachers in the teaching of investigative practical work; relevance of the materials in the teaching of KCSE Chemistry; clarity of instructions in the materials; complexity of the teaching approach, congruence with current teacher practice and cost associated with use of the approach (Ottevanger, 2013; Nieveen, 1999). Effectiveness was based on achievement of desired objectives and student response to instruction. An evaluation of the practicality and effectiveness of the materials was carried out. Evaluation involved checking on the teacher activities during the practical lesson and recording the observations as guided by the observation schedule and checking on the learner participation as they interacted with available resources that pointed to the effectiveness of the lesson. Practicality and effectiveness of the materials as gathered from lesson observation, logbook recordings, interviews, student questionnaires and concept maps informed the refinement and development of the final model of instructional materials for secondary school Chemistry practical work.

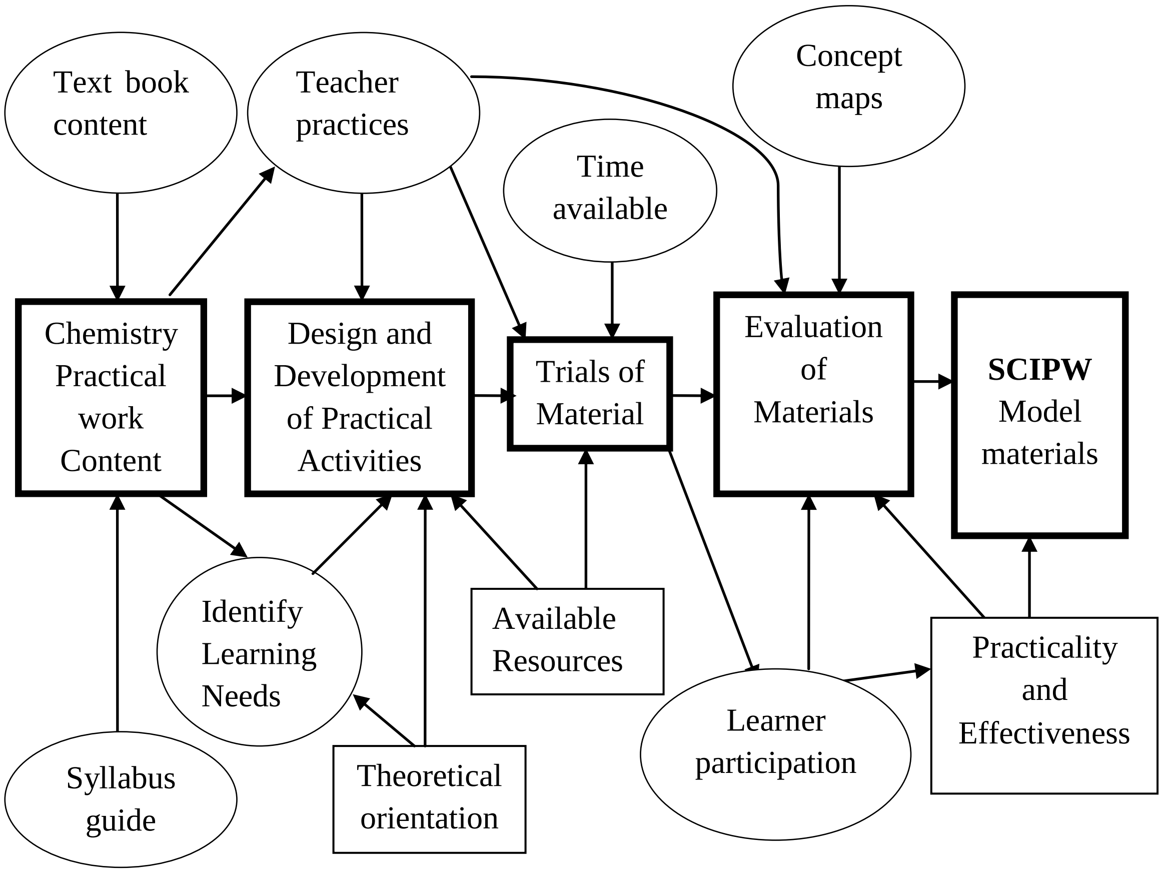


Figure 4.13: The SCIPW model for developing investigative practical work materials

Teachers' views indicated in the logbook as well as expressed during teacher interviews showed that they found the instructional materials to be providing them with necessary support for learner-centred investigative practical work. The instructions were clear and easy to follow and the complexity level was within the ability of both the teachers and the learners. Teachers, however, found the approach incongruent with their normal practical lessons. They pointed to the challenge of large classes with the amount of coordination required in the approach of teaching. They also felt that learners were challenged in involving themselves through the thinking of the processes of investigation. The indication with continued use of the approach in the six lesson series was that learners tended to adapt and also like the new approach. The cost of resources was higher than usual and the demand on teachers' time and participation was also high. The teachers however indicated that the outcome of learning would be higher and thus worthwhile.

Effectiveness is achieved when using the intervention results in desired outcomes (Ottevanger, 2013). Analysis of lesson observation schedule showed that 80.92% of expected teacher actions during an investigative practical lesson were observed section 4.4.2). The high percentage was taken as a positive indication of practicality and effectiveness of the instructional materials. Learners were also asked to draw up concept maps linking the concepts and skills learnt through the use of the instructional materials. The mean score from the concept maps was 80.55% which was also taken as an indication that meaningful learning had been achieved. Learners were requested to complete a questionnaire to show their perception concerning the lessons taught using the instructional materials. Most learners indicated that they were able to participate in the lesson activities (95.6%), enjoyed taking part in the lesson (90.7%), were able to understand more (88.2%) and felt motivated to learn Chemistry (83.3%).

In conclusion, the main goal of Secondary Chemistry Investigative Practical Work (SCIPW) Model is to give a route map to organize the development of instructional materials for use in Chemistry learning of practical work which ensures the learners intellectually and physically involved in the Chemistry learning activities. Learner is active during teaching and learning activities, which can lead to better understanding of science concepts and development of both manipulative and process skills. SCIPW model can be used to develop instructional activities of practical work not only in the Chemistry subject but also in other science subjects.

The iterative nature of DBR used in the study ensured feedback at each stage in the design was used in the next stage. The materials used in this study went through various evaluation activities (Ottevanger, 2013, Nieveen, 1999; Motswiri, 2009) which included appraisal by users; Chemistry teachers who use instructional materials and expert appraisal to enhance consistency. Use of concept mapping in the learning of Chemistry is important in summarizing important concepts learnt thus aiding conceptualization (Trowbridge & Wandersee, 1998; Kilic & Cakmak, 2013).

SCIPW is based on instructional systems design that occurred in five stages; analysis, design, development, implementation, and evaluation of instructional materials. Such a design should ensure that it closely conforms to the larger educational policy and structure of education in a given country to be acceptable by users. In this study the model closely relates to the Kenya Certificate of Secondary

Education (KCSE) syllabus and Kenya National Examinations Council (KNEC) regulations. Though model need to be used by the teachers to enhance Chemistry learning, teachers may be faced with the challenge of time for using the model. Countries that have had successful use of increased amount of practical work with supportive instructional materials such as Nuffield materials in Britain had to revise the curriculum to decrease the amount of content and emphasize on practical activities. It is therefore possible to use the SCPIW model if the curriculum developers reviewed the Chemistry curriculum in the light of inquiry based learning.

4.9. Conclusion

This chapter of the study describes the empirical analysis of needs for learner-centred practical work in Chemistry learning. It also provides a description of design, development and appraisal of instructional materials that support teachers in conducting investigative practical work and details the try out of the instructional materials in Chemistry classrooms as well as an evaluation of the materials. Both quantitative and qualitative data analysis was carried out. The study involved a five stage process with an aim of developing materials that would address the challenges that teachers faced in supporting their learners in investigative practical work.

From the empirical study, in stage one, questionnaire responses were analysed and the results coupled with lesson observations. It was found that teachers used practical work in Chemistry because they believed practical activities were important in the learning of science. They commonly used teacher demonstration for their practical work but indicated that they valued class activities. Content analysis of common instructional materials used by teachers during chemistry practical lessons was done. They were found to lack many opportunities for investigations and instead provided the learner with step-by-step procedures for the practical activities. Teachers were found to face various challenges in the use of practical work in their schools.

The second stage involved design and development of the first prototype of materials. Design specifications were made based on the five basic areas of learning for practical work: science content, scientific practices, literacy practices, participation structures, and assessment (Davis et al, 2014). The appropriateness of the materials judged was based on pedagogical appropriateness, content appropriateness and presentation format. The materials were then appraised by the 47 Chemistry teachers on training, three experienced Chemistry teachers and two Science Education experts who all agreed that the materials could be used in the classrooms. They suggested various modifications of the materials which were carried out.

Stage three involved a try out with three teachers in their Form One classes. This was carried out to explore the consistency and practicality of the materials. The lessons were observed, interviews were carried out with the teachers and the learners and the teacher kept a record of the happenings in their practical lessons in the logbook. Teachers were able to implement the lessons as expected and the learners were confident that they had learnt the concept well. The materials were refined in the view of the outcomes of the try out to come up with a third prototype.

In the fourth stage, the third prototype was evaluated for effectiveness and practicality when in use in the classrooms. Five teachers used them in their classes and the lessons were observed. The teacher also filled the log book and the learners filled up a questionnaire. Practicality was indicated by support, clarity, congruence, complexity, and cost when used in the context of the teachers' practice. The outcome indicated that the instructional materials were able to support learner centred investigative practical work. The fifth stage involved refinement of the materials and development of a model for development of such instructional designs. A model of practical work instructional design known as Secondary Chemistry Investigative Practical Work (SCIPW) instructional model was proposed (Figure 4.14). It provides a detailed guide to the development of instructional materials that support Chemistry teachers in planning, development and implementation of Chemistry investigative practical work lessons at secondary school level.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Introduction

The main focus of this chapter is on the presentation of a summary of the findings, their implications, conclusions and recommendations which are drawn from the of the study findings. The major results from both qualitative and quantitative data analysed are summarized. These results are discussed and the characteristics of the instructional materials that support Chemistry teachers in overcoming the challenges they face in investigative practical work are outlined. Conclusions are drawn and recommendations formulated.

5.2. Summary of the Findings

The summary covers the findings of the study with a view to address the purpose of the study which was to come up with a model of developing instructional materials that would influence secondary school students' participation in Chemistry practical work. The study used Design Based Research design in which five phases of the study were involved with the results of each phase informing the next phase. The instructional materials were developed through systematic, flexible, and iterative review, analysis, design, development, and implementation (Wang & Hannafin, 2004). The design focused on directly addressing the problems of practice and producing an applicable solution. Theoretical and empirical problem analyses in this design process were integrated. The findings reported here are based on primary data collected, literature review, design and development of the instructional materials as well as the evaluation of the instructional materials.

5.2.1. Objective 1: To find out the current practices in the teaching of Chemistry practical work in secondary schools.

One focus of the study was to find out current practices in the teaching of practical work in secondary school Chemistry. This was aimed at determining some of the challenges teachers faced in supporting learner-centred investigations. It was also meant to gather their views on what they thought were best practices that would support investigative practical work. Literature review and analysis of teacher questionnaire, lesson observation and document analysis schedule provided a view of needs for Chemistry learning and areas that teachers needed support to implement learner-centred investigative practical work. Literature revealed that practical work was of basic importance in the learning of Chemistry and that there was need for learner- centred practical activities. This is a major focus of the KCSE syllabus and was recommended by KNEC examiners, lack of which they associated with poor performance in Chemistry (KNEC, 2012). The teachers were in agreement that practical work is important in Chemistry learning because it arouses interest in learners and motivates them to learn. It also helps to verify facts/ theories or principles discussed in class and to make learners understand concepts more easily. This actually agreed with the importance of practical work derived from literature review (Hofstein, 2004; Millar, 2004; Achimugu, 2009; Twoli, 2006).

The achievement of these objectives may, however, be dependent on quality of practical work as well as the strategies used to involve learners in the practical activities. It was also indicative that teachers did not use learner- centred practical activities in their teaching (Motswiri, 2014; Kisangi & Ateng' 2006). The common practical activities carried out in schools involved learners being provided with step by step guide on all the activities they carried out thus not engaging them mentally in the practical activity (Hodson, 1992; Woolnough & Allsop, 1985; Motswiri, 2004; Pogrow ,1993; Lunetta et al. 2007). Most of the teachers (82%) indicated that the best method to teach Chemistry practical work was through class experiments that involved groups of student activities. It was however found that only 21.4% used class experiments while 64.3% used demonstration method. Though teachers said that they combined both demonstration and class experiment methods, 52.4% of the teachers did not use class experiment more than twice in a term. This pointed to the need for teachers to be supported in their endeavor to implement class experiments.

Curriculum materials that contain large amounts of specific and concrete guidelines on how to plan, organize and conduct a lesson can have great potential in supporting teachers' preparation and implementation of lessons (Van den Akker, 1988; Motswiri, 2004; Krajcik et al, 2007; Karaduman & Gültekin, 2007; Bekele & Melesse, 2010; Sunzuma et al, 2012). There was need to support five areas of learning for investigative practical work. These basic areas of learning practical work are science content, scientific practices, literacy practices, participation structures, and assessment (Davis et al, 2014). Learners engage in various scientific practices as a key to understanding their experiences and the science content being learnt. Literacy practices involve using scientific language, and engaging in scientific arguments and discourses while participation structures involve use of various strategies that support learners in inquiry.

There was need to develop appropriate instructional materials that encouraged secondary school Chemistry teachers to use investigative practical work. The teachers provided the learners with detailed step by step procedures to follow during practical activities. This mostly led to learners being involved in 'hands on' activities rather than 'minds on' activities. A high percentage of teachers involved in the study agreed that stimulating learners to reflect on their prior knowledge (95.2%) and designing experiments that relate to their life's experiences (57.1%) would enable learners to acquire meaningful learning in Chemistry. It was, however, noted that most of the teachers (80.9%) believed that providing learners with detailed procedures to follow was an appropriate way of involving learners in Chemistry practical activities. Most teachers (71.4%) did not allow learners to set up their own procedures or carry out procedures that interested them. The learners did not question the procedures set but just used them as they were provided.

Lesson observations also supported the view that learning in Chemistry practical work was not learner-centred and did not use an investigative approach. This pointed to the need to provide instructional materials that would give sufficient guidance to teachers in order to achieve learner-centred investigations that involved learners in setting up their plans for the experiments they carried out.

5.2.2. To find out the opportunities provided by curriculum materials for support of investigative practical work in Chemistry.

The need for support in subject content matter was identified during lesson observation. The instructional materials (textbooks) commonly used by teachers during Chemistry practical lessons in the topic *'acids and bases'* were identified and analysed. These textbooks provided the researcher with content matter appropriate for Form 1 Chemistry topic on acids and bases. The books were found to contain content that emphasized on lower order learning levels such as knowledge of facts and understanding with higher order thinking skills such as analyzing, synthesis, evaluation and hypothesizing receiving little attention. There was much emphasis on basic skills such as observation and manipulation and less focus on application, creativity and imagination. This was in agreement with the findings of Orado (2009) and Nyang'ai (2010) who recorded emphasis on practical work as being on lower order thinking skills and simple manipulative skills. There was need, therefore, to support these aspects of science learning by including appropriate scientific practices as well as literacy practices (Davis et al, 2014) in the instructional materials prepared for this study.

From the teachers' questionnaire as well as document analysis, the textbooks were identified as supporting investigations by mainly providing objectives for most of the practical activities and providing lists of required apparatus. They were, however, found to lack many other opportunities for investigations such as; provision of background information related to the practical activity, guiding questions to stimulate investigation, guide on planning for investigation, reference to prior knowledge, use of relevant phenomena, application of scientific facts and a guide on pooling results and using scientific arguments. All the books lacked opportunity to develop procedures or look for alternatives to given procedures and instead provided the learner with step-by-step procedures for the practical activities. There was therefore need to support teachers in these areas of implementing investigative practical activities. Generally there was need to obtain new ways such as pedagogical models and instructional materials for investigations that could be directly applied to secondary school Chemistry classrooms in supporting teachers implement investigative practical work.

5.2.3. Objective 3: Challenges facing teachers in the implementation of Chemistry practical work

An important focus of the study was to identify the challenges that secondary school Chemistry teachers faced in implementing learner centred investigative practical work. From lesson observations, teachers' views in the questionnaires, document analysis and even literature review, a conclusion was made that teachers faced various challenges in their endeavor to implement learner-centred investigative practical work. Lesson observations revealed lack of confidence and limited understanding of the science content matter by the teacher. There was, therefore, need for support in content matter of the practical activities.

There was lack of support in the development of investigative abilities such as prediction, questioning, hypothesizing, designing experiments and scientific arguments. The instructional materials that teachers were using provided the learner with step by step procedures to follow when carrying out experiments. The teachers indicated that learners did not question or modify the procedures given but simply carried out activities without giving much thought to them. This mainly led to rote learning instead of providing deep meaningful learning in Chemistry. Literature shows that detailed teacher guide on lesson organization and implementation could assist teachers in implementing activities that involve development of investigative abilities of learners (van den Akker, 1998; Ottevanger, 2001; Motswiri, 2004; Aksela, 2005; Krajcik et al, 2007; Ottevanger, 2013). The ability to make inferences and conclusions from experimental observation was also not provided with much support. The learners and the teacher tended to carry out experiments to verify what they already learnt and simply follow the conclusions indicated in the curriculum materials they were using.

Lack of collaboration and peer review during practical lessons was observed. The activities as laid down in the curriculum materials used in schools did not encourage learners to enquire from each other and challenge each other's thinking. This is because all procedures for the activities were well outlined and the expected outcome given. Providing opportunities for learners to do predictions as well as design their own experiments allows for varied views of the phenomena and provides learners with an opportunity for scientific arguments. Practical activities in the textbooks were not commonly based on learners' real life settings which makes it difficult for them to relate Chemistry with life outside the classroom. This could lead to lack of interest in the learning of Chemistry which in turn affects performance (Nyang'ai, 2010). While prior knowledge is the basis on which constructivism learning is built, the teachers were found not to find out the learners' prior knowledge or try to understand misconceptions held by the learner. The textbook content was also found to have little emphasis on learner's prior knowledge or relate Chemistry to the learners' environment. Teachers also faced the challenge of inadequate resources and time to prepare for the activities and to carry out investigations. There was need for support in improvisation of materials and provision of detailed requirements for the activity to ease teacher's preparation for the practical session.

5.2.4. Objective 4: Design, development and evaluation of the instructional materials for Chemistry investigative practical work

Theoretically and empirically based design specifications to support the five areas of practical work learning (science content, scientific practices, literacy practices, participation structures, and assessment) were formulated. The first prototype of instructional materials for six lessons were designed by changing the activities from the guided step by step procedure structure to problem solving investigations composed of activities to meet the specifications of the design. The appropriateness of the instructional materials considered during their formulation based on pedagogical appropriateness, science content, and presentation format of the written materials (Rubdy, 2003; The National Academy of Sciences, 1998; National Science Resources Center, 1997).

The materials were then appraised and evaluated on basis of quality criteria for curricular products which includes; relevance, consistency, practicality, and effectiveness (Nieveen 1999; Thijs, 1999; Motswiri, 2004; Ottevanger, 2013). Relevance was based on indication for need for the intervention and its design being based on state-of-the art (scientific) knowledge (Thijs & Van den Akker, 2009) as cited by (Ottevanger, 2013). This was ensured through context analysis of Chemistry practical work in Kenya, literature review on appropriate pedagogical approaches for investigative practical work, expert appraisal and generation of design specifications. Consistency was ensured by expert appraisal through formative evaluation of instructional material prototypes while practicality, and effectiveness were ensured through user appraisal, try out and evaluation during classroom use of the materials.

Chemistry teachers appraised the materials and indicated that the materials were relevant and practical for use in Form 1 Chemistry classes based on the KCSE syllabus. Two science education experts from the university appraised the materials and the research instruments. The appraisers concluded that the design specifications were consistent with constructivism knowledge and the context for which they were formed.

A try out of the materials with teachers was carried out to explore the consistency and practicality of the materials. During lesson observations, a lot of learner interaction was observed and high percentages of expected teacher actions were observed (77.4%) but there was poor time management thus, hurried conclusion and clean up. From teacher interview and logbook it was gathered that the instructional materials were useful in supporting preparation and implementation of investigative practical work. The learners also found the concepts easier to understand, lessons were interesting and they participated in the activities more than they do in their usual classes. Time management was found to be a problem to most teachers. Adjustments were made in the guide for imptovement.

The improved of the practical work instructional materials was used by 5 teachers in their classrooms. An evaluation on their practicality and effectiveness in the actual classrooms situation was carried out. Practicality was indicated by support, clarity, congruence, complexity, and cost when used in the context of the teachers' practice (Motswiri, 2004; Ottevanger, 2001; Nieveen, 1999). Lesson observations revealed high percentage of expected teacher action outlined by the researcher (80.92%) which indicated that the investigations were implemented as intended by the researcher (practicality-support). The teachers indicated in the logbook and during the interviews that the materials supported them in preparation and implementation of investigative activities. They indicated that the materials were clear on what was expected in investigative practical work. The level of complexity of the instructional materials was within their reach in terms of understanding how to translate the teacher guide into lesson activities and use them in their classrooms. They also indicated that their objectives for each lesson were achieved. The materials were therefore considered effective. The teachers perceived the suggested approach teacher guide incongruent to their usual practice but still perceived it as better than their usual approaches because the activities were easy to carry out. They perceived that the instructional materials caused them to make a shift in practice towards learner centred approach through active involvement of students. They also indicated that the suggested approach had a high demand on resources and cited the challenges of large class sizes, lack of resources, high work load and time limitations. They however were of the view that it was possible to carry out the proposed learner centred investigative practical work activities within the limitations of available resources in the Chemistry laboratories.

The learners indicated that they enjoyed the activities and were meaningfully engaged as they actively participated in the learning activities. They perceived the activities as effective in supporting their understanding of the content. The results from concept maps (average 80.6%) pointed to the fact that materials were effective in improving conceptualizations of content mater and developing basic observational skills.

Characteristics of instructional materials for investigative practical work

This study sought to isolate the characteristics of instructional materials that would provide teacher support for investigative practical work in secondary school Chemistry. After the final evaluation, the instructional materials were further refined to produce the final model of investigative practical work instructional materials that was appropriate for the learning situation. These materials were designed to support teachers in overcoming challenges they were facing in implementing secondary school Chemistry investigative practical work. The general structure of the investigative practical work instructional materials (teacher guide) achieved by several refinements of the original materials was as summarized on Table 5.1.

Table 5.1: General structure of the instructional materials

Section		Description
1.	**Background and lesson description**	• Provides a brief description of the activity and background information for the investigation. • May also provide the teacher with ideas on basic decisions required during preparation of the lesson.
2.	**Objectives**	• Outlines expected outcomes for the activity
3.	**Requirements**	• Outline materials such as apparatus and reagents required for the investigative activity. • May provide ideas on how to share the resources
4.	**Introduction**	• Guides the teacher on ways to introduce the lesson through discussion/activity • Suggests ways in which the teacher can gather information on the learners' prior knowledge.
5.	**Planning**	• Guides on how the teacher can facilitate formulation of procedures for investigation to learners working in groups.
6.	**Plenary Discussion**	• Discussion of procedures that the learners come up with. • Negotiation to a general procedure to develop learners' understanding of why they are doing a particular procedure.
7.	**Investigation**	• Guides on facilitation of the investigative practical work with learners working in small groups.
8.	**Discussion**	• Provides guidance on consolidation and discussion of experimental results from groups of learners.
9.	**Notes**	• The teacher is provided with notes on content that may be required for the learning of the concept.
10.	**Conclusion**	• Provides a description of how conclusion of the lesson can be done and suggestions for clean-up
11.	**Assignments**	• Suggestions for possible assignment and follow-up activities.

A practical work instructional scheme that would guide teachers in the planning and implementation of a lesson based on such practical work instructional materials was proposed. This scheme was referred to as **Secondary Chemistry Investigative Practical Work (SCIPW)** instructional model (figure 4.14). It outlines all the steps involved in guiding the teacher through the development and implementation of instructional materials that support Chemistry investigative practical work at secondary school level. The model of Secondary Chemistry Investigative Practical Work can be used design teaching strategies for any secondary level Chemistry classroom. The structure can be usefully applied for different chemistry topics or in any other science subject by the teachers.

5.3. Conclusions

Current methods of teaching practical work in Chemistry do not support learner centred practical work. Since the teachers had the concept of what would form best practices in engaging learners in practical work activities, they needed support for implementation of investigative practical work through appropriately designed curriculum materials. Teachers faced challenges in implementation of learner centred practical work. By engaging in design research, it was possible to get insights on how to develop instructional materials that address challenges facing teachers in the implementation of investigative practical work in secondary school Chemistry. This was done by isolating important areas of investigative activities and developing practical support guides.

The characteristics of a learner-centered classroom practice are that students be supported in: (i) planning and designing their activities, (ii) performing or implementing their plans and designs, (iii) carrying out analysis and interpretation of the results, and (iv) applying the knowledge they acquired as a result of taking part in investigative practical work (Lunetta, 1998). These formed the bases on which Chemistry investigative practical work instructional materials were developed and evaluated. The conclusion and the recommendations of the study are therefore based on ability of the materials to support teachers in achieving these areas.

In the investigative practical work orientation, the intention of the innovation was to use the instructional materials to guide teachers in organizing learning resources, preparing students for the concept of the study, guiding students during their practical work activities and assisting learners in constructing meanings of the results of the activity (Motswiri 2004). Teacher activities observed during the implementation of investigative practical work lessons were in line with the intended change in the teaching practice. Lesson planning an organizing for the requirements for the investigations was found to be well done by the teachers. During lesson introduction, the teachers were able to guide learners mainly through question and answer method to carry out predictions as well as hypothesizing. They also guided learners through brainstorming exercises, focus questions and helped learners think of safety implications of various exercises. During planning for the investigation, teachers were supported in assisting the learners plan and design their activities. Teachers made attempts to help students think about the plans they would use to carry out the investigation. This provided the lesson with the much desired characteristic of being ‘minds on’ as well as hands on.

The developed instructional materials, therefore, supported teachers in (a) Planning and organizing learning resources (b) Interrogating learner’s prior knowledge and relating content to it (c) planning and designing procedures for practical activities (d) performing or implementing learner activities (e) Pooling of the result and carrying out analysis and interpretation (f) applying the knowledge learnt.

The model for development of materials that support teachers in engaging learners in designing and carrying out investigations was developed. The use of SCIPW model by teachers and curriculum material developers would lead to development of materials that enhance students’ participation in practical work and hence improve the teaching of Chemistry.

5.4. Implications for practice

The findings have a major implication for teacher practice and teacher training. The effectiveness of learner-centred investigative activities is related to the teachers' ability to encourage interaction among students to talk about the plans and the data (Aksela, 2007). The use of the instructional materials to guide investigative practical activities is very engaging to the teacher because the teacher plays a key role in creating an environment appropriate for investigations. For the materials to be effective in class, it is basically necessary for the teachers to appreciate the use of the approach to teaching and its benefits. The more the teachers used the materials, the easier it became for them to carry out learner-centred investigations in class. The approach therefore required practice.

Practice on use of learner-centred investigative practical work should be integrated into both the in-service and pre-service teacher training. The SCIPW Instructional Model should be used to develop and implement materials during the training process. Practice on use of such a model would develop teachers' confidence in the use of investigative practical activities. It would enable teachers to understand the structure of the instructional materials which would consequently make it very easy to implement the lesson activities. The instructional materials provided here could be used as examples for the development of materials that would support learner-centred investigations. The characteristics of such materials are outlined (table 5.1) and SCIPW Instructional Model for their use described (section 4.5). For students to become good thinkers in Chemistry, teachers must be good thinkers themselves (Aksela, 2007). This implies that the teachers should develop investigative abilities and critical thinking in order to guide learners through conducting investigations. Use of investigative learner-centred investigative activities should be integrated into secondary school curricula so that teachers are able to appreciate and invest in the use of such materials.

5.5. Recommendations

5.5.1. Policy recommendations

Teachers who did not take time to read and understand the teacher guide well had difficulties in implementation. It is therefore recommended that teachers be exposed to instructional materials that support learner centred investigative practical work. This can be done in in-service teacher training programs such as SMASSE and during pre-service teacher training. To achieve the much desired learner centred learning and investigations as suggested by the syllabus and the KNEC reports, it is important to integrate training on the characteristics of learner centred lessons such as the use of Secondary Chemistry Investigative Practical Work (SCIPW) model. Embedding such materials in an in-service program would provide teachers with opportunities to interact with the materials which would address the problems associated with teachers' tendency to ignore reading the teacher guide.

Including use of student investigative practical work in pre-service program could assist teachers in developing the ability to design tasks that promote investigative abilities of learners and to construct their own materials based on the structure provided (Table 5.1.) It would also help teachers understand knowledge of students' thinking thus constructing meaningful learning in Chemistry. To promote this purpose, such in-service program would include assignments, discussions and use of such materials during micro-teaching as well as during the teaching practice.

As discussed earlier assessment is a major determining factor in teacher interests and their classroom practice. Chemistry teachers in Kenya mainly focus on preparing the learners to perform well in the national examinations. This explains the concern raised by some teachers on the ability to complete the Chemistry syllabus using the suggested approach. To enhance teachers' interest and use of learner centred investigative practical work, it is recommended that the assessment of practical work in Chemistry should be continuous and process based.

5.5.2. Recommendation for curriculum developers

One concern raised by teachers regarding use of investigative practical work was based on the wide Chemistry syllabus. They indicated that the method involved a lot of student activities and discovery methods that made teaching slower. They were therefore of the opinion that using the approach they would not be able to complete the KCSE Chemistry syllabus. It is, therefore, recommended that curriculum developers should consider revising Chemistry curriculum to provide enough time for investigative practical work.

5.5.3. Recommendation for developers of instructional materials

Developers of instructional materials should also use experimental structures that support investigations other than provision of step by step procedural guides observed in the commonly used instructional materials. this can be done using SCIPW model.

5.5.4. Recommendation for teachers

Chemistry teachers should develop and use learner centred strategies during chemistry practical lessons to ensure the learners are engaged in the design of plans and procedures for their practical work. The teachers can use the SCIPW model as a guide.

5.6. Suggestions for Further Research

This study was a design based research basically designed to create instructional materials that would support teachers in implementing investigative practical work. The findings are based on development and implementation of six lessons from the topic of acids and bases. The lessons were conducted by only five teachers. Larger and longer-term design research on other Chemistry topics with Chemistry teachers in Chemistry classrooms are needed to fully understand the effect of instructional materials in developing learner-centred investigative practical work in secondary school chemistry. This kind of study would also help understand the ease with which the teachers could adapt to the use of such instructional materials. Such studies can be carried out in other science subjects as well.

More experimental studies with control treatments could be carried out using the support of instructional materials developed in this study to determine their contribution to meaningful learning and performance of the learners in Chemistry.

There is need for development of assessment procedures appropriate for use of learner centred investigative practical work. Design based research could be used to develop alternative assessment practices for chemistry practical work.

More research study can be done on how the use of inquiry using this type of instructional materials and the SCIPW affects students' attitude towards the learning of Chemistry as well as their views on the nature of Chemistry. In addition, teachers need more knowledge of students' thinking and difficulties, in chemistry investigations and an understanding of the effects of different instructional strategies. This could provide many opportunities for research.

REFERENCES

Abrahams, I., & Millar, R. (2008). Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education*, 30(14), 1945-1969. doi: 10.1080/09500690701749305

Achimugu, L. (2009). *Strategies for Effective Conduct of Practical Chemistry Works in Senior Secondary Schools in Nigeria.* Ibadan. HEBN publishers' plc,

Aksela, M. (2005). *Supporting meaningful chemistry learning and higher-order thinking through computer-assisted inquiry: A Design Research Approach.* Thesis, University of Helsinki; Finland. Retrieved from http://ethesis.helsinki.fi,/julkaisut/mat/kemia

Ausubel, D. P. & Robinson, F. G. (1969). *School Learning: An introduction to educational psychology*. New York, NY: Holt, Rinehart and Winston, Inc.

Ball, D.L., & Cohen, D.K. (1996). Reform by the book: what is – or might be – the role of curriculum materials in teacher learning and instructional reform? *Educational Researcher, 25*(9), 6-8.

Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground, *The Journal of the Learning Science*, 13(1), 1–14. Retrieved from http://www.learnlab.org.b/2004_Barab_Squire.pdf.

Barraket, J. (2005). Teaching research method using a student centred approach? Critical reflections on practice. *Journal of University Teaching and Learning Practice*, 2(2), 64-74.

Baruque, L., Porto F., & Melo, R. (2003).Towards an instructional design methodology based on learning objects; *Paper presented at the International Conference on Computers and Advanced Technology in Education* (CATE 2003)

Bekele, A., & Melesse, K. (2010). Qualitative exploration on the application of student-centred learning in mathematics and natural sciences: the case of selected general secondary schools in Jimma, Ethiopia. *Ethiopia Journal of Education and Science,* 6(1), 1-20.

Blumberg, P. (2008). *Developing Learner-centered teaching: A practical guide for faculty*. San Francisco: Jossey-Bass.

Bodner, G. M. (1991). A View from Chemistry. In M. U. Smith (Ed.), *Toward A Unified Theory of Problem Solving: Views From the Content Domains* (pp. 21 – 34). Hillsdale, NJ: Lawrence Erlbaum Associates.

Branch, K., & Gustafson, K. (2002). *Design approaches and tools in education and training* (125-135). Nieveen, N. & Plomp, T. (Eds.), Dordrecht: Kluwer Academic Publishers.

Brooks, J.G., & Brooks, M.G., (1999). *In Search of Understanding: The Case for Constructivist Classrooms.* Association for supervision and curriculum development. Alexandria: Virginia. Retrieved from http://129.7.160.115/inst5931/constructivist.html

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Sciences,* 2(2): 141-178.

Brush, T., & Saye, J. (2000). Implementation and evaluation of a student-centred learning unit: A case study. *Education Technology, Research and Development*, *49*(1), 79-100.

Bybee, R. (2010). A new challenge for science education leaders: Developing 21st Century workforce skills. In *Science education leadership: Best practices for a new century,* ed. J. Rhoton, 33–49. Arlington, VA: NSTA Press.

Bybee, R., Rodger, W., Taylor, J.A, Gardner, A. Van Scotter, P., Carlson, J., Westbrook, A., & Landes, N. (2006). The BSCS 5E instructional model: Origins and effectiveness. *Colorado Springs, CO: BSCS*.

CDC-HKEAA, (2007). Science education key learning area; Chemistry Curriculum and Assessment Guide (Secondary 4 - 6). *The Hong Kong Chemistry Curriculum and Assessment Guide.* Curriculum Development Council and the Hong Kong Examinations and Assessment Authority.

CERG, (2007). *The current state of practical work in UK secondary schools- A CERG Pilot Research Project.* Chemical Education Research group. Bridget Price.

Cheung D., & Yip, D.Y. (2003). School-based Assessment of Chemistry Practical Work: Exploring Some Directions for Improvement. *Educational Journal,* 31(1).

Chiapetta, E.L. & Koballa, R.T. (2010). *Science institution in the middle and secondary schools. Developing fundamental knowledge and skills.* USA : Allyn and Bacon, Peason.

Christie, A. (2005). *Constructivism and its implications for educators.* Available at*:* http://alicechristie.com/edtech/learning/constructivism/index.htm

Clark, R.L., Clough, M. P., & Berg, C.A. (2000). Modifying cookbook labs to mentally engage students. *The Science Teacher, 67*(7)*,* 40-43.

Clarke, D. (1994). Ten key principles from research for the professional development of mathematics teachers. In D. B. Aichele & A. F. Coxford (Eds.), *NCTM Yearbook, Professional development for teachers of mathematics*. National Council of Teachers of Mathematics, Inc. Reston VA.

Cobb, P., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher,* 32(1), 9–13.

Cochran, W. (1977). *Sampling Techniques,* (3rd ed). New York: John Wiley & Sons.

Cohen, L., Manion, L.B., & Morison, K. (2000). *Research Methods in education*. London: Routledge.

Collins, A. (1992). Toward a design science of education. E. Lagemann, & L. Shulman (Eds.), *Issues in education research: Problems and possibilities (15-22).* San Francisco: Jossey-Bass.

Dass P.M. (2005). Using a Science/Technology/Society Approach to prepare reform-oriented science teachers: the case of a secondary science methods course. *Issues in Teacher Education,* 14(1).

Davis, E. A., & Krajcik, J. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher*, 34 (3), 3–14.

Davis, E. A., Arias, A. M., Bismack, A. S., Marulis, L. M., & Iwashyna, S. K. (2014). Designing Educative Curriculum Materials: A Theoretically and Empirically Driven Process. *Harvard Educational Review,* 84 (1), Spring.

DBRC. (2003). Design-Based Research Collective, Design-Based Research: An Emerging Paradigm for Educational Inquiry. *Educational Researcher*. 32. (1) 5–8.

Descombe, M. (2001). *The good research guide for small-scale social research projects.* Buckingham: Open University Press.

Dick, N., & Carey, L. (2005). *The Systematic Design of Instruction* (5th ed.). Harper Collins.

Dikmenli, M. (2009). Biology student teachers' ideas about purpose of laboratory work: *Asia-Pacific Forum on Science Learning and Teaching,* 10(2), 9. Retrieved from http://www.ied.edu.hk/apfslt/v10_issue2/dikmenli/dikmenli7.htm#seven.

Dillon, J. (2008). *A review of the research on practical work in school science.* London: King's College. Retrieved from http://www.scoreeducation.org/downloads/practical_work/review_of_research.

Domin, D.S. (2007). Students' perceptions of when conceptual development occurs during laboratory instruction. *Chemistry Education Research and Practice*, *8*(2), 140–152.

Dyasi, H.M. (2006).Visions of inquiry science; in Klentschy D.R., Worth M.P., & Binder, W. (eds) *Linking science and literacy in the K-8 classroom.* National Science Teachers Association. USA.

Eberlein, T., Kampmeier, J., Minderhout V., Moog, R. S., Platt T., Varma, P.N., & White H.B. (2008) Pedagogies of engagement in science, a comparison of PBL, POGIL, AND PLTL The International Union of Biochemistry and Molecular Biology. *Biochemistry and Molecular Biology Education* 36(4), 262–273.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *Journal of the Learning Sciences.* 11 (1), 105-122.

Efumbi, M.D. (2002). *An investigation into factors associated with low achievement of students in chemistry subject in Busia at Kenya Certificate of Secondary Education*. Unpublished master's thesis, Kenyatta University- Kenya.

Elliott, A.C., & Wayne, A.W. (2007). *Statistical Analysis Quick Reference Guidebook*: With SPSS Examples, SAGE Publications.

Elo S. & Kynga, S. H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing* 62(1), 107–115. doi: 10.1111/j.1365-2648.2007.04569.x

Felder, R. & Brent, R. (2009). Active learning: an introduction. *ASQ Higher Education*, 2(4), 1-5

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive developmental inquiry. *American Psychologist*, 34, 906 – 911.

Friedman, K. (2003). Theory construction in design research: criteria: approaches, and methods. Department of Organisation and Leadership, Norwegian School of Management, Norway. *Design Studies,* 6(24), 507–522. doi:10.1016/S0142-694X(03)00039-5; 2003 available at. https://design.osu.edu/carlson/id785/friedman.pdf

Fullan, M. (2001). *The new meaning of educational change (3rd Ed.).* New York: Teachers College Press.

Gagne, R. M. (1965). *The conditions of learning and theory of instruction.* New York: Holt, Rinehart & Winston.

Gallagher, J. (1999). Implementing needed reforms in science education: Research and development to enhance understanding and application. *Keynote address at a conference on 'Improving science teaching and learning through Research'* (January 10-14, 1999), National Taiwan Normal University, Taipei, Taiwan.

Gili, S.D. (2010). Science Education and Economic Development. Stanford University, USA. *Studies in Science Education, 35(1)1.* Retrieved from *http://www.informaworld.com*

Grossman, P., & Thompson, C. (2004): *Curriculum Materials: Scaffolds for New Teacher Learning. Center for the Study of Teaching and Policy:* A National Research Consortium. University of Washington.

Guba, E. G., & Lincoln, Y. S. (1981). *Effective evaluation: Improving the usefulness of evaluation results through responsive and naturalistic approaches*. San Francisco, CA: Jossey-Bass.)

Gunstone, R.F. (1996). International developments in improving the science and mathematics curriculum – understanding and supporting changes in the classroom. In C. Stoll, L. de Feiter, H. Vonk, & J. van den Akker (Eds.), *Improving science and mathematics teaching in southern Africa: Effectiveness of intervention. Proceedings of a regional conference in Windhoek, Namibia* (pp.60-68). Amsterdam: VU University Press.

Gustafon, K.L., & Branch, R.M. (2002). *Survey of instructional development models.* (4th ed.) Eric Clearinghouse on information and technology, Syracuse, N.Y. Retrieved from http://www.ericit.org/

Hall, R. H. (2014). *Constructivist Theory.* LITE Lab/ Digital Media. available at: http://web.mst.edu/~rhall/ed_psych/constructivism.html

Hattingh, A., & Rogan, P. (2007). Some factors influencing the quality of practical work in science classrooms. *African journal of research in science, mathematics and technology education*. 11, 75-90

Hidir, K. & Gultekin, M. (2007). The effect of constructivist learning principles based learning materials to students' attitudes, success and retention in social studies. Anadolu University Faculty of Education. *The Turkish Online Journal of Educational Technology*. 6 (3), 10. Retrieved from: hidirk@anadolu.edu.tr - mgulteki@anadolu.edu.tr

Hodson, D. (1992). In search of a meaningful relationship: an exploration of some issues relating to integration in science and science education. *International Journal of Science Education.* 14(5), 541—562.

Hofstein, A. & Lunetta, V.N. (2003). The laboratory in science education: foundations for the twenty-first century. *Science Education*, *88*(1), 28–54.

Hofstein, A. (2004). The laboratory in chemistry education: Thirty years of experience with developments, implementation and evaluation. *Chemistry Education Research and Practice*, 5(3), 247–264.

Hubber, R.A. & Moore, C.J. (2001). A model for extending hands –on science to be inquiry based. *School Science and Mathematics*. 101 (1); 32-41.

Huitt, W., Monetti, D., & Hummel, J. (2009). Designing direct instruction. Pre-publication version of chapter published in C. Reigeluth and A. Carr-Chellman, *Instructional-design theories and models: Volume III, Building a common knowledgebase* [73-97]. Mahwah, NJ: Lawrence Erlbaum Associates. Retrieved from http://www.edpsycinteractive.org/papers/designing-direct-instruction.pdf

Instructional Assessment Resources. *(2011). Assess teaching Response rates.* The University of Texas at Austinhttps://www.utexas.edu/academic/ctl/assessment/iar/teaching/gather/method/survey-Response.php

Inzahuli, S.M. (2007*). Factors Associated with Student's Performance in Physics and Chemistry in North Nandi District.* (Unpublished master's thesis). Baraton University, Kenya.

Isman, A. (2011). Instructional design in education: new model. *The Turkish Online Journal of Educational Technology*, 10 (1) 136-142

Januário, F.M. (2008). *Investigating and improving assessment practices in physics in secondary schools in Mozambique.* Ph.D. thesis. Assessment and quality assurance, University of Pretoria.

Johnstone¸ A.H., & Letton, K.M. (1991). Practical measures for practical work. *Education in Chemistry*. 28, 81-83.

Jonassen, D. H. (1999). *Operationalizing mental models: strategies for assessing mental models to support meaningful learning and design supportive learning environments.* Instructional Systems, Pennsylvania State University. Retrieved from http://www-cscl95.indiana.edu/cscl95/jonassen.html.

Kamau, D.M. (2004). *A study of the factors responsible for poor performance in chemistry among secondary school students in Maragua District.* (Unpublished master's thesis), Kenyatta University, Kenya.

Kang, N.H. & Wallace, C.S. (2005). Secondary science teachers' use of laboratory activities: Linking epistemological beliefs, goals, and practices. *Science Education*, *89*(1), 140–165.

Karaduman, H. & Gültekin, M. (2007). The effect of constructivist learning principles based learning materials to students' attitudes, success and retention in social studies. Anadolu University Faculty of Education. *The Turkish Online Journal of Educational Technology – TOJET* .6 .(3) 10.

Kawulich, B.B. (2004). *Data analysis techniques in qualitative research*, State University of West Geogia.

Keith M. L. (1992). *Science education in developing countries: issues and perspectives for planners*. Paris International Institute for Educational Planning (established by UNESCO)

Kennedy, D. (2011). Practical Work in Ireland: A Time of Reform and Debate University College Cork, Ireland. *Eurasia Journal of Mathematics, Science & Technology Education, 8(1), 21-34.* Retrieved from ejmste.com/v8n1/EURASIA_v8n1

Kesidou, S., & Roseman, J.E. (2002). How well do middle school science programs measure up? Findings from Project 2061's curriculum review. *Journal of Research in Science Teaching.* 39(6), 522-549. Retrieved from www.project2061.org/tools/textbook/mgsci/crit-used.htm

Kidman, G. (2012). Australia at the crossroads: A review of school science practical work Queensland University of Technology. *Eurasia Journal of Mathematics, Science & Technology Education*, 8(1), 35-47

KIE, (2006). *Secondary Education Syllabus*. Kenya Institute of Education. Nairobi: Kenya Literature Bureau.

Kiliç, M., & Çakmak, M. (2013). Concept maps as a tool for meaningful learning and teaching in chemistry education. *International Journal on New Trends in Education and Their Implications.* 4(4), 14. ISSN 1309-6249

Kim, M., & Chin, C., **(**2011). Pre-service teachers' views on practical work with inquiry orientation in textbook-oriented science classrooms . *International Journal of Environmental & Science Education*, 6 (1), 23-37.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). "Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching". *Educational Psychologist*. 41 (2), 75–86. doi:10.1207/s15326985ep4102_1.

Kisangi, A., & Ateng', O. (2006). *Enhancing teachers' capacity through in-service education and training: A Reflection on Projects for Strengthening Mathematics and Science Education*. Centre for Mathematics, Science and Technology Education in Africa.

Kliebard, H. (1992). Constructing a history of American curriculum. *Handbook of research on curriculum*. 157–184.

KNEC. (2008). *The year 2007 KCSE examination report*. Nairobi: Kenya National Examinations Council. Kenya.

KNEC. (2009). *Kenya Certificate of Secondary Education Results.* Nairobi: Kenya National Examinations Council.

KNEC. (2011). *The year 2010 KCSE examination report.* Nairobi: Kenya National Examinations Council, Kenya.

KNEC. (2012). *Syllabus and Regulations*. Kenya National Examination Council, Nairobi.

Krajcik, J.S., McNeill, K. L., & Reiser, B.J. (2007). Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education*, 92(1), 1-32. Retrieved from www.interscience.wiley.com.

Krajcik, J.S., Reiser, B. Moje, J E., & Marx, R. (2003). Design Strategies for Developing Science Instructional Materials. *Paper presented at the 2003 Annual Meeting of the National Association of Research in Science Teaching.* Philadelphia, PA. retrieved from: http://www.umich.edu/~hiceweb/iqwst/Papers/reiser_krajcik_NARST03.pdf

Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, *22*(140), 1-55.

Lunetta, V. N. (1998). The school science laboratory: Historical perspectives and centres for contemporary teaching. In P. Fensham (Ed.), *Developments and dilemmas in science education* (169–188). London: Falmer Press.

Lunetta, V. N., Hofstein, A., & Clough, M. P. (2007). Learning and teaching in the school science laboratory: An analysis of research, theory, and practice. In S.K. Abell & N. G. Lederman (Eds.), *A handbook of research on science education* (395–441). Lawrence Erlbaum, New Jersey.

Maor, D. (2000). A teacher professional development program on using a constructivist multimedia learning environment. *Learning Environments Research*, 2, 307–330.

McCombs. B., & Whisler. J.S. (1997). *The learner-centered classroom and school: Strategies for increasing student motivation and achievement.* San Francisco: Jossey- Bass

McKenney, S. & Reeves, T. (2013). Understanding the design research process: The evolution of computer-based support for curriculum development in southern Africa. *Paper presented at the annual meeting of the American Educational Research Association.* April 27-May 1, San Francisco.

Meadows, L., & Morse, J. M. (2001). Constructing evidence within the qualitative project. In J. M. Morse, J. Swanson & A. Kuzel, (Eds.). *The Nature of Evidence in Qualitative Inquiry.* (187 – 202), Thousand oaks, CA: Sage.

Mfumiko, F. (2006). *Micro-scale experimentation as a catalyst for improving the chemistry curriculum in Tanzania.* Doctoral dissertation, Eschede (NL) university of Twente. Available from: http://purl.org/utwente/55448

Millar, R. (2004). The role of practical work in the teaching and learning science. *Paper presented at meeting: High school science laboratories: Role and vision.* National Academy of Sciences. Washington, DC. Available at: www7. nationalacademies.org/bose/Millar_draftpaper_Jun_04.pdf

Millar, R. (2009). Analysing practical activities to assess and improve effectiveness: *The Practical Activity Analysis Inventory (PAAI). York:* Centre for Innovation and Research in Science Education, University of York. Retrieved from http://www.york.ac.uk/depts/educ/research/ResearchPaperSeries/index.htm

Millar, R. (2010). Practical work. In J. Osborne & J. Dillon (Eds.), *Good practice in science teaching: What research has to say* (2nd ed.). Maidenhead: Open University Press.

Millar, R., Tiberghien, A. & Le Maréchal, J.F. (2002). Varieties of labwork: A way of profiling labwork tasks. In D. Psillos & H. Niedderer (Eds.), *Teaching and Learning in the Science Laboratory* (9 – 20). Dordrecht: Kluwer.

MOE. (2012). *Task force on the re-alignment of the education sector to the constitution of Kenya 2010: Towards a globally competitive quality education for sustainable development. Kenya:* Ministry of Education, Kenya. Retrieved from http://www.vision2030.go.ke/cms/vds/Task_Force_Final_Report_Feb_20123.pdf

MOE. (2014). *Approved list of textbooks and other instructional materials for secondary schools.* Revised 13th ed. volume II ; Republic of Kenya Orange Book for Secondary Schools 2014.

Moeed, A. (2013). Science investigation that best supports student learning: Teachers understanding of science investigation. *International Journal of Environmental and Science Education.* 8, 537-559. doi: 10.12973/ijese.2013.218a

Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International Journal of Qualitative Methods 1 (2)*, Retrieved 5/7/2014 from http://www.ualberta.ca/~ijqm/

Motswiri, M. J. (2004). *Supporting chemistry teachers in implementing formative assessment of investigative practical work in Botswana.* Thesis. University of Twente, Enschede. Retrieved from http://doc.utwente.nl/4824/1thesis-motswiri.pdf

National Academy of Sciences (1998). *Teaching about evolution and the nature of science: Criteria for Contemporary Science Curriculum.* National Academy Press. Washington, DC. Available at www.nap.edu/readingroom/books/evolution98.

National Academy of Sciences, (1997). *Science for all children: a guide to improving elementary science education in your school district*. Washington, DC: The National Academies Press. Retrieved from: http://www.nap.edu/openbook.php?record_id=4964&page=1

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2004). *How people learn: Bridging research and practice*. Washington, DC: National Academy Press.

National Science Resources Center. (1997).“Criteria for Selecting Inquiry-Centered Science Curriculum Materials” (chapter 5). In *Science for All Children: A Guide to Improving Elementary Science Education in Your School District* (63-75). National Science Education Standards (NSES), Washington, DC: National Academy Press.

National Science Teachers’ Association. (1990). The NSTA position statement on science technology-society (STS). *In NSTA Handbook* (47-48). Arlington, VA: Author.

Nieveen, N. (1999). Prototyping to reach product quality. In J. van den Akker, R.M. Branch, K. Gustafson, N. Nieveen, & Plomp, T. (eds), *Design approaches and tools in education and training* (pp. 125-135). Dordrecht: Kluwer Academic Publishers.

Novak, J.D., & Gowin, D.B. (1983). *Learning how to learn*. Cambridge, Cambridge University Press.

Novak, J.D., & Wandersee, J.D. (eds) (1990). Perspectives on concept mapping. Journal of Research in Science Teaching, 20 (10); Special Issue.

Nuffield Chemistry, (1966). *The sample scheme stages I and II: the basic course.* Britain*:* Nuffield Foundation, Longmans.

Nyang'ai, D.A. (2010). *Investigation into factors influencing poor performance in secondary school chemistry in Kenya.* Unpublished M.Ed thesis. Kenya: Kenyatta University, Nairobi.

O'Donnell, A. M. (2004). A commentary on design research. *Educational Psychologist*, 39(4), 255-260.

O'Donnell, C. (2007). *Research on exemplary, effective, and equitable curriculum materials: New York ECLIPSE Enhancing Collaborative Leadership for Improved Performance in Science Education. Science Education Curriculum Showcase.* Washington, DC. Availble at http://www.p12.nysed.gov/ciai/mst/sci/nyeclipse/NYResearchStudiesODonnell032107.pdf.

Omosewo, E.O (2006). Laboratory teaching method in science-based disciplines *African Journal of Educational Studies* (AJES) 4(2) 65-73. A journal published by the Faculty of Education, University Botswana, Gabrone, Botswana.

Orado, G. (2009): Factors influencing performance in chemistry practical work among secondary schools in Nairobi Province. Unpublished M.Ed. Thesis, Kenyatta University, Kenya.

Osborne, J. (1993). Alternatives to practical work. *School Science Review,* 75 (271), 117-123.

Ottander, C., & Grelsson, G. (2006). Laboratory work: the teachers' perspective. *Journal of Biological Education*, *40*(3), 113–118.

Ottevanger, W. (2001). *Teacher support materials as a catalyst for Science Curriculum Implementation in Namibia.* Doctoral Dissertation, Enschede, Netherlands: University of Twente.

Ottevanger, W. (2013). Using design research to develop teacher support materials in order to facilitate the successful implementation of a new science curriculum in post-apartheid Namibia. In T. Plomp, & N. Nieveen (Eds.), *Educational design research – Part B: Illustrative cases* (pp. 381-405). Enschede, the Netherlands: SLO.

Pacific Policy Research Center. (2010). 21st Century skills for students and teachers. Honolulu: Kamehameha Schools, Research & Evaluation Division.

Piaget, J. (1956). *The Psychology of Intelligence*. Boston: Routledge and Kegan.

Plomp, T., & Nieveen, N. (Eds.). (2007). *An introduction to educational design research*. Enschede, the Netherlands: SLO.

Pogrow, S. (1993). Where's the beef? Looking for exemplary materials. The changing curriculum. *Association for Supervision and Curriculum Development* 50(8), 39-45.

Reiser, B. J., Krajcik, J., Moje E., & Marx, R. (2003). Design strategies for developing science instructional materials. *Paper presented at the 2003 Annual Meeting of the National Association of Research in Science Teaching*, Philadelphia, PA available at: http://www.umich.edu/~hiceweb/iqwst/Papers/reiser_krajcik_NARST03.pdf.

Rubdy, R. (2003). Selection of materials. In B. Tomlinson (Ed.), *Developing materials for language teaching.* (pp. 37-57). London: Continuum.

Sadler, D.R. (1989). Formative assessment and the design of instructional systems. *Instructional Science,* 18, 119-144.

Schneider, R.M., & Krajcik, J. (2002). Supporting science teacher learning: The role of educative curriculum materials. *Journal of Science Teacher Education*, 13(3), 221-245.

SCORE, (2009).*Getting practical: a framework for practical science in schools.* London: DCSF. Available at: www.scoreeducation.org/downloads/practical_work/framework.pdf

SCORE. (2007). *Practical work in science: a report and proposal for a strategic framework.* London: The Science Community Representing Education, (SCORE). Retrieved from *http://www.score-education.org/media/3668/report.currentissues.*

Singer, M., & Tuomi, J. (Eds) (2004). Selecting instructional materials: A guide for K-12 science. *Committee on Developing the Capacity to Select Effective Instructional Materials,* National Research Council. Retrieved from: http://www.nap.edu/openbook/0309092426/html/index.html

Slavin, R. E. (1988). *Educational psychology: Theory into practice.* Englewood Cliffs: Prentice Hall.

Smith, P.L., & Ragan, T.J. (1999). *Instructional design*. New York: John Wiley & Sons.

Snyder, W., & Fuller, B. (1990). Interventions within the context of teacher work life. In W. Snyder, & P.T. Ramatsui (Eds.), *Curriculum in the classroom* (pp. 159-173). Gaborone: Macmillan.

Stoffelsma, N. & Kwetu, (2004). *Curriculum support materials as tools for active learning in teacher development in Ghana; progress and evidence of its quality*. Ghana

Sunal, S.C., & Haas, M. E. (2002). Social Studies for the Elementary and Middle Grades. A Constructivist Approach. *Theory of Problem Solving: Views From the Content Domains* (21 – 34). Boston: Allyn and Bacon.

Sunzuma, G., Ndemo, Z., Zinyeka, G., & Zezekwa, N. (2012). The challenges of implementing student-centered instruction in the teaching and learning of secondary school mathematics in a selected district in Zimbabwe. *International Journal of Current Research,* 4, (05), 145-155. Retrieved from http://www.journalcra.com

Tecle, A.T. (2006). *The potential of a professional development scenario for supporting biology teachers in Eritrea.* Doctoral dissertation Eschede *(NL),* University of Twente. Available from: http://purl.org/utwente/55985

The National Science Foundation, (2013). *Professional Development that supports school mathematics reform; A monograph for professionals in science, mathematics, and technology education,* USA. http://www.nsf.gov/pubs/2002/nsf02084/chap1_4.htm

Thijs, A. (1999). *Supporting science curriculum reform in Botswana: The potential of peer coaching.* Doctoral dissertation. Enschede: University of Twente.

Thiong'o, M. (1986). *Study of quality of facilities that exist for teaching O-level chemistry in some selected schools.* Unpublished Med. Thesis, Nairobi: Kenyatta University.

Thomas, D. R. (2003). *A general inductive approach for qualitative data analysis*. School of Population Health, University of Auckland.

Tobin, K., Kahle, J.B., & Fraser, B.J. (eds). (1990). *Windows into science classroom: Problems associated with higher-level learning*. London: Falmer Press.

Todd D. L. (ed). (2013). *The Oxford Handbook of Quantitative Methods in Psychology* volume 1. Foundations Oxford University Press

Tripp, S., & Bichelmeyer, B. (1990). Rapid prototyping: an alternative in instructional design strategy. *Educational Technology research and Development*, 38(1),31-44. (ERIC document Reproduction service no. EJ412 118)

Trochim, W.M. (2006). *The research methods knowledge base, 2nd Edition*. Internet www page, at URL: <http://www.socialresearchmethods.net/kb/>

Trowbridge, J. E., & Wandersee, J. H. (1998). Theory-driven graphic organizers. In J. J. Mintz, J. H. Wandersee & J. D. Novak (Eds.), *Teaching science for understanding.* New York: Academic Press.

Trowbridge, L.W., Bybee, R.W. & Janel, C.P. (2004). *Teaching secondary school science, "Strategies for developing scientific literacy"* New Jersey: Pearson, Ohio.

Twoli, N.W. (2006). *Teaching secondary school chemistry*. Nairobi: Neema Publishers, Kenya.

Van den Akker, J. (1988). The teacher as learner in curriculum implementation. *Journal of Curriculum Studies*, 20(1), 47-55.

Van den Akker, J. (1998). The science curriculum: Between ideals and outcomes. In B. Fraser, & K. Tobin (Eds.), *International handbook of science education* (pp. 421-447). Dordrecht: Kluwer Academic Publishers.

Van den Akker, J. (1999). Principles and methods of development research. In J. van den Akker, R. Branch, K. Gustafson, N.M. Nieveen, & T. Plomp (Eds.), *Design approaches and tools in education and training* (pp. 1-13). Dordrecht: Kluwer Academic Publishers.

Van den Akker, J., & Plomp, T. (1993): Development research in curriculum: Propositions and experiences. *Paper presented at AERA Annual Meeting*,12-16, Atlanta.

Van den Akker, J., & Voogt, J. (1994): The Use of Innovation and Practice Profiles in the Evaluation of Curriculum Implementation . Faculty of Educational Science and Technology, University of Twente. *The*

Netherlands Studies in Educational Evaluation. 20 503-512. Retrieved from http://doc.utwente.nl/57387/1/Akker_94

Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes*: Harvard University Press.

Wachanga, S.W., & Mwangi, J. G. (2004). Effects of Cooperative Class Experiment Teaching Method on Secondary School Students' Chemistry Achievement in Kenya's Nakuru District. *International Educational Journal*, 5(1), 26-36.

Wang, F., & Hannafin, M. J. (2005). Design-based research and technology: Enhanced learning environments. *Educational Technology Research and Development, 53*(4), 5-23.

White, R.T., & Gunstone, R.F. (1992). *Probing understanding*. London, UK: Falmer Press.

Woolnough, B.E., & Allsop, T. (1985). *Practical Work in Science*. Cambridge: Cambridge University Press.

Wosyanju, C. (2008). *The system of education in Kenya.* Retrieved from http://international.iupui.edu/kenya/resources/Education-in-Kenya.pdf

Yager, R.E. (1991). The constructivist learning model. *The Science Teacher*, 58(6) 52-57

Yandila, C.D., Komane, S.S., & Moganane, S.V. (2003). *Towards learner-centred approach in senior secondary school science lessons.* Department of Mathematics and Science Education; University of Botswana.

APPENDICES

APPENDIX I: TEACHERS' QUESTIONNAIRE

This questionnaire is part of a study project designed to find out Chemistry practical work teaching practices and how they can be improved to make learning of chemistry more learner-centred. You have been chosen to assist in finding out more about current practices in practical classrooms and if need be how we can improve them. The information you will give in this questionnaire will only be valuable for research and will therefore be held confidential by the researcher. Please answer the questions honestly.

SECTION 1: <u>Background information</u>

1. Type of school (tick one)

Boys [ ] Girls [ ] Mixed [ ]

2. Gender (tick whether you are a male or a female)

Male [ ] Female [ ]

3. Academic/ Professional qualification

M.Ed [ ] B.Ed [ ] B.Sc [ ]

S1 [ ] PGDE [ ] U.T [ ]

4. Teaching experience: How many years have you been teaching Chemistry

[__________________________] years

SECTION 2: <u>Practical Activities Used By Chemistry Teachers</u> *(tick where appropriate)*

1. What type of practical activities do you use in your Chemistry classroom?

Demonstration[ ] Class experiments/ group activities [ ]

Project [ ] Individual student activities [ ]

Other (specify) ____

2. Which one of the above activities do you most prefer using in your classrooms?

....

3. Why do you prefer the method indicated in 2 above

……………………………………………………………………………..

4. How often do you use each of the above methods of practical work?(tick appropriately)

Method	**Never**	**Once a term**	**Once a week**	**Twice a week**	**Thrice a week**	**More often**
Class experiments/ group activities						
Teacher Demonstration						
Project						
Individual student activities						
Other (specify)						

5. Why do you use practical work in teaching chemistry? <u>Tick all that apply</u>

a. [ ] to make learners understand a concept more readily.

b. [ ] to keep learners engaged/busy.

c. [ ] to verify facts/ theories or principles discussed in class.

d. [ ] to arouse interest in learners and motivate them.

e. [ ] To make them relate chemistry with life outside the classroom.

f. [ ] Because it is a requirement by the school/ department/ ministry

g. [ ] Because the learners demand for practical sessions.

h. Other (specify)____

6. **How do you encourage learners' involvement in practical work?** Indicate by use of a tick your level of agreement with the statements.

I INVOLVE LEARNERS IN PRACTICAL WORK BY:	Strongly Agree	Agree	Not sure	Disagree	Strongly disagree
Placing them in groups					
Providing them with detailed procedures to follow.					
Designing experiments that relate to their life's experiences.					
Allowing them to design their practical experimental procedures.					
Stimulating them to reflect on their prior knowledge.					

7. **How often, during Chemistry practical lesson do you and the learners do the following activities?** (Tick where applicable);

Activity	**Never**	**Some times**	**Most times**	**Always**
They work in groups				
I direct them on what to do (give procedures)				
I let them design their own experimental procedures				
I guide them to develop and carry out their own procedures				
I allow them to carry out procedures that may be of interest to them.				
I allow the learners develop procedures on the questions they raise				
They make peer review; giving their points of view about the results of experiment				

SECTION 3: **<u>Instructional Materials</u>**

1. Which instructional materials do you use in conducting form one Chemistry practical lessons in **the topic on acids and bases**? Please indicate by a tick how often you use each type of material.

Material	Always	Very Often	Often	Rarely	Never
KLB Secondary Chemistry Book 1					
(Muchiri and Maina) Principles of Chemistry Bk 1					
Longhorn Chemistry Bk 1					
Comprehensive Chemistry Bk 1					
N.M. Patel Secondary chemistry Bk 1					
Chemistry bk 1 teacher guide (specify for which books)					
Others (specify)					

2. Please indicate by use of a tick your level of agreement with the statements below in regard to **the quality of the materials/books you use in supporting investigative practical work** by providing the following: KEY***: (SA) =Strongly Agree; (A)=Agree; (N)=Neutral; (D)= Disagree (SD)=Strongly disagree***

	The books used to teach practical work in Chemistry:	***SA***	***A***	***N***	***D***	***SD***
a	They provide clear objectives of the practical activity					
b	The practical activities are related to learners' needs/ interests					
c	Practical activities are based on learners real life settings to make them relate chemistry with life outside the classroom					
d	They provide the intended outcomes of the practical					

e	They give some background knowledge related to the practical activity					
f	They provide detailed step by step experimental procedures					
g	They give a list of apparatus required for practical					
h	They provide grouping suggestions					
i	Safety precautions are clearly indicated					
j	They give opportunity for predictive guiding question					
k	They give learners opportunity to develop their own practical procedures					
l	They guide the teacher on probable questions from learners					
m	They guide learners on writing a report					
n	They have sufficient Assessment options					
o	Allowance to look for alternatives to procedures given					
p	Encourage thoughtful reflection on experience					

3. What do you think could be improved or included in these materials to make them better able to facilitate/support the teacher in organising practical work?

___

___

APPENDIX II: DOCUMENT ANALYSIS SCHEDULE

1. **Chemistry learning aspects emphasized by practical work in curriculum materials**

		Observed/not observed in				
	Aspect /domain of chemistry learning emphasized	**KLB**	**LHC**	**PC**	**CC**	**PSC**
1	Knowledge of facts					
2	Understanding					
3	Hypothesizing /predicting					
4	Application of scientific facts					
5	Creativity and imagination					
6	Analysis, Synthesis and Evaluation					
7	Observational skills					
8	Manipulative skills					
9	Data recording					
10	Data interpretation					

Code Key

KLB- *Secondary Chemistry Book 1 by Kenya Literature Bureau*

PC-*Principles of Chemistry Book 1 by Muchiri and Maina.*

LHC-*Longhorn Secondary Chemistry Form 1 by Ngaruiya, G., Kimaru, J. & Mburu, P.*

CC- *Comprehensive Chemistry Book 1*

PSC -*Secondary Chemistry; Form 1 by Patel, N.M.*

2. Opportunities for investigation on acids and bases in the Chemistry books

Opportunities for carrying out		Instructional material/book				
		KLB	LHC	PSC	CC	PC
a	Clear objective of the practical activity					
b	Background information related to the practical activity					
c	List of apparatus required					
d	Grouping suggestions					
e	Safety precautions					
f	Provide a guiding question					
g	Gives step-by-step practical procedures					
h	Reference to prior knowledge					
i	Teacher guide on probable questions from learners					
j	Guide on pooling results and support arguments					
k	Providing a relevant phenomena					
l	Opportunity to develop procedures or look for alternatives to given procedures					
m	Assessment opportunities					

APPENDIX III: LESSON OBSERVATION SCHEDULE

Date ____

Name of school (optional) ____________________Code __________

Topic
____

Name of teacher _______________qualification ________________

Lesson number ____

Number of students__________Boys ________ Girls ____________

The following statements indicate actions that the teacher is expected to show in the course of a learner- centred practical lesson. Use a (√) if action is observed and (x) if action is not observed.

Lesson Introduction

	ACTION	**Observed** (√) **Not observed** (x)	**Comments**
1.	Discusses background of the problem		
2.	Discusses objectives of the lesson		
3.	Helps learners clarify the question to be answered by the activity		
4.	Informs learners how participation will be carried out.		
5.	Stimulates learners to reflect on their prior knowledge		
6.	Distributes problem sheets and/or Lists apparatus		
7.	Discusses stages of investigation i.e. informs learners about the timing of the various activities in the investigation (e.g., planning, post planning discussion, experimenting, and report writing)		

Lesson Development

ACTION		Observed (√) Not observed (x)	Comments
1.	Uses small groups of 2-4		
2.	Encourages students' approach (Teacher allows learners 'room to choose' their own approach)		
3.	Guides by questions & answers not 'telling'		
4.	Encourages group collaboration		
5.	Monitors experimental set-ups : goes round groups checking as they work.		
6.	Ensures collection of apparatus is orderly		
7.	Guides learners to generate procedures		
8.	Asks students (groups) to specify assumptions		
9.	Attunes instruction to learner's ideas.		
10.	Encourages self-time management and stops learners at appropriate times to review various lesson activities.		
11.	Encourages active involvement of learners in the activities by demonstrating and supporting thinking processes in learners.		
12.	Facilitates peer plan review (provide alternatives or advice with reasons why we think the plan is not workable or safe)		
13.	Encourages students to ask questions seeking clarification on their work.		
14.	Teacher makes sure learners use materials/ equipment correctly to execute the activity		
15.	Teacher allows learners to draw own conclusions and pool results together		
16.	Encourages and guides students to discuss possible experimental discrepancies in the results by asking the students to reflect on the activities		

Lesson Conclusion

ACTION		**Observed** (√) **Not observed** (x)	**Comments**
1.	Teacher gives feedback summarising by highlighting major points of the investigation		
2	Teacher guides students to make conclusions based on data collected from the experiments they carried out.		
3	Asks for students' opinion when responding to class questions.		
4	Reminds students to draw conclusions that relate to their specified assumptions made earlier.		
5	Ensures clear up before next lesson is done in an orderly manner		
6	Gives students homework/ Assignment		

APPENDIX IV: MATERIALS APPRAISAL GUIDE

These materials are prepared for use in Chemistry practical work with an aim of improving learner-centred practical activities. Please go through each lesson guide and in comparison with the common practice (**from textbooks and laboratory manual worksheets**) where procedures are clearly spelt out and strictly followed, help us gather information that may be useful in improving the materials for use in chemistry form one classrooms.

1. Does the material reflect the expectations of the Chemistry KCSE syllabus?
   ……………………………………………………………………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………
2. For what purpose(s) can you use the teacher guide given during lesson preparation.
   ……………………………………………………………………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………
3. How does the information provided in the teacher guide help you understand what is expected of you in the lesson.
   ……………………………………………………………………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………
4. What is your opinion about time allocated for each activity? Point out specific areas whre timing should be adjusted.
   ……………………………………………………………………………………
   ……………………………………………………………………………………
   ……………………………………………………………………………………
5. How best can you describe the role of the following during the lesson;

Teacher……………………………………………………………………………
…………………………………………………………………………………….

Learner……………………………………………………………………………
…………………………………………………………………………………….

6. Do you think the teacher's role is clear? Explain.
………………………………………………………………………………
………………………………………………………………………………

7. What is your opinion on practicality of the material in chemistry classroom? Can it be used?
………………………………………………………………………………
………………………………………………………………………………

8. Do you think students will like the approach? Why?
………………………………………………………………………………
………………………………………………………………………………

9. To what extent is the material useful in supporting preparation and implementation of learner- centred practical work?
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

10. Which areas need improvement? Give suggestions on how can they be improved eg What specific things would you like to see in these materials yet they are missing?
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………
………………………………………………………………………………

11. What would be the benefits and challenges (or problems) of implementing the activities in your normal classes?

Benefits…………………………………………………………………………
………………………………………………………………………………

Challenges………………………………………………………………………
………………………………………………………………………………

12. Give additional comments and/or suggestions
………………………………………………………………………………
………………………………………………………………………………

APPENDIX V: TEACHERS' LOGBOOK

Lesson No.: ____________ Date: ____________________

Lesson topic: ____

Number of pupils in class: **Boys __________ Girls ________**

Experiences with the exemplary materials:

1. During Lesson preparation

a. Does the instructional material provided reflect the objectives required by KCSE syllabus____

b. For what purpose(s) did you use the teacher guide (TG) during lesson preparation.

____

Does the material help the teacher reduce the time used in lesson preparation and planning? Explain how it assists.

____

c. Was the information provided in the teacher guide enough to help you understand what was expected of you in the lesson? YES [ ] NO[ ]

Explain:____

d. What challenges if any did you encounter during the preparations?

____

g. Which areas need improvement? Give suggestions on how can they be improved.

____

2. During the lesson.

a. How best can you describe your role during the lesson

b. Were all the students involved in the activity?

Yes [ ] No [ ]

If NO explain why

____

c. What problems/challenges if any did you encounter during the lesson?

____

____

d. Suggest ways in which these challenges can be overcome.

e. ____

f. In what ways could the teacher guide help you in running students activities in your classes?

____

f. In your opinion was the objective of the lesson achieved?

Yes [ ] **No [ ]**

If No, state the particular aspects that were not achieved and explain why.

g. **Comment on the structure and clarity of the materials**.

Where the instructions in the teacher guide clear and easy to follow?

h. Was Teacher guide was clear about what was expected of you in the learner centred teaching approach? Explain.

3. General ideas

a. How does this material constructively relate to the learners prior knowledge or day to day activities that they identify with?

What is your opinion on use of these lesson materials in supporting student investigations?

b. Which parts needed improvements and why?

d. What would be the benefits and challenges of implementing the activities in this lesson series in your normal classes?

Benefits____

Challenges

e. What is your opinion on the sustainability of the suggested teaching approach considering the materials available in your laboratory? Explain your response.

c. How would you compare the strategies in these materials with the ones you have been using from the convectional materials?

Additional comments or suggestions for improvement

Give any additional comments you would like to make in relation to making the teacher guide more helpful to your class practice?

APPENDIX VI: INTERVIEW GUIDE FOR TEACHERS

You have participated in Chemistry lessons on acids and bases using materials that were intended to support you in guiding learner-centred practical learning. I would like to know your opinion about teaching of Chemistry practical work using the instructional materials provided and your experiences. The information you will give will help in refining the materials to come up with better materials for teaching Chemistry practical work. All the information gathered from the interview is confidential and your identity will not be disclosed. Please be as honest as possible and feel free to answer the questions.

General Information

Date ____________________________School code _______________________

Teacher __________________Teaching Experience ____________________years

1. What is your opinion on use of these lesson materials in supporting student investigations?

2. What would be the benefits and challenges of implementing the activities in this lesson series in your normal classes?

3. In what ways could the teacher guide help you in running students activities in your classes?

4. Give any additional comments you would like to make in relation to making the teacher guide more helpful to your class practice?

5. What did you find challenging in preparing and implementing the lessons?

6. Was the teacher guide format easy to follow and how practical was the use of the teacher in preparing and conducting the practical lesson?

7. Did the exemplary materials offer clear information about what was required of the practical lesson?
8. Do you feel the Teacher guide was clear about what was expected of you in the innovation? Explain.
9. Did you consider the materials as consistent with other curriculum materials and the science curriculum at KCSE level?
10. Were the practices suggested in the Teacher Guide in line with what you expect in your practice for implementing learner-centred teaching approach?
11. How would you compare the teaching approach you have been using before with the approach suggested by the materials?
12. What is your opinion on the sustainability of the suggested teaching approach considering the materials available in your laboratory? Explain your response.
13. Do you consider the time you have for teaching the syllabus enough to implement the suggested practice? Explain your response.
14. How do you experience the benefits of the curriculum materials considering the efforts you made; was it worth the trouble you took?
15. How would you compare the strategies in these materials with the ones you have been using from the convectional materials?
16. What general statement can you make about the lesson series?

APPENDIX VII: STUDENTS' QUESTIONNAIRE

Gender (tick whether you are a male or a female) Male [ ] Female [ ]

This questionnaire seeks to get your opinion regarding the six lessons you carried out in this study. Please give your honest opinion about the lessons. Your answers will be held confidential and used for the purpose of the study only. Do not indicate your name on this paper. There are five choices for each statement given ranging from strongly agree **(SA)** Agree **(A)** not sure **(N),** Disagree **(D)** to strongly disagree (SD). Tick in the box where you think it is appropriate.

	Statement	SA	A	N	D	SD
a	I enjoyed the practical activities we carried out					
b	I was able to participate actively during the lessons					
c	All my group members actively participated during the lessons					
d	The was teacher supporting our discussions instead of telling us what to do					
e	The lessons were interesting					
f	I enjoyed developing the procedures for the practical					
g	Setting procedures for practical work is difficult					
h	Developing procedures made me think what I was doing					
i	Developing procedures and using them made me understand about acids and basis					
j	This method of learning was motivating					
k	The lessons were clear on what we were required to do.					
l	I was always longing for the next lesson to see what the teacher would bring.					
m	The experiments were easy to carry out					
n	There should be more investigations in chemistry instruction					
o	Doing practical work by setting our own procedures makes practical work easier and more satisfying.					

Explain any problems you might have faced in carrying out the investigations

APPENDIX VIII: SAMPLE INSTRUCTIONAL MATERIALS USED IN THE STUDY

LESSON ONE

TEACHER GUIDE

Time: 40 Minutes

Topic: ACIDS, BASES AND INDICATORS

Experiment: Determining Whether a Solution is Acidic, Basic or Neutral

Background and General description of the lesson

This is a laboratory based activity in which the learners will be introduced to acids, bases and indicators. This involves a laboratory investigation. This lesson gives the learner 'hands on' experience testing common home chemicals to determine whether they are acidic, basic or neutral. In teacher led discussions, the students identify the questions that should be answered. For example which substances should be classified as acids or bases using litmus indicator. In the practical activity the learners compare the colours of litmus indicator in the solutions they are provided with and then share their findings with their colleagues in class. They then write a report on the activities carried out and the findings.

Note: This part is the teacher's guide and therefore the teacher should read through it carefully and use the ideas described to guide learning in the classroom.

Objective

By the end of the lesson the learner should be able to determine whether common household substances provided are acids, bases or neutral by use of litmus indicator.

Materials required- *Each group requires:*

- A set of six clean test tubes or small transparent glass/plastic containers. *
- 8 strips of red and 8 strips of blue litmus paper.
- Samples of the following common solutions in small beakers or tumblers; Dilute hydrochloric acid, lemon juice, distilled water, baking soda, vinegar, wood ash, common salt (sodium chloride) solution, toothpaste solution
- Piece of paper

*if test tubes are not available, the solutions can be tested directly from the containers holding them because litmus indicator used is in form of paper.

Prior to the start of the lesson, decide how you would like to handle the distribution of the materials for investigation. Some teachers prefer to place the materials on the demonstration table f or learners to pick at a time they are directed to do so while others place them on working benches as per groups constructed.

INTRODUCTION: 5 minutes

Begin the lesson by asking them to note down on a piece of paper, the substances they use at home in two groups; acids and bases. They can draw a line in the middle of the paper and write acids on the left hand side and bases on the right side. Some learners may be reluctant since they do not know the basis on which the classification is performed. It is important to inform them that it should just be a guess. (*This exercise is meant to trigger their thinking about the solutions they commonly use at home. It may also enable the teacher to know the misconceptions held in the learners' mind).*

Gather their feedback by reading some of the responses. Find out why they think some substances are acids or basis. E.g. If a learner says lemon is acidic, then ask him why he/she reasons so. **You are likely to find a number of contradicting**

opinions. (*Some common contradictions include*; *common salt solution, sugar solution, ethanol, kerosene, methylated spirit which are commonly mistaken to be is acidic and yet they are neutral. Baking soda is also mistaken to be acidic while it is basic).* Some may correctly guess that lemon juice, orange juice, citric acid, sour milk and battery acid are acidic. [**DO NOT PROVIDE THE ANSWERS TO WHICH SOLUTIONS ARE ACIDS OR BASES AT THIS POINT**]

Keep the guesses aside and bring up the **objective of the investigation**; they should be able to determine for themselves whether common household substances provided are acids, bases or neutral by use of litmus indicator.

Ask the learners the how they would try to find out if unknown solution they find at home is an acid or a base. Some may suggest tasting as a way of knowing if a substance is an acid or a base. Use this to highlight the danger of tasting as a method of testing, e.g. in the case of tasting poisonous solutions or even fruits. You can use questions such as: *What would happen if you tasted a liquid that is battery acid? (Most learners have used lead-acid accumulator commonly referred to as battery and know that the acid is corrosive).*

Introduce the concept of indicators and their importance in identifying acids and bases safely. Acid/base **indicators** are substances that form different colours when in acid or base. Indicators can be in two forms; liquid indicators and paper indicators. Liquid indicators are added in drops to the solution being tested. Paper indicators are made from liquid indicators and are used to either quickly test solutions or to test substances like gases that cannot be easily tested with liquid indicators.

Discuss the stages of investigation and timing to enhance time management. This investigation involves: planning the procedure to carry out the investigation, discussion of the procedure, carrying out the procedure and discussion of the results. Let the learners know that after every stage, they shall be required to carry out the discussion with the teacher.

PLANNING FOR INVESTIGATION: 7 minutes

Remind them of the objective of the lesson and inform them that this session requires them to discuss and develop a procedure (in groups) for determining whether the solutions they have are acidic, basic or neutral. Inform them of the time available for this session and that time management is important.

Divide the learners into groups of 2 or 3 pupils. Ask the learners to list down the substances they are going to test (the ones they are provided with- ***a list of the requirements may be provided at this point***). Ask them to discuss and predict based on their familiarity with these substances whether they are acidic or basic. Encourage them to write a reason beside each prediction made. Then have them put aside their predictions until later in the lesson. While they discuss, move round the groups to find out what is happening they need assistance. ***Do not assist them predict though***.

When each group is **through with prediction**, provide them with **litmus papers,** inform them that litmus is the indicator and ask them to discuss and come up with a simple procedure they can use to test whether each substance provided is an acid or base *separately*. ***Remind them not to mix the substances***.

They should write the procedure they come up with in their notebooks. Move round the groups to find what is happening and offer help by **stimulating their thinking through questions such as**;

- *How would the indicator colour on the litmus paper come in contact with the solution being tested? (***Answer***; by dipping the paper into the solution)*

- *How can you tell whether the test solution is an acid or base?(* **Answer***; Knowing the expected colour change- litmus is blue in base and red in acid)*
- *Why is it important to use both blue and red litmus paper to test the same solution? (* **Answer***; some solutions are neutral and have no effect on litmus)*
- *Why would it be unwise to dip/use the litmus paper used to test solution A in solution B?* **(Answer***; the solutions could mix up leading to wrong observations).*

PLENARY DISCUSSION: 5 minutes

Call for the attention of learners. Have a random selection of groups to present the procedures they have come up with. Facilitate the discussion by asking questions such as; *how would we know the solution is acidic?* ***Litmus will turn RED in an ACID and BLUE in a BASE. Both red and blue litmus papers will remain UNCHANGED in a NEUTRAL solution.*** Make comments on the plans and advice the rest of the groups to check their plans against the comments. Ask the learners to modify their procedures accordingly (Since litmus indicator is in form of paper, the solutions can be tested directly by dipping both the red and blue litmus paper into the solutions in the containers holding them. Alternatively they can put a little solution in a test tube and dip both blue and red litmus paper into the solution).

Give them necessary precautions: *They should avoid spills of solutions on their skin and in the case of a spill they rinse quickly with running water and inform the teacher. Wear safety goggles, gloves and an apron- if available.*

THE INVESTIGATION 10 minutes

Allow the learners to carry out the procedures and record the observations in their note books as they progress.

This is a simple experiment that requires execution of simple procedures (allowing too much time might lead to idleness and thus class management problems)

DISCUSSION OF RESULTS: 8 minutes

Discuss the investigation outcomes. Ask groups to present their findings. You can develop a table such as the one shown (table 1.1.) and ask each group to provide results for the test of at least one solution and fill in the table. Together conclusions can be made on whether each solution is basic or acidic.

Table 1.1. Tests of solutions with litmus

SUBSTANCE	**OBSERVATION**		**CLASSIFICATION**
	Effect on Red Litmus Paper	**Effect on Blue Litmus Paper**	**Acid/Base/Neutral**
Hydrochloric acid,			
lemon juice			
distilled water			
baking soda solution			
vinegar			
wood ash solution			
Sodium chloride solution			
Toothpaste solution			

CONCLUSION: 5 minutes

Ask volunteers to share their predictions. Did any group predict correctly which substances are acids and which are basis? Let them change the predictions made at the beginning of the lesson according to the findings of the investigation. For solutions not used in this investigation yet mentioned in the predictions, the teacher can tell the learners if they are acidic, basic or neutral and challenge them to test them using indicators. Tell the learners to write a short report summarizing what they have learnt as a result of these investigations.

NOTES

Common substances we use are acidic, basic or neutral. Sour taste indicates presence of acids while bitter taste indicates presence of bases. Some substances have the characteristic of changing colour in the presence of an acid or a base. These can be used as acid/base indicators. Litmus indicator paper turns from blue to red in an acid and from red to blue in a base. Neutral solutions have no effect on litmus paper (red litmus paper remains red while blue litmus paper remains blue).

Distilled water, sugar and common salt solution have no effect on litmus paper because they are neutral. Citrus fruits such lemons, oranges and passion contain citric acid which changes litmus to red. Vinegar and hydrochloric acid are acidic and change litmus red. Wood ash and toothpaste solution change litmus blue because they are basic. Table 1.2 shows the expected results.

Table 1.2. Results of test of solutions with litmus

SUBSTANCE	**OBSERVATION**		**CLASSIFICATION**
	Effect on Red Litmus Paper	**Effect on Blue Litmus Paper**	**Acid/Base/Neutral**
Hydrochloric acid,	Remains red	Turns red	Acid
Lemon juice	Remains red	Turns red	Acid
Distilled water	Remains red	Remains blue	Neutral
Baking soda solution	Turns blue	Remains blue	Basic
Vinegar	Remains red	Turns red	Acid
Wood ash solution	Turns blue	Remains blue	Basic
Sodium chloride solution	Remains red	Remains blue	Neutral
Toothpaste solution	Turns blue	Remains blue	Basic
Methylated spirit/ethanol	Remains red	Remains blue	Neutral
Kerosene	Remains red	Remains blue	Neutral
Sugar solution	Remains red	Remains blue	Neutral

LESSON ONE STUDENT GUIDE

What is the solution?

Some substances that we eat are sour while others are bitter. Sour taste indicates presence of acids while bitter taste indicates presence of bases. Common substances used in our homes are either basic, acidic or neutral using taste to classify substances is not an accurate method and can also be dangerous. Since some substances are poisonous or corrosive. There are some substances that show different colours when in acids and when in bases. Such substances are called indicators. Litmus is one such indicator. Litmus is red in acidic solutions, blue in basic solutions and is not affected by neutral solutions.

Objective of the lesson

To determine whether common household substances provided are acids, bases or neutral.

The investigation

- You are provided with the following solutions:
    - dilute hydrochloric acid,
    - lemon juice,
    - distilled water,
    - solution of baking soda,
    - vinegar,
    - wood ash solution,
    - common salt (sodium chloride) solution,
    - toothpaste solution.
- The solutions are basic, acidic or neutral.
- You are also provided with strips of blue and red litmus indicator paper to test your solutions.

You are required to;

a. Think up a plan for identifying the solutions as acids, bases and indicators. You should not use any other reagents.
b. Write down the plan (procedure) you will use to carry out the investigation
c. Implement your planned experiment.
d. Make a report on what you have done and the outcomes of the experiment.

LESSON TWO: TEACHER GUIDE

Time: 80 Minutes

Lesson Topic: Make Your Own Indicator from Red Cabbage

Preliminary knowledge

- The learner should know that substances can be acidic, basic or neutral
- Colour change in indicators can be used to determine whether the substance is an acid or base

Background and General description of the lesson

In the first lesson, some substances were found to be acidic while others were found to be basic. This was done by use of indicators. It is important to know how to prepare simple indicators by use of extracts from flowers and other coloured plant materials. Litmus indicator and other commercial indicators used could not determine which solutions were more acidic or basic than others. In this investigation, the learners will be introduced to an indicator that shows a range of colors according to how acidic or basic the solution is. The red/purple cabbage will be used to prepare acid/base indicator which will be used to test some common solutions.

It is important to note that at this level the learners will not been introduced to the pH scale. The lesson is meant to:

i. Create awareness in learners that some acids are more acidic than others while some bases are more basic than others.
ii. Develop an understanding of what makes the indicators and the skill of the learners in preparing their own indicator.
iii. The strength of the acid or base can be indicated by use of an indicator whose colour changes depending on the strength of acid or base.

This lesson has two sections i) preparation of indicator and ii) use of the indicator to test solutions.

Red cabbage juice contains a natural pH indicator that changes colors according to the acidity of the solution. Red cabbage juice indicator is easy to make, exhibits a wide range of colors, and can be used to make your own pH paper strips. *Red/purple cabbage can be purchased in most supermarkets and at some grocery stores. (You can substitute red cabbage for other coloured plant material such as a common flower with purple leaves, coloured flower petals and skin of grape fruits or brinjals).*

Objectives

By the end of the lesson the learner should be able to;

1. Prepare an indicator from red/purple cabbage juice
2. Test household solutions using red cabbage indicator and classify them as strong acids strong acids weak acids, Neutral, weak bases and strong bases.

Materials required

For section one: preparation of indicator

- red cabbage
- blade or knife
- tile or clean surface on which to cut the cabbage
- distilled water
- filter papers
- One large glass beaker (250 or 500ml) or other clean pan for boiling the cabbage.
- 100 ml beakers or other small glass/plastic containers(according to the number of groups in class)
- burner with tripod stand and gauze or stove

For section two: using the indicator to test solutions.

- Diluted battery acid (sulphuric acid)
- lemon juice
- ammonia/ or baking soda
- distilled water

- sodium hydroxide solution
- dilute hydrochloric acid
- red cabbage juice
- droppers
- a set of six test tubes

INTRODUCTION: 5 minutes

The teacher leads a discussion on review of previous lesson. Remind the learners that the indicator used earlier did not inform on level of acidity. Can use guiding questions to indicate levels of acidity in all acidic solutions is not the same. Can use guiding questions like: *what would be happen to the skin when a) lemon juice and b) battery acid are poured on it?*

Give the learners the objectives of the lesson. Let them know they are going to make an indicator solution that changes colour according to the acidity or alkalinity of the solution. ***Avoid introducing the concept of pH scale until the next lesson.*** The indicator is easy to make! We will make it together and distribute it for use by individuals (or they can make in their groups if the burners are available).

PREPARATION OF THE INDICATOR: 15 minutes

Display to the learners the apparatus to be used in this section or hand out a printed list of the apparatus. Let the learners know that the purple colour in the cabbage leaves is what they need to extract and use as an indicator. Tell them that the colouring matter just like the green colour in vegetables used at home is soluble in water. Ask the learners to suggest ways in which the colour can be extracted. *You stimulate thinking by relating the extraction to how green vegetables release their pigment in cooking water.*

Allow the learners to chop the cabbage into small pieces, place the pieces in the large beaker and pour the water to cover the cabbage. Place on the burner and allow it to boil for at least five minutes/ until the colour leaches out of the cabbage.

Decant out the plant material to obtain a red-purple-bluish colored liquid. (The exact color you get depends on the pH of the water. When distilled water is used a purple colour is obtained. When tap water is used a blue coloured solution is obtained).

Pour about 25ml of the red cabbage indicator into each 100 ml beaker for each group. Allow the solution to cool.

Make your pH paper strips using red cabbage indicator. Take filter paper and soak it in a **concentrated** red cabbage juice solution about two minutes, remove the paper and allow it to dry. Cut the filter into strips and you can use them to test the pH of various solutions. (The paper strips can be prepared for use in the next lesson. **They cannot be used for this lesson since they are not dry).**

Safety Precautions:

- Take care to avoid burning when boiling water and when decanting the solution from the cabbage leaves.
- Allow the indicator solution cool before using it.
- The indicator solution and the test solutions are all non-toxic and can be poured down the sink after use. If your hands or eyes come in contact with any of these, simply rinse them thoroughly with water.
- The indicator solution can stain your clothes, so it is a good idea to wear an apron (or lab coat if available) when handling the indicator. If the indicator does get on your clothes, try using a stain remover and then washing them in cold water

TESTING THE SOLUTIONS-DISCUSSION: 10 minutes

During the time that the indicator solution is boiling, you can divide the learners in groups of two to three and distribute the apparatus for section 2.

Give the learners a list of apparatus and solutions to be used and ask them to discuss and develop appropriate procedures that they would use to test for acidity or alkalinity of the solutions using red cabbage indicator. Given that they had used litmus indicator, let them come up with a plan on how to use the indicator in solution. While they discuss move round the groups to find out what is happening they need assistance.

Plenary Discussion 10 minutes

Allow the learners from various groups to present the procedures they come up with. **Engage the learners in a discussion on the procedures they intend to adopt.** You can polish the procedures through question answer method. Let the learners modify their procedures in the light of the discussion. *This may involve putting a little amount of solution in a test tube and adding a small amount of indicator solution.* Facilitate further discussion by asking how the change in colour would be related to how acidic or basic the solution is. ***They should discover that they need a colour guide.*** Then give them a guide on the colours expected and their meanings as shown on table 2.1. *This can be copied on the writing board.*

Table 2.1. Red Cabbage Indicator Colours

Type of Solution	Strongly acidic	Weakly acidic	neutral	Weakly basic	Strongly basic
Color	Red	Red - orange	Violet-Purple	Blue-Green	Greenish Yellow

They should relate the colours formed by the solutions to this guide

The Investigation 15 minutes

Allow the learners to implement the plans and record their findings in their note books. Move around the group and guide them where need be. Remind them to note down the findings in their note books

Discussion of the results 15 minutes

Discuss the outcomes of the investigation. Let the learners examine their findings against each other as randomly selected groups present their findings. You may develop a table on which learners can summarize their results similar to table 2.2.

Table 2.2. summary for the investigation

Substance	**Colour observed when mixed with cabbage juice indicator**	**Classification ***
Diluted battery acid(sulphuric acid)		
Lemon juice		
Ammonia or baking soda		
Distilled water		
Sodium hydroxide solution		
Dilute hydrochloric acid		

*The classification reffered to here is either: ***Strongly acidic, Weakly acidic, Neutral, Weakly basic or Strongly basic.***

Conclusion 5 minutes

Discuss the ability of such an indicator to estimate the strength of acid or base. Notify them that this indicator may however change its composition with time (*just like vegetables/food go bad when stored for some time).* More reliable commercial indicator can therefore be used inn the place of red cabbage juice. (*this is to be covered in the next lesson*)

Assessment and clean-up 5 minutes

You may want to provide an unknown solution and ask the learners to determine their classification by testing using the red cabbage juice.

Tell the learners to clean up the apparatus and tidy their working tables. (*You may chose to retain the unused solutions or future use or have them poured out: it is adviceable to give them small volumes of solutions/enough for single use, so that the next experiment involves use of fresh solutions to avoid contamination)*

Notes

The pigment in red cabbage is known for its ability to change colors depending on the pH (level of acidity) that it comes in contact with. Red cabbage contains a pigment molecule called flavin (an anthocyanin). Blue, yellow and red colors of flowers, fruits and some leaves are caused by those pigments. The color of the juice changes in response to changes in its hydrogen ion concentration. Very acidic solutions will turn anthocyanin a **red** color. Basic solutions turn it to in **greenish-yellow**. Neutral solutions result in a **violet-purple** color. Therefore, it is possible to determine the pH of a solution based on the color it turns the anthocyanin pigments in red cabbage juice.

The tale 2.2 may be completed to ;

Substance	**Colour observed when mixed with cabbage juice indicator**	**Classification ***
Diluted battery acid(sulphuric acid)	Red	Strongly acidic
Lemon juice	Red-orange	Weakly acidic
Ammonia or baking soda	Blue-green	Weakly basic
Distilled water	Purple	Neutral
Sodium hydroxide solution	Green yellow	Strongly basic
Dilute hydrochloric acid	Red	Strongly acidic

LESSON TWO: STUDENT MATERIALS

Make your own indicator!

Introduction

You can prepare your own indicator by use of extracts from coloured flowers and plant materials. Today we will prepare an indicator from **red/ purple cabbage**. Last lesson we found that some substances are basic while others are acidic. We did not however find out if some acids are more acidic than others or if some bases are more basic than others. The indicator we prepare today changes the colour depending on how acidic or basic the solution is. We shall test some household solutions using red cabbage indicator and classify them as ***strong acids, weak acids, Neutral, weak bases and strong bases.***

Aim

1. Prepare red cabbage juice indicator
2. Test household solutions using red cabbage indicator and classify them as strong acids strong acids weak acids, Neutral, weak bases and strong bases.

The investigation

Part 1: You are provided with red/purple cabbage leaves, blade or knife, distilled water, a burner/ heater or stove, and a large glass beaker or small cooking pan.

Write down in your notebook how you would prepare a solution containing the cabbage pigment/ extract the colour from the cabbage for use as an indicator ***(you will carry out this procedure together with your teacher)***

Part 2: You are given a beaker or tumbler containing the red cabbage juice with a dropper, Diluted battery acid(sulphuric acid), lemon juice, ammonia/ or baking soda, distilled water, sodium hydroxide solution, dilute hydrochloric acid and a set of six test tubes.

a. Device a plan for testing which solutions are strong acids, weak acids, Neutral, weak bases and strong bases by use of colour change of red cabbage indicator solution.
b. Write down the procedures in your notebook. (**You must discuss your procedures with the teacher before using them to carry out the experiment)**
c. Carry out the procedures of the experiment you have planned.
d. Write a report of what you did and the findings of your group.

LESSON THREE: TEACHER GUIDE

Time: 40 Minutes

STRENGTH OF ACID/BASE AND PH VALUE

Aim: In this lesson, the learners should be able to describe pH as a measure of the degree of acidity or alkalinity of a solution.

Background of the lesson

Acids and alkalis are referred to as weak or strong according to their behaviour in a solution. This can be experienced in that the lemon is sour than an orange and yet both are acidic and thus sour. A universal indicator can be used to determine how strong the acid or base is. Universal indicator is prepared by mixing a number of common indicators together so that the mixture obtained can show various colours at different pH values.

General description of the lesson

This lesson involves the learner gathering data to show some solutions are more acidic or basic than others by use of universal indicator. The learner should be able to attach pH values to colour changes of the indicator.

Objectives

1. Relate liquid color to pH scale and therefore determine the pH values of solutions using universal indicator.
2. Classify solutions in terms of strong acids weak acids, Neutral, weak bases and strong bases.

Materials required

- universal indicator solution/or universal indicator paper
- universal indicator chart/ pH chart
- six test tubes
- The following solutions:
    - Diluted battery acid/ dilute sulphuric acid
    - lemon juice
    - vinegar
    - common salt (sodium chloride) solution
    - sodium hydroxide solution
- Solution A (baking soda/ sodium hydrogen carbonate)- provided at the end as part of assessment

Introduction 5minutes

The lesson is introduced by a teacher-led discussion. Introduce the lesson by giving the objective of the lesson.

Review the previous lesson on use of red cabbage indicator on solutions where solutions were found to have different levels of acidity and alkalinity. Guide the learners into understanding that the colours can be matched to specific values of pH on the pH chart. (can show the learners a sample of the pH chart and how the colour of the solution is matched to the colour on the pH chart and a value of pH identified.

Teacher informs learners about the timing of the various activities in the investigation (e.g., planning, post planning discussion, experimenting, and report writing) Helps students plan use of time available.

Planning of the investigation (10minutes)

Introduce learners to the materials available or the experiment. You can provide them with a list of materials and apparatus. Organize the learners into groups of **2 or 3** and let them come up with a scheme on how they can test the strength of acids or bases they are provided with.

As the discussion in groups take place, move round the groups guiding them through a realization that the colour of the solution can be matched against specific colours given on a chart. (Teacher engages learners in metacognition discussions about the procedures they intend to adopt) This can be done through questions like; *how would you know whether the solution that turned red is more acidic or basic than the one that turned green?* Let them write down the procedures they come up with in their notebooks.

.**Discussion of the procedure (5 minutes)**

Teacher encourages critical review of the plans with the learners (e.g., how do they think would achieved the objectives). *Providing alternatives or advice with reasons why we think the plan is not workable or safe.*

When they have come up with appropriate procedure, allow them to pick the apparatus from the demonstration table *(if they were not already distributed*). **DO NOT PROVIDE SOLUTION A AT THIS STAGE.** *(If the solutions are to be picked from the demonstration table, you can allow the learner to pick a single solution, test it, record the observation and then pick the nert solution in a clean test tube. This minimizes time wastage during the activity and disregards the need* *to label the test tubes).*Do not allow the learners use the materials before they lay down all the procedures.

Remind the learners to write down their procedures and to record all the observations (colour changes) in their note books.

Students should record their results as they identify the solutions by recording the colour, comparing with the pH scale, and noting the numerical pH value.

Discussion of results 10 minutes

Discuss the results of the experiment. To ease and organize the recording, you can make a table on the writing board similar to the table below and guide learners through questioning to complete the table. More solutions can be added as desired.

Solution	**Colour of indicator**	**pH value**	**Classification**
Diluted battery acid			
Lemon juice			
Vinegar			
Salt (sodium chloride) solution			
Sodium hydroxide solution			
Solution A (baking soda)			

Use the summary table to assist learners complete the table appropriately.

Guide the learners through classification of substances into **strong acids** (with pH value 0-4), **weak acids** (with pH value above 4 and below 7) **Neutral** (with pH 7), **weak bases**,(with pH value above 7 to 10) and **strong bases** (pH value above 10 to 14)

Assessment 5 minutes

You may provide the learners with an unknown **solution A** to test for its pH and classify it accordingly.

Tell the learners to write a laboratory report of the experiment carried out.

Clean up 5minutes

Let the learners clean the test tubes and arrange them appropriately in the test tube rack.

Notes

The values of pH range between 0-14.where a pH 7 indicates a neutral solution while all pH values below 7 indicates that the solution is acidic and those above seven shows the solution is basic. The pH signifies the degree of hydrogen ion release into a solution (it is the –log H^+). The pH scale ranges from 0 to 14. The closer to 0 the stronger the acid, whereas the closer to 14, the stronger the base. A pH of 7 is neutral, or neither basic nor acidic. Thus the pH value of strong acid solution is 0, neutral solution pH is 7 and strong alkali solution pH is 14. The numerical values and colours can represent pH values.

The completed table should be like as shown below:

Solution	**Colour of indicator**	**pH value**	**Classification**
Diluted battery acid	Red	1	Strong acid
Lemon juice	Orange / yellow	5-6	Weak acid
Vinegar	Orange/yellow	5	Weak acid
Salt (sodium chloride) solution	Green	7	neutral
Sodium hydroxide	Purple/violet	12-14	Strong base
Solution A (baking soda)	Blue	9-10	Weak base

***Note;** the pH value is specific within the values shown according to the colour that the universal indicator in the solution matches.*

STUDENTS' INSTRUCTION

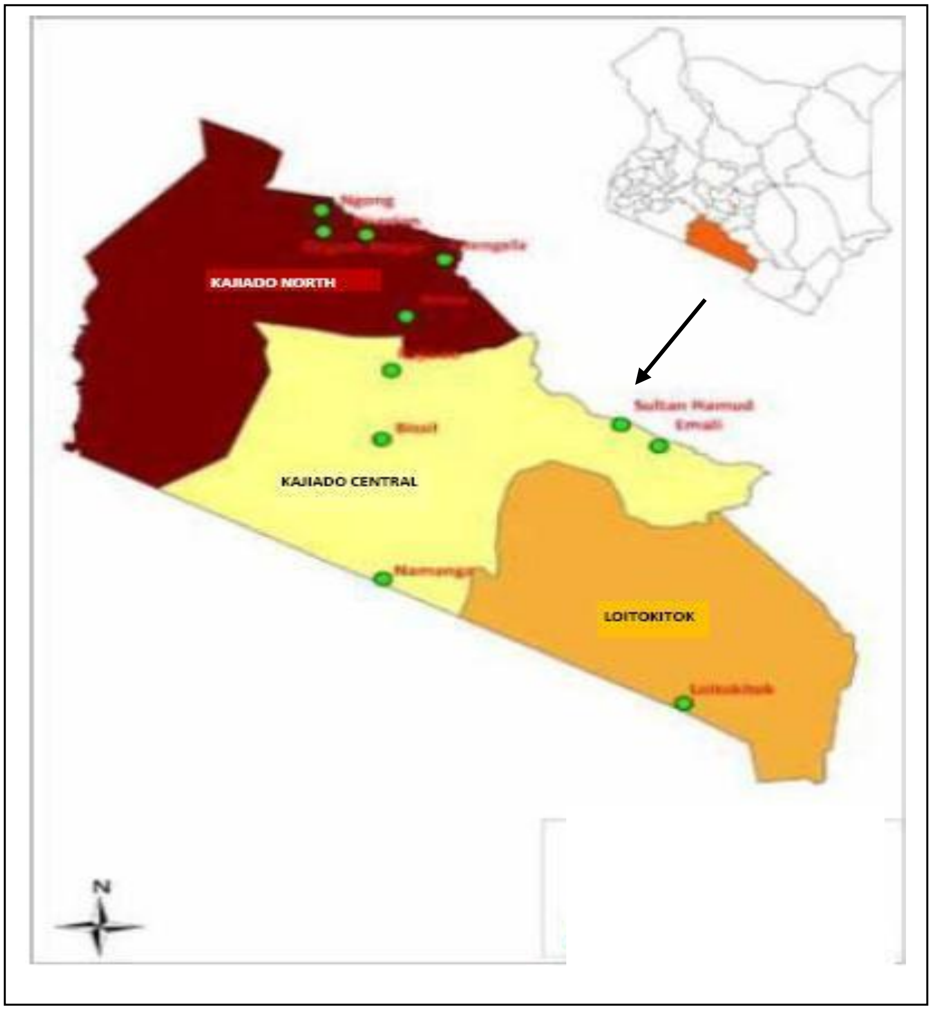
Though some substances are acids while others are basic, their acidity/alkalinity is not of the same strength. The colours of universal indicator may be useful in determining how acidic or basic solutions are. You are provide with: Diluted battery acid, lemon juice, vinegar, salt (sodium chloride) solution and sodium hydroxide solution. You are also provided with universal indicator solutions

(a) Think up a scheme and plan for identifying all the solutions as strong acids, weak acids, strong alkalis and weak alkalis or neutral. You may not use any other reagents.

(b) Implement your planned experiment

Homework: Write a report about the procedures followed, results/observations and conclusions made. This report will be shared with other students

APPENDIX IX: MAP OF STUDY LOCALE (KAJIADO COUNTY)



APPENDIX X: RESEARCH AUTHORIZATION

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.

Date:

16th January, 2015

NACOSTI/P/15/9660/4410

Monica Gakii Ituma
Kenyatta University
P.O. Box 43844-00100
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Developing instructional materials that address challenges facing teachers in secondary school chemistry investigative practical work; a case of Kajiado County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Kajiado County** for a period ending **1st June, 2015.**

You are advised to report **the County Commissioner and the County Director of Education, Kajiado County** before embarking on the research project.

On completion of the research, you are required to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

SAID HUSSEIN
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kajiado County.

The County Director of Education
Kajiado County.

APPENDIX XI: RESEARCH PERMIT

THIS IS TO CERTIFY THAT:
MS. MONICA GAKII ITUMA
of KENYATTA UNIVERSITY, 5166-200
Nairobi,has been permitted to conduct
research in *Kajiado County*

on the topic: *DEVELOPING INSTRUCTIONAL MATERIALS THAT ADDRESS CHALLENGES FACING TEACHERS IN SECONDARY SCHOOL CHEMISTRY INVESTIGATIVE PRACTICAL WORK; A CASE OF KAJIADO COUNTY, KENYA*

for the period ending:
1st June,2015

Permit No : NACOSTI/P/15/9660/4410
Date Of Issue : 16th January,2015
Fee Recieved :Ksh 2,000

....
Applicant's Signature

....
Secretary
National Commission for Science, Technology & Innovation