UNIVERSITY OF SOUTHAMPTON

Faculty of Social and Human Sciences

Southampton Education School

DESIGN AND EVALUATION OF A PROFESSIONAL DEVELOPMENT PROGRAMME TO SUPPORT ACTIVITY-BASED BIOLOGY TEACHING AND LEARNING IN TANZANIAN SECONDARY SCHOOLS

by

Wadrine Maro

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ABSTRACT

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This study aims to design, implement and evaluate a professional development programme for biology teachers in Tanzania. The proposed activity-based approach to teaching supported by the 5Es instructional sequence (adapted from Bybee *et al.*, 2006) is new in the Tanzanian secondary schools context. Consequently, this study addresses the following research questions.

1) What are the characteristics of an effective professional development programme that adequately supports learning and teaching of biology in Tanzania?
2) How can a professional development programme be practically designed and implemented to enhance Tanzanian biology teachers' pedagogical knowledge and skills?
3) What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?

The study included 675 students, 35 teachers, 7 student teachers, and 3 experts in the field of science education. A design-based research methodology involved both qualitative and quantitative data collection methods and analysis. Teachers' reactions to the professional development workshop were positive. They were satisfied with the content and follow-up coaching activities. The new knowledge and skills helped teachers to support students through interaction with materials and discussion in small groups to acquire meaningful learning.

Findings of classroom observations, teacher interviews, student evaluation questionnaires, and focus group discussions showed that the adoption of the newly developed *excitement* stage in the 5Es instructional sequence was useful and relevant to teachers' instructional approaches. It supported them to move away from overly didactic practices to activity-based and student-centred teaching and learning approaches. Student focus group discussions indicated positive opinions about their teachers' adoption of the new approaches. Students reported differences from their regular classes, which served to enhance better understanding of the taught concepts. These positive changes included, more student involvement in the lesson activities and teachers being more supportive and open to questions. This study has confirmed findings from previous research about the important role of curriculum materials as a component of teachers' professional development experience. In addition, findings of the study demonstrated that the 5Es instructional sequence provided teachers and students with opportunities to practice effective science teaching and learning approaches. It is hoped that this approach is adopted more widely in Tanzanian secondary schools, so that future students may experience success and be inspired to continue their studies of science.

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DECLARATION OF AUTHORSHIP

I, Wadrine Maro, declare that the thesis entitled:

Design and Evaluation of a Professional Development Programme to Support Activity-Based Biology Teaching and Learning in Tanzanian Secondary Schools

and the work presented in the thesis are my own, and have been generated by me as the result of my own original research. I confirm that:

- The work was done wholly or mainly while in candidature for a research degree at this University;
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this university or any other institution, this has been clearly stated;
- Where I have consulted the published work of others, this is always clearly attributed;
- Where I have quoted from the work of others, the source is always given with the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all the main sources of help;
- Where the thesis is based on work done by myself, jointly with others, I have made clear exactly what was done by others and what I have contributed myself; and
- None of this work has been published before submission.

Signed:

Date: March, 2013

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Chapter 1

Introduction to the Study

This study aims to design, implement and evaluate a teacher professional development programme to support activity-based biology teaching and learning in Tanzanian secondary schools. This chapter presents the background of the study, a statement of the problem, significance of the study and the research questions. Other sections are an overview of the research methodology and a summary of the thesis chapters.

The motivation for conducting this research originated from my own experiences as a classroom science teacher and teacher educator for the past 20 years. It was a great opportunity to participate in the investigation of possible solutions for prevailing problems and challenges in the teaching and learning of science in Tanzanian secondary schools and contribute to the improvement of student learning outcomes.

1.1 Background of the study

The Tanzanian government recognises the important role of science and technology education. Science education influences the quality of people's lives and development of people's standards of living in all of its elements such as economic, social, and environmental aspects (United Republic of Tanzania - URT, 1996). The government of Tanzania believes that schools can play an important role in developing the knowledge and skills of science and technology among its citizens. In the school curriculum it gives emphasis to the teaching of science, mathematics, and computer studies in order to promote technological and scientific development in the country (Ministry of Education and Culture - MOEC, 1995). In 1996, the Tanzanian government implemented a policy stipulating that "science and technology shall be essential components of education and training in the whole education system" (URT, 1996: 3).

Several studies conducted in Tanzania on teaching and learning of science in secondary schools have revealed that the predominant teaching and learning methods in secondary school science classrooms are traditional and teacher-centred (Bathlomew, 2008; Mafumiko, 2006; Osaki *et al.,* 2002). Such methods do not give much room for critical analysis of concepts, but rather enable students' to regurgitate facts for teachers. Skills and knowledge are transmitted to students, who remain passive receivers for most of the lesson. The best learner in this context is the one who can reproduce facts in the examinations through memorisation. There is very little interaction between the teacher and students, and the teacher rarely provokes students into asking questions. Though this method of teaching has pedagogical merits such as imparting information, this is not always the reason behind the teacher's choice. It may quite often be the choice because it is a familiar method, and gives importance to the teacher's dominance of the teaching and learning process (Osaki *et al.,* 2002; Tillya, 2003).

Furthermore, researchers have indicated that teachers use 'chalk and talk' methods in the teaching and learning process even when there is a possibility of using other methods (Chonjo & Welford, 2001; Osaki, 2007). The schools involved in these studies had laboratory equipment and science books which were not used by teachers in the teaching and learning process. The studies also revealed that most teachers lacked the skills of how to promote student-centred teaching and learning procedures such as observations, generation and testing of hypotheses through experimentation, discussion of findings from observations and experiments, data organisation and reporting.

According to Dillon and Manning (2010), the teaching of science requires specific teaching and learning techniques because learning scientific concepts and methods involves understanding and conceptual linkage of various scientific representations. Teaching and learning techniques must have the necessary provision for students' active engagement with explanatory ideas and evidence, so as to enable them to make connections between scientific theories and concepts and the real purposes and practice in the world they live (Millar, 1991; Tytler, 2003). It is from this conception that teaching strategies adopted by teachers to bring about changes in the students' behaviour, world view, or conceptions of phenomena are regarded as very important.

Researchers in science education have suggested the use of student-centred teaching strategies Lawrenz *et al.*, (2009) such as activity-based learning with hands-on experiences where the students are not only manipulating the objects, but they are engaged in in-depth investigations with objects, materials, phenomena, and ideas, and draw meaning and understanding from those experiences (Haury & Rillero, 1994; Millar, 2010) . When an activity-based approach (Section 3.4.3.1) is used in the context of inquiry-based instruction, students do not only participate actively in lessons but also gather evidence that helps develop their conceptual understanding (Hewson & Hewson, 1998; Lumpe & Oliver, 1991). Unlike laboratory work, activity-based approaches do not necessarily need any special equipment and medium, they can utilise everyday gadgets, simple set-ups, or low cost items and materials, that can be found and assembled very easily (McGervey, (1995).

Several studies in the literature show that hands-on activities help students to:

i) Outperform students who follow traditional, text-based programmes (Bredderman, 1985; Freedman, 1997; Staver & Small, 1990; Stohr-Hunt, 1996; Turpin, 2000);
ii) Enhance their understanding and replace their misconceptions with scientific ones (Ünal, 2008);
iii) Develop positive attitudes toward science (Bergin, 1999; Bilgin, 2006; Kyle, Bonnstetter, & Gadsten, 1988; Hofstein & Lunetta, 2003);
iv) Encourage their creativity in problem solving, promote student independence, improves skills such as reading, arithmetic, and communication (Haury & Rillero, 1994; Staver & Small, 1990).

For students to truly learn science concepts, they need practical opportunities to apply knowledge and help in integrating or exchanging the knowledge they gain (Millar, 2010; Woolnough, 1991).

1.2 Statement of the problem

Several problems and challenges have been raised by researchers about ineffective methods of science teaching and learning in Tanzanian secondary schools, which do not cope with the scientific advancement and complexities as advocated by science education reformers. Generally, there are multiple concerns associated with the quality and quantity of teachers, the curriculum, and availability of teaching and learning materials including laboratories, equipment and consumables (Mafumiko, 2006). Problems in these areas often overlap and sometimes it is not easy to explain one problem area without touching on another (Mafumiko, 2006). Teachers often claim that the syllabi are too long to be covered within the available timeframe, thus they are forced to teach didactically to meet examination requirements (Leeuw, 2003). This in turn does not contribute to an understanding of the taught concepts. Another concern is the availability of qualified teachers in schools. Currently there is a critical shortage of science and mathematics subject teachers (Buretta, 2003; Mushashu, 2000; Ministry of Education and Vocational Training – MOEVT, 2010).

According to MOEVT (2010), the recent expansion of the secondary school sector has also increased the number of students per classroom, which is not matched by the supply of teachers and resources. Teachers who are qualified to teach in Ordinary level (O-Level) secondary schools have significant problems due to the poor teaching preparation they received while in colleges, and opportunities for attending in-service programmes are limited due to lack of funds (Babyegeya, 2006; Bathlomew, 2008; Chonjo & Welford, 2001). The majority of teachers lack substantial subject knowledge (Chonjo *et al.*, 1996; Mushashu, 1997; Schizya, 1997), as well as pedagogical content knowledge, i.e. the distinctive body of knowledge for teaching which leads to an understanding of how a particular topic is organised and presented effectively to the diverse interests and abilities of learners (Shulman, 1986;1987). As a result, most students do not perform well in their final examinations which hinder them joining science related courses in higher education (Section 2.5.1).

Based on these challenges, conducting research for the purpose of supporting both teachers and students in the teaching and learning of science in Tanzanian secondary schools is vital.

This study is an attempt to contribute towards the improvement of student learning and understanding of biology as one of the compulsory O-level science subjects in Tanzanian secondary schools. The plan was to design a small scale, locally grounded intervention (a professional development programme) comprising a professional development workshop to enhance biology teachers' learning and practising an activity-based approach supported by the 5Es instructional sequence Bybee *et al.*, (2006) (Table 6.1). Other components included teachers' support curriculum materials (Appendix A2), school follow-up coaching to help teachers implement the new approaches in their respective classrooms, and a supportive school environment (Figure 4.3).

1.3 Significance of the study

Studies on teaching and learning of science and teachers' professional development (PD) have addressed a number of problems and challenges in these areas, and have suggested measures to alleviate the situation (Kitta, 2004; Teclai, 2006; Tillya, 2003). However little has been done in Tanzania as well as other Sub-Saharan African countries to design a teacher PD programme that embeds curriculum materials to enhance teachers' learning and bring about conceptual changes, which in turn can benefit student involvement in, and understanding of their lessons. Therefore, this study has both practical and theoretical significance. Practically, this research contributes to in-service learning of teachers through development of a PD programme and teacher support curriculum materials which include specific learning strategies and an instructional sequence. These were designed for use by teachers and implemented (adopted and enacted) with a goal of solving instructional problems or challenges related to science (biology) teaching and learning in Tanzanian secondary schools. Therefore, these outputs are useful to schools and in the broader education community. The further significance of this research is the professional development of participants. Teachers' participation in the design and research activities was regarded as an important form of professional development because it enhances their knowledge and skills about effective science instructional methods, which in turn contribute to the improvement of students' participation in the learning and understanding of biology.

Findings of this research will provide evidence and challenges to educational stakeholders responsible for designing science teachers'professional development programmes in Tanzania, in the hope that it will stimulate them to further investigate the challenges associated with teaching and learning of science in Tanzanian secondary schools.

1.4 Research questions

The study was guided by three research questions:

1) What are the characteristics of an effective professional development programme that adequately supports learning and teaching of biology in Tanzania?
2) How can a professional development programme be practically designed and implemented to enhance Tanzanian biology teachers' pedagogical knowledge and skills?
3) What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?

1.5 Overview of research methodology

The study adopts Design Based Research (DBR) methodology (Design-Based Research Collective -DBRC, 2003; McKenney & Reeves, 2012; Wang, & Hannafin 2005). This is defined as a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration between researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories (Wang & Hannafin, 2005).
In combination with other research approaches, DBR has the potential to help develop effective educational interventions, and to offer opportunities for learning during the

research process (Van Den Akker *et al*., 2006). Studies conducted through DBR methodology in contexts similar to Tanzanian secondary school systems have shown promising benefits (for example, Kitta, 2004; Mafumiko, 2006; McKenney, 2001; Ottevanger; 2001: Tilya, 2003).

The design and research activities in this study were implemented, and evaluated through the DBR framework. Both qualitative and quantitative methods were used for data collection and analysis which included: classroom observations, interviews, questionnaires, achievement tests, and analysis of documents. Figure 1.1 illustrates the three stages of the study, i.e. the preliminary analysis, design of the intervention, and implementation and evaluation, (Section 5.3.3) together with some anticipated outcomes.

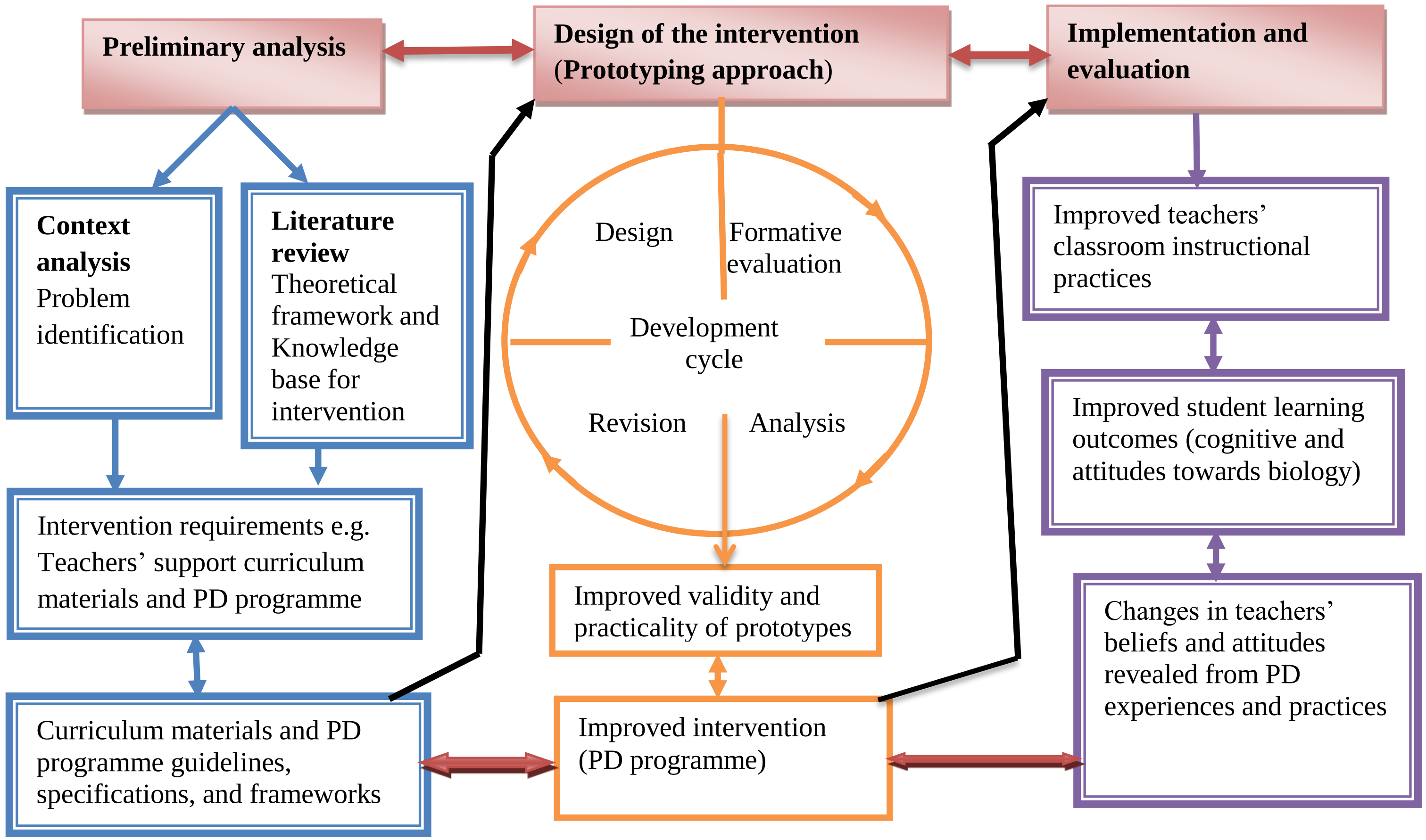


Figure 1.1: Stages of the study

Note:

Shows the evolution of the three stages of the study and the interrelatedness of the outcomes.
Shows the activities and outcomes of the Preliminary analysis stage.
Shows the activities and outcomes of the design/prototyping stage
Shows the activities and anticipated outcomes from the implementation stage
Connects the activities and outcomes of the three stages of the study

1.6 The thesis chapters

The thesis is organised into eight chapters that are outlined below:

Chapter 1 situates the research problem in the context and highlights the importance of carrying out the intervention for the improvement of science teaching and learning in Tanzanian secondary schools;

Chapter 2 discusses the context of the study and the preliminary field-based investigation to clarify the nature and extent of problems/challenges in the teaching and learning of science (biology) in Tanzanian secondary schools;

Chapter 3 describes the constructivist theoretical framework of the study and its role in the teaching and learning process;

Chapter 4 reviews the literature on teachers' professional development and describes the development of the professional development programme of the study;

Chapter 5 discusses the rationale for adopting the Design Based Research methodology to guide the study activities. This includes the description of the specific data collection methods and analysis;

Chapter 6 presents the design and formative evaluation of the curriculum materials and professional development programme;

Chapter 7 presents findings of evaluation of the implementation of professional development programme and impact on teaching and learning;

Chapter 8 is the final chapter of the thesis and provides a summary, discussion of the main findings of the study, conclusions, and recommendations.

Chapter 2

The Context of the Study

2.1 Introduction

This chapter analyses the context of the study about the design, implementation and evaluation of a PD programme to support activity-based biology teaching and learning. The primary goal of the context analysis was to gain a better understanding of the research problem at hand, clarify contextual boundaries of feasible changes that address the problem, and examine tentative design guidelines and parameters. Findings of the context analysis were obtained with the help of documentary analysis, classroom observations, review of previous studies, projects on science teaching and learning in Tanzania, science teachers' training, and science teachers' professional development. This information partly addresses the first research question of the study: *What are the characteristics of an effective professional development programme that can adequately supports learning and teaching of biology in Tanzania?*

Section 2.1 presents general information about Tanzania. Section 2.2 outlines the Tanzanian education system which includes a historical overview of education and curriculum policies. Section 2.3 illustrates the curriculum policies. Section 2.4 presents the Tanzanian education and training structure. Section 2.5 presents the secondary education curriculum, science teaching and learning and associated constraints. Section 2.6 discusses secondary school teacher education and associated constraints. Section 2.7 outlines science teachers' professional development initiatives conducted to improve science teaching and learning in secondary schools in Tanzania. Section 2.8 presents provisional findings of the preliminary field-based investigation conducted in two secondary schools, and Section 2.9 presents a summary of the chapter and implications of these findings for the study.

2.2 General information about the United Republic of Tanzania

The United Republic of Tanzania was formed from the union of two countries which are Tanganyika (currently Tanzania mainland) and Zanzibar also known as (Tanzania Isles). The Union Government which was formed in 1964 operates under Union Constitution and has full responsibility of some of its main sectors including Foreign Affairs, Defence, Home Affairs and sub-sectors such as Higher Education. Zanzibar has full autonomy for its basic education.

This country is located in East Africa and has an area of 945,087 km^2 and the population in 2009 was estimated to be 43,739,000 (World Bank, 2009). The landscape of the mainland is flat and low along the coast but rises up to a plateau constituting the greater part of the country. It contains the highest mountain in Africa, the Kilimanjaro Mountain, with an elevation of 5895 metres on its northern border. It has three of Africa's Great Lakes on its borders, Tanganyika in the west, Victoria in the northwest and Nyasa in the southwest. The Republic of Tanzania is bordered in the north by Kenya, Uganda, Ruanda and Burundi in the northwest, Democratic Republic of Congo (DRC) in the west, Zambia and Malawi in the southwest, Mozambique in the south and in the east it has a coastline bordering the Indian Ocean. The climate of this country varies from tropical along the coast to temperate in the highlands. Figure 2.1 shows the political map of Tanzania.

The country's economy depends heavily on agriculture, which accounts for half of the GDP and employs 80% of the work force. The Tanzanian economy is characterised by its small manufacturing sector, which is hardly competitive in the international market. Rural incomes and living conditions have shown little improvement over the past two decades (Osaki, 2007). Therefore skilled human resources are still one of the barriers for the implementation of many programmes in the country. More investment in human resource development is necessary, especially in the areas of education, agriculture, science, and technology (Mafumiko, 2006; Osaki, 2007).

Figure 2.1 Political map of Tanzania

Source: http://www.mapsoftheworld.com/Tanzania

2.3 Curriculum policies

Until 1995 Tanzania did not have a comprehensive education and training policy, therefore the Government established the Tanzania and Education and Training Policy (ETP) to improve its education sector (Saunders & Vulliamy, 1983). The major purpose of this policy was to guide, synchronise and harmonise all structures, plans and practices; to ensure access, equity and quality at all education levels, and to act as a mechanism for management and financing of education and training. In addition the policy also provided guidance and direction of school curriculum policies in the country. The policy stipulates clearly that the government will continue to co-ordinate and supervise the preparation and delivery of curriculum for primary, and secondary school levels, as well as teachers' colleges (MOEC, 1995). The government undertakes these activities through the Tanzania Institute of Education (TIE) which develops, monitors, and evaluates schools and teacher education curricula.

2.3.1 Medium of instruction

A bilingual policy is another important feature in the Tanzanian formal education structure. This requires children to learn both the National language (*Kiswahili*) and a foreign language (*English).* In the government owned primary schools *Kiswahili* is the medium of instruction, while *English* is taught as a compulsory subject. In secondary education the medium of instruction is *English*, and *Kiswahili* is taught as a compulsory subject. In Advanced secondary and tertiary levels of education *Kiswahili* appears as one of the subjects used to form subject combinations, but it is not compulsory.
There is a great concern about the weakness brought about by this policy and how it relates to the quality of education. Despite the great efforts to improve the use of *English* in secondary schools, the *English* proficiency of both teachers and students remains low and the pressure to switch to a *Kiswahili* medium is mounting (Mafumiko, 2006). For example in the current study *English* language was mentioned by teachers and students as one of challenges experienced toward effective classroom interactions during implementation of the activity-based lessons (Section 7.5.4).

2.4 Education and training structure in Tanzania

Education and Training in Tanzania is organised under the Ministry of Education and Vocational Training (MOEVT) and the Ministry of Regional Administration and Local Government. Other ministries are involved in Sector-Specific Professional education and training (Government of United Republic of Tanzania - GURT, 2001a). In addition formal and non-formal education is provided by communities, Non-Governmental Organisations (NGOs), and individuals in co-ordination with central Government Ministries.

The formal education system in Tanzania is the one adapted from the British Colonial education structure after independence in 1961. It is predominantly academic and hierarchically divided, ranging from Primary to Tertiary levels. The nature of this education system has for a long time shaped the school curricula and examinations that serve as an important device to select students for further education rather than providing feedback on the basic skills and literacy (MOEC, 1995). The existing structure of formal education and training system in Tanzania is **2-7-4-2-3+** - meaning two years of Pre-Primary education; seven years of Primary education; four years of Ordinary Level (O-Level) secondary education; two years of Advanced Level (A-Level) secondary education; and, three to five years of university education depending on the type of degree programme. For example, Engineering and Pharmacy degrees take four years and Medicine takes five years. Other degrees, including Education, take three years. Besides formal schooling there are other channels of post-primary and post-secondary education and training such as: certificate and diploma training colleges/institutions which take less than three years of training.

The criteria used to promote students from one level of education to another are grades obtained from their final examinations, at each level that are usually set by an external examination body. The centralised education provision in Tanzania is administered through two units: the Tanzania Institute of Education (TIE) for curricula matters, and the National Examination Council of Tanzania (NECTA) for examinations. Tertiary education has its own curricula orientations and quality assurance.

2.5 Secondary education curriculum

The secondary education curriculum was diversified in the early 1970s into streams such as; commerce, home economics, technical and agriculture. The options aside from the compulsory subjects vary from stream to stream, however there is a set of core subjects including Mathematics, English, *Kiswahili*, Civics and Biology, which are compulsory at O-Level, Physics, Chemistry, History and Geography are core subjects but optional after the second year of secondary education. Computer science is also an additional subject. Religious instruction is obligatory to all students. A- Level students study subject combinations of their choices depending on their performance in the National O-Level examination. Civics education is a compulsory subject to all A-Level students while Basic Applied Mathematics (BAM) is a subsidiary subject to all students who do not study Advanced Mathematics, with exception of those who are studying languages.

2.5.1 Science teaching and learning in Tanzanian secondary schools

In Tanzania the formal teaching and learning of science begins at primary school level where students are taught general science limited to basic concepts in biology, chemistry and physics. Learning is guided by a science syllabus for each level of primary education from standard 1-7.

Secondary science is based on the individual subject syllabuses. At O-Level biology, chemistry and physics are taught as core subjects. In the first two years (Form 1 and Form 2) of O-Level education all three subjects are compulsory for all students. In Form 3 and 4 chemistry and physics are core subjects and optional for students majoring non-science subjects. Biology remains as a compulsory subject to all O-Level students. The maximum time for O-Level science subjects per week is 2 hours and 40 minutes (4 periods per week, each single period is 40 minutes). For A-Level the maximum time is 6 hours and 40 minutes per week (10 periods per week) each double period is 80 minutes (MOEC, 2002). The time allocated by the government for each level ensures that the respective syllabuses will be covered within the specified time of each level. However classroom realities in schools show that there are several problems affecting the realisation of the school timetable (Chonjo, *et al.,* 1996; Mafumiko, 1998; Osaki, 1999; Bathlomew, 2008).

These problems have created some challenges in teaching and learning secondary science that include lack of, or non-use of laboratories and other teaching and learning materials and resources. In most schools this has resulted in students doing science subjects theoretically, and most achieving poor grades (Ministry of Education and Vocational Training - MOEVT, 2010). Ineffective teaching and learning approaches in the classrooms (such as excessive use of a lecture-style method) resulted in students relying on the teachers' notes, and the acute shortage of qualified science teachers has exacerbated the problem resulting in poor performance. For example, The Performance Audit Report on school inspection in Tanzania in 2009 indicated that there were high levels of failure in science and mathematics since 2003 (URT, 2009). The percentages of students who failed in physics, chemistry and biology in 2004 Form 4 examinations were 43%, 35% and 45% respectively. Similarly in 2005 figures were 45%, 35% and 43%.

Table 2.1 presents the students' performance in biology subject in the final Form 4 examinations between 2006 and 2010.

Table 2.1 Students' performance in biology Form 4 final examinations (2006-2010)

Year	No. of students	Passed	%	Failed	%
2006	83,253	42,795	51.40	40,273	48.6
2007	122,532	70,415	57.47	52,117	42.53
2008	161,947	71,566	46.28	83,065	53.72
2009	236,326	102,982	43.43	134,157	56.50
2010	350,601	103,393	30.49	244.208	69.51

Source: National Examination Council of Tanzania (NECTA, 2011).

The data in Table 2.1 shows that as the number of candidates increased yearly, the number of students who failed in biology increased. This situation is similar for subjects such as physics and chemistry.

Several studies conducted in Tanzania affirmed that reasons for continuing poor performance of students in science subjects included teachers' preference in using traditional lecture-style teaching and learning methods (Bathlomew, 2008; Mafumiko, 2006), acute shortage of teaching and learning materials and equipment in most schools especially in the new Government Community schools (Bathlomew, 2008; MOEVT, 2010), shortage of science teachers in some schools, and teachers lack of both content and pedagogical content knowledge (Chonjo & Welford, 2001; Kitta, 2004; Babyegeya, 2006).

2.6 Secondary school teacher education and re-training

In Tanzania, teachers are educated in teachers' colleges. The management and provision of teacher education programmes are largely the responsibility of the government through the Ministry of Education and Vocational Education. In its appraisal document, the Education Sector Development Programme (ESDP) recognised that teaching, like other professions, is in a constant state of renewal and that the initial, induction, and in-service training are different phases of the same generic process, namely teacher education (Government of United Republic of Tanzania - GURT, 2001b). The three categories of teachers prepared are:

i) Certificate teachers for primary schools: Teachers from this category are prepared to teach specific subjects in the primary school curriculum;
ii) Diploma teachers' teach O-Level in secondary schools: Teachers from this group are trained to teach two teaching subjects in the O-Level secondary school curriculum;
iii) Graduate teachers teach A-Level in secondary schools and teachers' colleges.

The teachers' preparation programmes in Tanzania are: pre-service and in-service (GURT, 2001b).

2.6.1 Pre-service science teachers' programmes

There are two levels of pre-service programmes GURT (2001b) one takes place at Diploma teachers' colleges, and the other takes place at the University level. At Diploma level the programme takes two years and it enrols students from A-Level, especially those who have not met the minimum entry qualification for the degree programmes. The pre-service teachers' curriculum component comprises both academic and professional subjects. Here teachers are prepared to teach two science subjects at O-Level secondary schools. The professional component focuses on provision of pedagogical skills together with foundation knowledge in principles of education, curriculum, psychology, and educational management.

Pre-service teachers who join Universities usually study for three years. Their curriculum comprises two teaching subjects for those who study Bachelor of Science with Education (B Sc.Ed) and one teaching subject for those in Bachelor of Education (B. Ed). The other part of their curriculum is a professional component similar to the Diploma teachers' with eight weeks of field work (teaching practice) in secondary schools and teachers' colleges.

2.6.2 Constraints in pre-service teacher education at diploma level

One of the major obstacles in the preparation of pre-service science teachers' is the financial constraint. Underfunding or *ad hoc* funding makes long term planning difficult at institutional level (Kitta, 2004). For example, Diploma colleges are sometimes forced to close earlier for vacation due to lack of funds. While Tanzania has come a long way in restructuring and running of pre-service teacher training programmes have not often been formally evaluated and revised until foreign assistance is available (Osaki, 2007). This factor has affected the quality of the knowledge base of pre-service teachers who graduated from previous programmes that were based on an ineffective curriculum (Meena, 2009). The continuous enrolment of academically weaker students in Diploma teachers' colleges from A-Level secondary schools has contributed to the problem of having O-Level teachers with little subject content knowledge, and has also affected the selection and use of appropriate methods for classroom discourse (Osaki, 2007; Bathlomew, 2008).
These constraints render science teachers who are inadequately prepared and provide inadequate teaching foundations for subsequent in-service education programmes.

2.6.3 In-service teacher education

In-service education programmes are considered an effective way to help teachers grow professionally (MOEC, 2001). Professional inputs for teachers are regarded to have a substantial impact on students (MOEC, 2001). Emphasising in-service education the Tanzania Government through the Education and Training Policy declares that: "In-service teacher training and re-training shall be compulsory in order to ensure teachers' quality and professionalism" (MOEC, 1995: 33).

There are two patterns through which in-service education programmes for secondary school science teachers are conducted (MOEC, 2001). The first one is conducted by Universities such as the University of Dar es Salaam, in collaboration with the Curriculum Development Unit (TIE) and officials from the Ministry of Education. In this collaboration science teachers are provided with knowledge and skills on specific topics by lecturers from departments of the College of Science and School of Education. The second pattern involves individual university lecturers and other facilitators from the Ministry of Education organising in-service training for teachers in their respective working zones or regions. The Ministry of Education via departments such as teacher education or secondary education are responsible for organising in-service training for teachers and educators.

2.6.4 Constraints in science teachers' in-service training

Even though there is a policy for in-service teacher education, the current level of support for in-service teacher education in Tanzania is inadequate, mainly due to lack of funds and management problems (Babyegeya, 2006). Running most in-service teachers' programmes depends on foreign aid and grants (Bathlomew, 2008; Osaki, 2007). The majority of teachers have no access to in-service courses or seminars (Kitta, 2004; Osaki, 2007). Despite several curriculum reforms in primary, secondary and teachers' colleges, teachers have not refreshed their knowledge to cope adequately with reforms, and as a result new or unfamiliar topics are left untaught or not dealt with effectively (Mushashu, 2000). Mostly, teachers teach as they were themselves taught, and the evidence shows that teachers lack the necessary competencies and confidence to deal with classroom instructional activities. In most cases, this is because they never learned these aspects from their initial teacher preparation and in their schooling (Mafumiko, 2006). This is the area where compulsory in-service education for science teachers' is most urgent.

The following section illustrates professional development initiatives which have been implemented to improve science teaching and learning in Tanzania.

2.7 Science teachers' professional development initiatives undertaken in Tanzania

Efforts have been made by the Government of Tanzania, via the Ministry of Education and through private sectors, towards empowering secondary school teachers to improve their teaching methods through in-service training workshops. The established science and mathematics projects included Science Education in Secondary School-SESS (1996-2006). This project was designed to improve classroom performance in secondary science and mathematics by supporting in-service training of teachers, and was jointly financed by the Tanzanian and German Governments. Only 15 secondary schools were involved in this project which aimed at equipping these schools with science equipment, resources and textbooks and facilitated in-service programmes for science and mathematics teachers.

An internal evaluation of this project in the year 1999 showed that, while textbooks and laboratory facilities had increased in targeted schools, changes to classroom practices were minimal, because teachers hardly used the provided resources in their lessons (Osaki, 1999). In 2006, SESS project was integrated in the secondary education department of the Ministry of Education and Vocational Training (MOEVT) for monitoring and safety of materials and equipment left in schools (Osaki, 2007). Another project, the Science Teacher Improvement Project (STIP), was supported by the German and Tanzanian government organisation GTZ (Osaki, 2007). The STIP project operated in schools owned by the Christian Social Services (CSSE) from 1995 to 2003, and it emphasised strategies for doing science experiments called the Starter Experimental Approach (SEA). In this approach, skills on how to manage scientific experiments were discussed in the trial workshops. This project ended abruptly in 2003, and its ideas integrated into the SESS project for administrative and management reasons, i.e. the project shared the financial support with SESS project.

Another project was the Teacher Education Assistance in Mathematics and Science (TEAMS) which focused on the PD of science and mathematics of A-Level and undergraduate teachers at the University of Dar es Salaam from 1995 to 2004 (Osaki, 2007). The project was jointly funded by the government of Tanzania and the Netherlands. Its major focus was staff development and capacity building in science and mathematics education. The TEAMS project has contributed to the review and introduction of pre-service undergraduate science courses that are closely connected to the secondary school curriculum in order to improve the quality of secondary school teachers' preparation.

One other project was the Education II Project which was supported by The African Development Bank (ADB) and implemented by the Faculty of Education, University of Dar es Salaam in collaboration with the Ministry of Education and Culture (MOEC, 2002). It focused on capacity building among science teachers' and educators enabling them to identify and use appropriate teaching materials and methods during preparation and execution of lessons. The main outcomes of this project include development of modular training materials for science and mathematics teachers, science and mathematics college educators, secondary and teachers' college inspectors and headmasters /headmistresses. Even though the Education II project ended in 2006 it has not been evaluated (Osaki, 2007). The lessons learned from implementation of the above mentioned projects include:

i) Increased laboratory supplies in some schools do not necessarily make teachers more inquiry oriented (Chonjo *et al.,* 1996; Osaki, 2007);
ii) Student-centred approaches, laboratory experiments and other innovations taught in the workshops may not be practiced in schools if there were no follow-up strategies including peer coaching, mentoring and effective school management (Kitta, 2004; Osaki, 2007);
iii) The supply of textbooks and other materials were not accompanied by addressing local relevance and teacher support on how to motivate and encourage their use for instructional activities (Osaki, 1999: 2007);
iv) As enrolment expands students' diversity increases and teachers need to be prepared for a more constructivist approach to teaching and handling of individual student problems (Osaki, 2007).

Reflection from the above mentioned projects together with other efforts made by the Ministry of Education and Vocational Training emphasises the potential of pedagogical content knowledge in teachers' education in order to improve science teaching and learning (Osaki, 2007). Furthermore, lessons learned from past projects (Hongoke, 1997; McKenney, 2001; Ottevanger, 2001) indicate that innovation succeeds only if there is a pioneer group of teachers to carry out or catalyse the innovation until the new generation of transformed teachers is ready to continue to carry out the innovation. Similarly, Bransford, Brown, and Cocking (1999: 191-2) found that:

> Teachers are the key to enhancing learning in schools, in order to teach consistently with new theories of learning, extensive learning opportunities for teachers are required. We assume what is known about learning apply to teachers as well as students.

The following section presents the findings from the preliminary field-based investigation which was conducted by the researcher prior the present study (in April, 2010).

2.8 Preliminary field-based context analysis

This section presents a situational analysis of teaching and learning of biology in two schools. The researcher conducted three unstructured classroom observations during the context analysis stage of the study in order to investigate the current situation in the teaching and learning biology in secondary schools. This included how teachers prepared for the teaching and the instructional methods they used in classroom interactions. Another reason was to solicit collaboration with the key participants of the study in order to ascertain potential causes of prolonged use of ineffective instructional approaches in the teaching and learning of science (biology), and gain insights about their possible needs. Three teachers' in two schools were involved in the classroom observations (Table 2.2) after granting permission to be observed.

Table 2.2: The profile of teachers involved in the classroom observation

Schools	**Participants**	**Sex**	**Qualification**	**Teaching Experience**	**No. of students**
S1	Teacher A	F	Dip	16 years	52
	Teacher B	M	B Ed. Sc	8 years	55
S2	Teacher C	F	Dip	10years	48

The observed lessons and length were:

- *Transport in living things* taught to Form *II* students (teacher A). Lesson time 80 minutes;
- *Classes of division (angiospermophyta*) taught to Form *III* students (teacher B). lesson time 80 minutes; and
- HIV and AIDS (the *causes, transmission and prevention*) taught to Form *I* students (teacher C). Lesson time 40 minutes.

The lessons were audio-recorded, transcribed, and qualitative content analysis was used to summarise data and categorise them into themes indicating the observed instructional activities such as general observation, lesson introduction, presentation and conclusion. Information from teachers' lesson plans was sought to support findings from classroom observations and the researcher's field notes. The following sections provide descriptive analysis of the preliminary field-bsed classroom observations.

General observation. School S1 had one laboratory used by all science subjects while school S2 had two laboratories, one for chemistry and biology subjects and another for physics. A few students in school S2 had biology textbooks on their desks which were not used during the lesson. The nature of interaction between the teacher and students in all classes was unidirectional because most of instructional time was dominated by the teacher's explanation of the lesson facts and writing notes or diagrams on the blackboard. There were no teaching aids apart from using blackboard illustrations which were meant for students to copy and not for supporting students' understanding of teachers' explanations. Students remained passive listeners, they neither asked questions nor were they involved in doing practical work or in discussions. The main student activities were copying notes from the blackboard and teachers' explanations, and occasionally, answering a few questions from their teachers.

Lesson introduction. The initial activity observed across all teachers was reviewing the previous lesson. Two teachers used a question and answer technique while the other teacher provided students with a summary of the previous lesson on the *distinctive features of angiospermophyta.* Teachers used 4-6 minutes in the lesson for the introduction before an explanation of the new lessons.

Lesson presentation. Most of the instructional time was used in this part of a lesson (i.e. 25-45 minutes) which was dominated by teachers' explanations of the lesson facts and writing of short notes on the blackboard. While Teacher A and B drew diagrams on the blackboard to support their explanations of the lessons, Teacher C read her lesson notes, whilst writing on the blackboard. Students remained passive listeners and sometimes, they were copying notes and diagrams.

Lesson conclusion. The lesson conclusion was characterised by students copying notes from the blackboard; in Teacher C's class it was hard to differentiate between the previous part of the lesson and the conclusion because the same activities continued throughout. There was no explicit attempt by teachers to summarise or evaluate the taught concepts or to use other techniques to check for students' understanding. Teacher B asked one question from his lesson content but students' answers were superficial which did not impress their teacher who continued asking for further information.

Qualitative content analysis was used to analyse data from teachers' lesson plans to find out how teachers prepared for the observed lessons and whether their instructional practices were in line with intentions indicated in their lesson plans. Findings show that all teachers had specific lesson objectives, two teachers' had indicated that students would be involved in doing experimentation and observations, but there were no specific strategies about how to implement the activities including the required materials stated in their lesson plans. These findings contradicted the observed teachers' classroom practices.

The findings from this field-based investigation suggested that teachers might have realised the importance of using experiments and observations in their lessons (as also indicated in their syllabuses), but they did otherwise. The informal discussion with teachers after each classroom observation confirmed that teachers preferred to use chalk and talk methods because it helped them to cover a larger amount of lesson content which would enable them to teach all the required biology topics in the syllabus in time available. Two teachers said that they faced challenges in using practical activities including laboratory experiments with students because they were unfamiliar with their preparation and organisation, and the fact that their schools did not have laboratory technicians to provide assistance made it more difficult to conduct experiments with students. They further argued that sometimes, they read about procedures for conducting practical activities from biology textbooks.

2.9 Summary and justifications for the study

From the context analysis it is evident that the increased enrolment in secondary schools in Tanzania is not matched by improvements in the teaching force, curriculum, teaching and learning materials, resources, or improvement in student learning outcomes. The policy documents such as the MOEVT (2010) and MOEC (2002) emphasised the need to expand the teaching and learning of science and consequently expand enrolment in science subjects in higher education, which will encourage increased annual student intake in science subjects at secondary school level. However this emphasis contradicts the findings of context analysis. For example, findings in Section 2.5.1 indicated that there were high levels of failure in the science final national examinations which resulted in a shortage of students specialising in science subjects in higher education. Similarly, findings from the field-based investigation revealed that teaching and learning of secondary science takes place in a very restricted environment, and the predominant teaching methods in Tanzanian secondary school science classrooms are teacher-centred.

Most secondary schools have unqualified and under-qualified teachers with little or no pedagogical knowledge and skills. Furthermore, qualified science teachers also lack confidence in the preparation and teaching of their lessons due to the inadequate teacher education they received in colleges and poor science learning background from secondary schools. The content analysis of past studies further indicates inadequate in-service training opportunities for science teachers. The projects mentioned in this chapter were externally funded and not sustainable. Most teachers who attended these projects workshops had problems in practising the acquired knowledge and skills in their respective classrooms, probably due to differences in settings (i.e. between the workshop and teachers' classrooms) in terms of resources and materials and lack of follow-up support. Most of the in-service teacher training did not focus on the impact of PD on student learning outcomes, which is an indicator of teaching and learning effectiveness.

Chapter 3

The Theoretical Framework of the Study

3.1 Introduction

This chapter presents the constructivist theoretical framework of the study, its application in science teaching and learning, and implementation strategies. Constructivist learning theory guided the process of developing teachers' support materials, and activities in the teachers' professional development workshop. The chapter begins with a brief description of why the study opts for a constructivism perspective. Section 3.3 discusses constructivism as a theoretical framework and theory of learning, which has roots in Piaget's cognitive and Vygotsky's social cultural perspectives on teaching and learning. Section 3.4 discusses the importance and roles of students' prior ideas and conceptions in the instructional process. This section also presents effective approaches to teaching and learning of science. Section 3.5 discusses Bybee's '5Es' instructional model as a framework for supporting teachers in lesson planning and teaching in ways advocated by constructivists, and Section 3.6 summarises the chapter and implications for the study.

3.2 Why constructivism learning theory?

The way we define learning and what we believe about the way learning occurs, has important implications for situations for facilitating changes in what people know and do (Ertmer & Newby, 1993). Learning theories provide instructional designers with verified instructional strategies and techniques for facilitating learning, as well as foundations for intelligent strategy selection. According to Shuell, as interpreted by Schunk (1991: 2), "learning is an enduring change in behaviour, or in the capacity to behave in a given fashion which results from practice or other forms of experience". Schunk defined five questions to distinguish learning theories:

i) How does learning occur?
ii) Which factors influence learning?
iii) What is the role of memory?
iv) How does transfer of learning occur?
v) What types of learning are best explained by the theory?

Ertmer and Newby (1993) added two questions specifically important to the instructional designer:

i. What basic assumptions/ principles are relevant to instructional design?
ii. How should instruction be structured to facilitate learning?

This section briefly outlines the basic concepts of educational learning theories such as behaviourism, cognitivism, and constructivism (Pritchard, 2010), by considering the abovementioned questions.

3.2.1 Behaviourism

Behaviourism is based on observable changes in behaviour which focuses on a new behavioural pattern being repeated until it becomes automatic, including the use of instructional cues, practice, and reinforcement (Pritchard, 2010). The key elements in the learning process are the stimulus, the response, and the association between the two. Behaviourists (e.g. Pavlov, Watson, Thondike and Skinner) did not explicitly address memory; although the acquisition of 'habits' is discussed, little attention is given as to how the 'habits' are stored or recalled. Learning involves discrimination (recalling facts), generalisation (defining and illustrating concepts), association (applying explanations) and chaining (automatically performing a specified procedure). The role of a teacher is to:

i. Determine which cues can elicit the desired responses;
ii. Arrange practice situations in which prompts are paired with the target stimuli that initially have no eliciting power, but which will be expected to elicit the responses in the natural setting; and

iii. Arrange environmental conditions so that students can make correct responses in the presence of those target stimuli and receive reinforcement (Gropper, 1987).

3.2.2 Cognitivism

In the late 1950s learning theory began to make a shift away from the use of behavioural models to models from the cognitive sciences. Cognitive theories stress the acquisition of knowledge and internal mental structures (Section 3.3.1). They focus on how information is received, organised, stored, and retrieved by the mind. Cognitivists presumably do not place great emphasis on environmental conditions to facilitate learning, but other factors such as learner's thoughts, beliefs, attitudes, and values are also key elements of the learning process (Ertmer &Newby, 1993). Memory is regarded as prominent, because cognitivists regard it as the result of learning. The actual goal of instruction for behaviourism and cognitivism is often to communicate or transfer knowledge to students. However, behaviourists focus on environmental condition while cognitivists emphasise efficient processing strategies. Specific assumptions that have direct to instructional design include:

The role of the teacher is to:

i) Understand that individuals bring various learning experiences to the learning situation which can impact learning outcomes;
ii) Determine the most effective manner in which to organise and structure new information to tap the learners' previously acquired knowledge, abilities, and experiences;
iii) Arrange practice with feedback so that the new information is effectively and efficiently assimilated with the learners cognitive structure (Ertmer &Newby, 1993; Pritchard, 2010).

3.2.3 Constructivism

Constructivism is based on the premise that we all construct our own perspective of the world, through individual experiences and schema. The philosophical assumptions underlying both behaviourism and cognitive theories are primarily objectivism (Jonassen 1990), but the constructivist approach is more learner-centred. Constructivists look at the learner as more than just an active processor of information (Pritchard, 2010). Learners create their own meaning of knowledge. Therefore, the goal of instruction is not to know particular facts, but to interpret and elaborate on information. As one moves along the continuum from behaviourism and cognitivism, to constructivism, the focus of instruction shifts from teaching to learning, from passive transfer of facts, and routines to the active application of ideas to problems (Ertmer & Newby, 1993). Both learners and environmental factors are important. The key elements in the learning process are activity (practice), concept (knowledge), and culture (context) (Brown, Collins, & Duguid, 1989). Understanding can be facilitated by involvement in authentic tasks anchored in meaningful contexts. The role of the teacher is: i) to instruct learners on how to construct meaning, and ii) to align and design experiences for the learner so that authentic relevant contexts can be experienced. Instructions in constructivism have the following principles (Ertmer & Newby, 1993; Pritchard, 2010):

i. An emphasis on the identification of the context in which the skills will be learned and subsequently applied;
ii. An emphasis on learner control and the capability to manipulate information;
iii. The need for information to be presented in different ways;
iv. Supporting the use of problem solving skills to go beyond the information given;
v. Assessment focused on the transfer of knowledge and skills.

Based on this brief comparative analysis of the three learning theories, this study is influenced by the constructivist perspective as discussed in the following sections.

3.3 The constructivist theoretical framework

The constructivist theoretical framework provides a basis for understanding how human beings integrate new knowledge into existing cognitive structures and then make sense of that knowledge (Ferguson, 2007). Studies that use constructivism as a theoretical framework set out to answer questions on how people construct knowledge in a particular setting, and the effects of people's behaviour and those they interact with on knowledge construction (Ferguson, 2007). For example a study conducted in Midwestern, USA by Hand *et al.,* (1999) examined junior secondary school students' responses to the implementation of a constructivist approach to the teaching of science. Findings of an open-ended questionnaire and semistructured interviews show that students were more actively involved, had more discussions, practical work, and more fun. The constructivist teaching and learning strategies led to greater understanding of concepts. It was seen that students were more active in the learning process. They had an opportunity to see and control their thinking, constructed correct knowledge, and were more confident in their understanding of science.

Similarly, the evaluation of Math Wings project in the USA (a programme to improve mathermatics teaching and learning which uses a constructivist approach to teaching) has shown positive results in a number of different school districts. Comparison of schools using the programme effects to matched schools that did not use the programme showed positive programme effects on standardised tests. The children in the programme schools did better than those in the matched schools. The tests focused on basic skills as well as higher-order skills (Madden *et al.*, 1999).

On the other hand, not all studies show positive results though. One USA study looking at the implementation of a science teaching reform programme that used a constructivist framework reported no effects on either achievement or pupil attitudes to science. While research that used data on the level of implementation of the constructivist teaching within the same programme likewise found no effects (Shymansky *et al.,* 2000)

Constructivism has been a major theoretical influence in contemporary science education. It is an epistemological theory which defines the nature of knowledge and understanding Guba and Lincoln (1994) and from an epistemological point of view constructivism is a theory of how we gain knowledge and is used to explain how we know and what we know (Von Glasersfeld, 1996). Educators' beliefs about how people learn (i.e. their personal epistemology) whether verbalised or not, often help them make sense of, and guide their practice (Lorsbach & Tobin, 1993).

3.3.1 Constructivist learning process

Constructivism considers learning as a construction of knowledge by individuals. In this theory of learning it is acknowledged that students may bring prior ideas to instruction (Von Glasersfeld, 1996). In science education, the students' prior ideas may be in conflict with scientific knowledge being taught, and hence, would affect the students' conceptual understanding (Scott *et al.,* 1994). Knowledge construction is viewed as an active process, and social interactions among students are central in the construction of knowledge by individuals (Von Glasersfeld, 1996). Where students have some prior knowledge or concepts, such knowledge is crucial to the students' understanding of the new information or concepts (Cakir, 2008). Therefore, the teaching and learning process should be an active negotiation to process meaning which involves finding out and engaging with students' ideas wherever possible (Carr *et al.,* 1994; Scott *et al* ., 1994).

The constructivist theory of learning has its roots in Piaget's cognitive and Vygotsky's social cultural perspectives on teaching and learning of science. Piaget's cognitive perspective on learning, regards human beings as an active, independent meaning-makers who construct their knowledge, as opposed to simply receiving it (Moore, 2000; Piaget, 1975).

When individuals construct knowledge, the new information is either integrated into the existing understanding, a process Piaget calls *assimilation*, or if the new information contradicts the existing knowledge, restructuring of knowledge occurs to adapt the new information in a meaningful manner, which he called *accommodation* process. In this cognitive view of learning, human beings achieve a balance between *assimilation* and *accommodation* through their interactions with their physical and social environments, and Piaget called this process *equilibration*, or self-regulation (Moore, 2000). From a cognitive perspective, *equilibration* entails comprehension of science concepts. Therefore, to assist students in the learning process the teacher should be aware of students' existing knowledge and any cognitive conflicts that students may experience, so as to engage them in meaningful activities. Such activities should help students to work with their prior ideas during the teaching of the scientific concepts being explored in the topic in order to resolve their conflicts and enhance conceptual understanding (Posner *et al.*, 1982). Ausubel (1963) also promoted the cognitive approach to learning from what he called *meaningful* learning. He emphasised that, prior knowledge or existing *schemata* are of central importance if the learner is to meaningfully acquire new information or concepts. Ausubel postulated that meaningful learning occurs when new information is subsumed by existing relevant concepts, and these concepts undergo further change and growth (Novak, 1998). Therefore, effective instruction requires the teacher to choose important or relevant information to teach, and to provide the means to help students relate this information to concepts they already possess (i.e. *existing schemata*).

Vygotsky's socio-cultural perspective of teaching and learning emphasises the process of social interaction in one's construction of knowledge. In this view learning occurs when the students interact with people who have additional relevant knowledge (Vygotsky, 1978). For Vygotsky, language is a tool that a student uses to construct knowledge during social interactions with others in order to develop a personal understanding, i.e. students need to talk with their peers and the teacher in order to articulate their prior ideas about a concept, or their explorations made in an investigation, to clarify their thinking and correct their misconceptions (Driver *et al.*, 1994; Osborne, 1997).

According to Vygotsky, students have two levels of development: the actual developmental level that refers to the already mature mental abilities which enable the student to solve problems independently, and the potential developmental level that refers to higher mental functions that are not yet mature. The student can use these higher mental functions to solve problems only with the help of an adult or a peer who has more relevant knowledge than him/her. The difference between these two levels is what Vygotsky calls the Zone of Proximal Development (ZPD). The ZPD is accessed through student-teacher interaction or cooperative problem solving with peers (Liang & Gabel, 2005). From this perspective the teacher can help students understand scientific concepts by assigning challenging tasks and engaging students in small groups and whole class discussions with the guidance of teachers through scaffolding, i.e. allowing students to perform tasks that would normally be slightly beyond their ability without that assistance and guidance from the teacher (Duffy & Jonassen, 1992). Eventually, a teacher can withdraw leaving the student under full control of the newly constructed extension of their knowledge. Therefore, the knowledge is personally constructed in the process that is mediated by social interaction (Driver *et al.*, 1994; Windschitl, 2002).

Although the term 'constructivism' encompasses a variety of theoretical positions and has mainly been applied to learning theories, focusing on 'learning' as a conceptual change Driver and Oldham (1986) and to curriculum development and teaching, mainly in science (Osborne & Wittrock 1985). It also provides some clear pointers towards teaching strategies that might assist students in conceptual reconstruction Hodson & Hodson, 1998), such as:

i) Identifying students' views and ideas;
ii) Creating opportunities for students to explore their ideas and to test their robustness in explaining phenomena, accounting for events and making predictions;
iii) Providing stimuli for students to develop, modify and where necessary, change their ideas and views;
iv) Supporting their attempts to re-think and reconstruct their ideas and views.

Students' prior conceptions and social interactions with teachers and peers are very central in the constructivist theory of learning. The assumption is that students use prior conceptions as a foundation for the new knowledge and during interaction with others, students use their previous ideas to negotiate for the meaning of what is being taught (Carr *et al.*, 1994; Driver *et al*., 1994; Cakir, 2008). Therefore, working with students' prior experiences and using active teaching and learning strategies are fundamental classroom practices in the constructivist teaching and learning process.

3.4 The importance of determining students' prior experiences

Determining students' existing ideas and conceptions has been recognised as an important variable in science teaching and a necessary part of teaching strategies (Ausubel, 1968; Driver *et al.,* 1994; Goodrum, Hackling & Rennie, 2001; Osborne & Witttock, 1983). These authors argued that teaching science is effective when students' existing ideas, values, and beliefs which they bring to a lesson are elicited, addressed, and linked to their classroom experiences. There is a common belief that students do not arrive in the classroom as empty vessels into which new ideas can be poured by teachers (Carr *et al.,* 1994; Leach & Scott, 1995; Tytler, 2002). They have prior ideas and conceptions about the events and phenomena in the world around them which might be different from those intended by the teacher and the scientific community.

Meaningful learning occurs as students consciously and explicitly link their new knowledge to the existing knowledge structure (Ausubel, 1968; Wittrock, 1994). This implies that the effective instructional approach has to be based on what is already known by the learner. Therefore, the diagnosis of learners' pre-existing knowledge is important for teachers in order to plan subsequent teaching activities and help students link the new material to what they already know. Driver (1989) used a constructivist epistemology as a referent in her research on children's conceptions in science, where she found that children's prior knowledge of phenomena is an important part of how they come to understand school science. Often, the interpretation of phenomena from a scientific point of view differs from the interpretation that children construct; meanings that fit their experiences and expectations. This can often lead children to construct meanings different from what was intended by a teacher.

Determining students' existing ideas and conceptions may increase students' awareness of them, which is necessary for meaningful learning (Ausubel, 1968; Mintzes, Wandersee & Novak, 1998). According to Vosniadou (1997: 39), 'students do not appear to know that their explanations of physical phenomena are hypotheses that can be subjected to experimentation and falsification. Their explanations remain implicit and tacit'. When students become aware of their previously 'tacit' ideas, they have a chance to compare them with scientific ones and change them if necessary.

Determining students' prior ideas and conceptions also helps teachers confront any alternative ideas or misconceptions students may have held at an early stage in the learning process so that these do not hinder student learning (Littledyke, 1998). Through determining students' prior conceptions teachers can develop appropriate instructional strategies that move these underdeveloped ideas and conceptions towards scientific ones (Hipkins *et al.,* 2002). According to Hipkins *et al.,* (2002) when teachers take into account and build on students' existing ideas, experiences and values, science education can become more inclusive for students from diverse cultures, girls and boys, students with special needs and special abilities.

3.4.1 Eliciting students' prior ideas and conceptions

The literature reports a wide range of instructional approaches and activities that teachers can use to elicit students' existing ideas and conceptions, these include: reviewing previous work and stating goals, questioning, group discussions, brainstorming, debating ideas, providing examples, and conducting experiments (Cimer, 2007). On the use of the questioning technique, Cimer (2007) indicated that, open-ended questions are more effective in eliciting students' prior conceptions because they expose deficiencies in students' responses. This is probably because open-ended questions allow students to express their opinions, unlike closed questions which seek predetermined responses.

3.4.2 Working with students' prior ideas and conceptions

Working with students' ideas and conceptions is the key to constructivist practices. Students do not change their ideas or conceptions easily, but they change them only if they see that the most scientifically valid ideas make sense to them and are more fruitful than their own in explaining a phenomenon and making predictions (Hodson & Hodson, 1998; Posner *et al.,* 1982). Many attempts have been made to change students' alternative ideas into scientifically accepted ones. One of the approaches has been the Conceptual Change Model (CCM) that involves the teacher making students' alternative frameworks explicit prior to designing a teaching approach that is intended to promote dissatisfactions. Students' dissatisfaction with the current belief can be induced by presenting anomalous data from text or, events, then a new scientific concept is introduced that competes with the existing theory, leading to a state of cognitive conflict in the learner's mind. When students resolve the conflict, they replace their old theory with new theory (Posner *et al.,* 1982; Strike & Posner, 1992). According to Posner *et al.,* (1982) the new conception should be *intelligible, plausible,* and *fruitful*. An intelligible conception is sensible if its meaning is understood by the learner; plausible means that in addition to knowing what the conception means, the learner finds it believable; and, the conception is fruitful if it helps the learner to solve other problems.

Peer interaction is another strategy which can be used by teachers to challenge students' prior conceptions (Cimer, 2007; Posner *et al.*, 1982). Peer interaction can be a valuable strategy by producing productive discussions whereby students experience dissatisfaction with their existing conceptions, and develop plausible new concepts and see the relevance of new knowledge in a different context (Abrams, 1998; Treagust & Duit, 2009).

Furthermore, conducting investigations or inquiry can also strongly challenge students' prior conceptions. They can apply their own ideas, observe the process or phenomenon, make predictions about the results and record the results of the experiment. When they achieve unexpected results, or find that others disagree with their interpretations, or see that their current ideas will not solve the new problem, their existing conceptions are challenged (Goodrum *et al.,* 2002). As a result they come to the understanding that they should either modify or discard these prior conceptions and construct new ones (Driver *et al.,* 1996; Osborne & Freyberg, 1985).

After determining students' existing ideas and conceptions, and making students aware of them, teachers need to introduce scientific concepts to help them construct new knowledge. For this, teachers can use short lectures or presentations; show a video or film, read a passage from the textbook or reference book (Glenn, 2001; Trowbridge *et al.*, 2000). In addition, Rosenshine (1997) suggests that this explanation phase should be clear and short, and should allow time for students to process new information and restructure their understanding. However, teachers should not rely on lectures too much for introducing new knowledge and skills because, as a traditional teaching method, lecturing can make students passive in the lessons, leaving too little time for them to process the new information (Parkinson, 2004). A strictly lecture-based presentation of facts and concepts may lead students to believe that everything has been figured out already and in order to pass their examination they must memorise facts and concepts instead of trying to understand them (Cimer, 2007).

The two important conditions that teachers should consider in explaining new concepts or ideas are creating attention in students and providing students with examples and opportunities to practice their ideas. The use of visual teaching aids can:

i) Provide more concrete meaning to words;
ii) Show connections, and relationship among ideas explicitly;
iii) Provide a useful channel of communication and make memorable images in students' minds;
iv) Make lesson material more interesting to students (Harlen, 1999; Joyce *et al.*, 2000a).

In order for students to comprehend new ideas or concepts and construct their own knowledge they need to see clear examples of what the new ideas and skills represent (Rosenshine, 1997; Trowbridge *et al.,* 2000). Furthermore, in learning new material or skills, students should be given an extensive opportunity to manipulate the environment (Joyce *et al.*, 2000a). As suggested by Piaget (1975), students' cognitive structure will grow only when they initiate their own learning experiences for example, Rosenshine (1997) suggests that, teachers should provide tasks where students can engage in cognitive processing activities with other students, or with the teacher, or working alone.

In addition, teachers should encourage informal discussion and structure science activities so that students are required to explain and justify their understanding, argue from the data, justify their conclusions, and critically assess the scientific explanations of a concept under study (Abrams, 1998). For effective learning of the new concepts to occur, teachers need to encourage students to apply the new concepts and skills in different contexts, which can help them achieve higher learning outcomes and use their knowledge and skills to solve problems in their everyday life (Schollum & Osborne, 1985). Teachers can employ various methods to help students to apply their knowledge, such as conduction of practical work, field trips, simulations, writing activities, and role- play (Millar, 2002; Tytler, 2000; Wellington, 1998).

3.4.3 Students' involvement in the lesson

Recently, there has been much emphasis on participatory lesson activities because there is a general agreement that effective learning requires students to be active in the learning process (Abell & Lederman, 2007). Active teaching and learning involves the use of strategies which maximise opportunities for interaction between teachers and students, and amongst the students themselves, as well as between students and materials and the topic at hand. In addition, researchers believe that the more students are involved in the learning process, the more they learn the topic and likely to develop a sense of ownership in relation to their learning (Deboer, 2002; Trowbridge *et al.*, 2004). Meaning can only be formed in students' minds by their own active efforts and cannot be created by someone else (Saunders, 1992). This suggests that students are not simply passive recipients of information from the teacher, computer, textbooks or, any other source of information during the learning process as advocated by traditional teaching and learning methods which are teacher-centred. Instead they have to grapple with an idea in their own minds until it becomes meaningful to them.

Active learning approaches can empower students to make good decisions and take an active role in their own learning, increase their motivation to learn, foster, and value the diverse voices of students (Deboer, 2002). This is opposite to passive learning approaches such as lecture-style, where the teacher seeks to transfer thoughts and meanings to passive students with an assumption that all students have the same level of background knowledge in the topic, and are able to absorb the materials in the same pace (Lord, 1999).

Different methods and strategies have been suggested for involving students in lessons and engaging them in active learning (Deboer, 2002; Trowbridge *et al.*, 2004). One of these methods, which is embraced in this study, is an activity-based approach. These approaches advocate the constructivist classroom practices and help students make deeper, more meaningful knowledge constructions than those derived from traditional classroom practices (Brooks & Brooks, 1993).

3.4.3.1 Activity-based teaching and learning approach

The term activity-based is usually used interchangeably and synonymously in the literature with, hands-on science/learning, hands-on activities, and learning by doing (Flick, 1993; Prawat, 2000a). This study adopted the same stance. Activity-based learning, however, is not simply manipulating objects; it is engaging in in-depth investigations with objects, materials, phenomena, ideas, and drawing meaning and understanding from those experiences (Haury & Rillero 1994; Meinhard, 1992). An activity-based approach requires students to become active participants instead of passive learners. Laboratory and field activities are methods which give students hands-on experiences (Woolnough, 1991).

According to Haury and Rillero (1994) an activity-based approach involves three components: i) *hands-on*; students are actually allowed to physically perform science tasks as they construct meaning and acquire understanding; ii) *minds-on*; the activities focus on the core concepts, allowing students to develop thinking processes and encouraging them to question and seek answers that enhance their knowledge, and thereby acquire an understanding of the real world; and iii) *authentic;* students are presented with problem-solving that incorporates real-life questions and issues in the format that encourages collaborative effort, dialogue with teachers or experts and generalisation to broader ideas and application. Activity-based teaching can be differentiated from lectures and demonstrations by the central criterion that students not only interact with materials or make observations but, it involved developing thinking processes and construction of meaning in order to acquire understanding. The assumption is that direct experiences with natural phenomena will provoke curiosity and thinking (Lumpe & Oliver, 1991).

3.4.3.2 The benefits of activity-based teaching and learning

Activity-based teaching and learning is embedded in constructivist theories of learning and used in science classrooms with positive outcomes, due to the fact that it focuses on providing students with physical experiences that induce cognitive conflicts and encourages students to develop new knowledge schemes (Bybee, 2004; Cimer, 2007). Generally, there is a plethora of benefits that teachers and curriculum developers adduce to hands-on learning to justify the approach in science. For example, McGervey (1995) observed that hands-on activities are a means of fostering students' participation in physics classes and can be used to illustrate basic concepts that are often overlooked. Similarly, Carlton (2000) argued that hands-on activities could be used to overcome misconceptions. Benefits for students are believed to include:

i) Increased learning, i.e. increased motivation to learn;
ii) Increased enjoyment of learning;
iii) Increased skill proficiency including communication skills;
iv) Increased independent thinking and decision-making based on direct evidence and experiences; and
v) Increased creativity (Haury & Rillero, 1994).

Research supports many of these claims by providing evidence that the learning of various skills and science content is enhanced through activity-based science programmes (Haury & Rillero, 1994). These benefits seem more than sufficient justification for promoting activity-based learning. However, Haury and Rillero (1994) provide an important addition- that it makes science fun for both the student and the teacher. Given the recent concerns about science anxiety and avoidance, enjoyment of science learning seems a worthy goal to be considered in choosing instructional approaches in science (Dillon & Manning, 2010).

In order for any instructional approach or method to be successful, effective lesson planning is essential (Henson & Eller, 1999; Harlen, 1999). A lesson plan requires teachers to be clear about the purpose and goals of the lessons and the sequence of the lesson activities. The planning process involves clarification of the roles of the teacher and student activities. Thus it makes it easier for students to follow the teacher's material, and encourages them to participate more in the lesson and take responsibility of their own learning (Calderon *et al.*, 1996). Effective lesson planning has a positive effect on student learning (Glenn, 2001). It is in the acknowledgment of what has been addressed in the aforementioned literature that this study adapted the 5Es instructional model Bybee (1997) (described in the following section) to guide teachers in the planning and teaching of the activity-based lessons. This will help to move students through a scientific investigation by starting their lessons with identification of prior conceptions make students aware of them and, in the light of these ideas, help students construct their own understanding. Teachers should also provide opportunities for students to apply their newly acquired knowledge to different situations.

3.5 The 5Es instructional model

Science reformers have argued that constructivism (in its many forms and interpretations) is not widely used in school science and technology education because teachers find it difficult to implement (Matthew, 1997). Some educators believe there is not enough time due to an overcrowded curriculum, while others find its construct, theoretical framework and practices difficult to comprehend (Richardson, 1997). Similarly, teachers do not consider constructivism as an approach to teaching and learning that can be followed to implement a teaching programme (Aubusson, Watson & Brown, 1998).

Nevertheless, it has been shown that constructivist theory can be implemented through different teaching models or designs, one of these being the *Five 'Es'* (Bybee, 1997; McNeill & Krajcik, 2008; Trowbridge, *et al.*, 2004). The *Five Es* (5Es) is an instructional model based on Piagetian theory. It is built around a structured sequence, and designed as a tangible and practical way for teachers to implement constructivist theory (Bybee, 1997). It purposefully promotes experiential learning by motivating and interesting students as they are encouraged to engage in higher-order thinking. This is not to say that by following such a model students will automatically become interested in the content presented, and therefore motivated to construct meaning for themselves, and so critically analyse and incorporate new views and different perceptions. Rather, the model provides a tangible referent (Ritchie, 1998; Tobin & Tippins, 1993) for teachers to support their developing expertise in structuring a learning environment that will facilitate students' interaction with a learning context in a critical reflective and analytical way.

In the 5Es model, students move through five stages of instruction: *Engagement, Exploration, Explanation, Elaboration* and *Evaluation* in a cyclical fashion as shown in Figure 3.1 (Bybee, 1997). The cyclical character indicates that, "constructivism is a dynamic and interactive process of how humans learn" (Bybee, 1997: 176). Each of these stages takes a student through a process of relatively unstructured experiences to more formal learning instruction. According to Bybee, the stages will enable students to use the existing conceptions to deal with new phenomena (i.e. assimilation), and to replace or re-organise the students' central conceptions (i.e. accommodation) as stated in Piaget's theory.

Designed primarily by science educators for secondary science teaching, the 5Es model has a classic constructivist structure, Trowbridge *et al.,* (2004) envision a five-stage model in which learners begin to investigate phenomena and eventually complete the learning cycle by creating conceptions, theories and generalisations based on their work. This model was first used as an inquiry lesson-planning model in the Science Curriculum Improvement Study (SCIS) programme, a K-6 science programme in the early 1970s in the United States of America. The early learning cycle had three stages i.e. *exploration, invention, and discovery* proposed by (Karplus & Thier, 1967). Using the learning cycle approach during the *exploration* stage the objects and phenomena are explored through hands-on activities with guidance thereafter, the teacher 'invents' the science concepts in the second stage (rather than defining them at the outset of the lesson as in the traditional approach). The introduced concept enables students to incorporate their exploration in the third stage and apply it to new examples.

The 5Es instructional model has been used in the Biological Science Curriculum Studies (BSCS) science programmes in the USA, as well as in other texts and materials (Bybee *et al*., 2006). The major instructional features of the five stages in the 5Es model are described below.

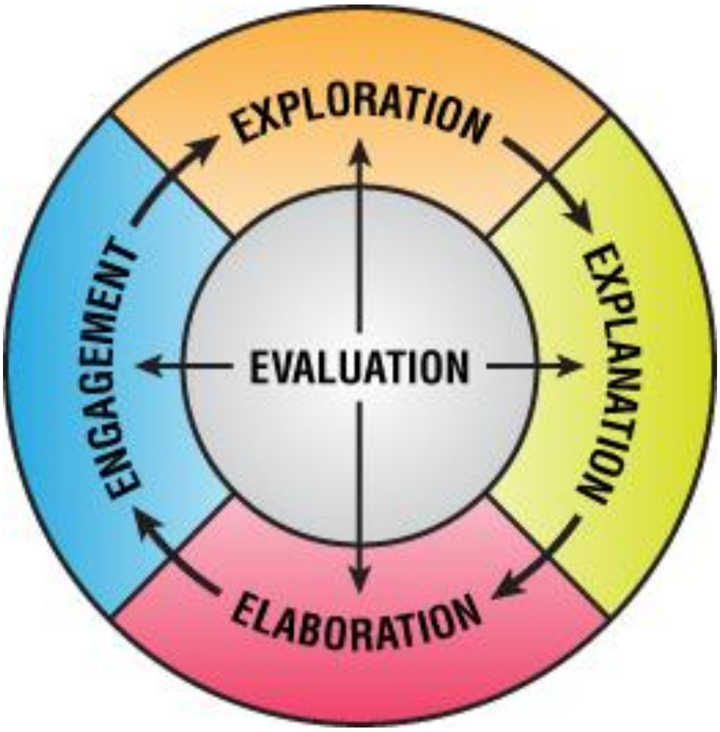


Figure 3.1 The Five Es instructional model
Source: (Bybee, 1997)

Engagement. In most instances, the teacher will want to begin with the e*ngagement*. In this stage the teacher wants to raise questions and elicit responses from students that will give the teacher an idea of what they already know.

This is also a good opportunity for the teacher to identify misconceptions in students' understanding. During this stage, students should be asking questions (e.g. *How can I find out? Why did this happen*?). Examples of engaging activities include the use of discrepant events, i.e. surprising or exciting events and activities that challenge students' preconceptions and awaken their curiosity (Lorsbach, 2006). Evaluation of the e*ngagement* phase focuses on what students already know about the topic at hand. In the current study this stage was replaced with the '*excitement'* in order to match the requirements of the context used (Section 6.2).

Exploration. During the e*xploration* stage students should be given opportunities to work together without direct instruction from the teacher. The teacher should work as a facilitator or a coach, which allows students the time and opportunity to investigate the objects, materials and situations, and helps students to frame questions by asking questions and observing. Using Piaget's theory, this is the time for *disequilibrium*. This is the chance for students to test predictions and hypotheses and/or form new ones, try alternatives and discuss them with peers, record observations and ideas and suspend judgment. Evaluation of Exploration focuses on the process, i.e. on students' manipulation and data collection rather than the product of students' data collection. Usually teachers ask questions such as: *How well are the students' collecting data?, Are they carrying out the procedure correctly?, How do they record data?,* and *Is it in a logical form or haphazard?* Answers for these questions will establish experiences that a teacher can use later to formally introduce a concept, process or skill (Ergin, 2012).

Explanation. During the *explanation* stage, the teacher should encourage students to explain concepts in their own words, ask for evidence and clarification of their explanation, and listen critically to one another's explanation and those of the teacher. This is a kind of social interaction advocated by Vygotsky's constructivist perspective between the student, teacher, and other students to reinforce their increased knowledge. Students should apply observations and data in their explanations. At this stage the teacher should provide definitions and explanations of concepts, processes or skills by using students' previous experiences as a basis for this explanation in order to facilitate the extension of students' Zone of Proximal Development (Vygotsky, 1978). The key to this stage is to present scientific concepts, processes, or skills in simple and meaningful ways (Ergin, 2012). The evaluation of the *Explanation* stage focuses on how well students use the information they have collected in relation to their prior conceptions to come up with new ideas.

Elaboration. During the *elaboration* stage students should apply concepts and skills in new (but similar) situations and use formal labels and definitions. The teacher should involve students in experiences that apply, and extend the learned concepts or skills. Students have to consider alternative explanations and use of the existing data and evidence as they explore new situations.

Exploration strategies apply here as well because students should be using the previous information to ask questions, propose solutions, and make decisions, experiment, and record observations (Lorsbash, 2006). Evaluation in this phase focuses on students' problem solving and critical thinking skills and ability to apply their understanding to a new situation.

Evaluation. *Evaluation* should take place throughout the learning experience. The teacher should observe students' knowledge and/or skills, application of new concepts and change in thinking. This is an important opportunity for the students to use the acquired knowledge and skills and evaluate their own understanding (Ergin, 2012). Teachers may provide practical activities or ask questions that would encourage future investigations (Lorsbach, 2006).
Students should respond to open-ended questions and looking for answers that use observations, evidence, and previously accepted explanations.

3.5.1 The impact of the 5Es model in science education

The range of applications of the 5Es Instructional model is one way to gauge its impact. For example, findings from web-based searches conducted by the five different Biological Science Curriculum Study (BSCS) research teams (2006), including reviewing of tables of contents, abstracts, and citations in articles, handbooks, journals, and summaries of chapters, showed that the 5Es model was used extensively in the United States of America, and internationally:

i) As a State and School District Science Frameworks in the USA;
ii) In teacher education programmes or resources for teacher education;
iii) In the curriculum to provide instructions or instructional guidelines for teachers;
iv) In teachers' lesson plan documents;
v) As an instructional sequence that guides a learning experience for students;
vi) In professional development programmes to develop a number of courses taught in the short-term workshops or offered online (Bybee *et al.*, 2006).

Reports on the effectiveness and applications of the 5Es instructional model Bybee *et al.*, (2006) which compared the 5Es model to other models of instruction (such as traditional models and the Science Curriculum Improvement Study (SCIS) indicated that the 5Es model is effective in helping students reach important learning outcomes in science. For example, Coulson (2002) explored how varying levels of fidelity to the 5Es model affected student learning. The study involved 1,550 nine to ten grade levels students on a selected-response test administered at pre-test and post-test instruction. The results demonstrate strong and statistically signifuicant gains in student achievement, i.e. students whose teachers taught with the medium or high level of fidelity to the 5Es instructional model experienced learning gains that were nearly double those of students whose teachers did not use the model, or used it with low levels of fidelity.

Wilson *et al.*, (2010) conducted a comparative study on the impact of using the inquiry-based 5Es compared with commonplace science materials and teaching in the USA. The study used a randomised design in laboratory setting with 58 students aged 14-16 who were randomly assigned into two groups. Results indicated that students taught using inquiry-based materials organised around the 5Es instructional model reached significantly higher levels of achievement than students experiencing commonplace teaching strategies (as defined by national teachers' survey data). This effect was consistent across a range of learning goals, i.e. knowledge, reasoning, and argumentation.

The 5Es instructional model is not only effective in enhancing students' understanding and achievement; it also enhances teachers' classroom management skills. Marek, Eubanks & Gallaher (1990) examined the relationship that exists between high school science teachers' understanding of the Piagetian developmental model of cognition, integrated with the 5Es instructional model, and classroom teaching practices. Teachers in the study had expressed dissatisfaction with the teaching methods they used, and subsequently attended a National Science Foundation sponsored in-service-programme designed to examine laboratory-centred science curricula. Results indicated that teachers who exhibited a sound understanding of the Piagetian developmental model of cognition and the 5Es model were able to successfully integrate their students' laboratory experiences with class discussions to construct science concepts.
The effectiveness of the 5Es model is also addressed in other studies (e.g. Ates, 2005; Ebrahim, 2004; and Akar, 2005).

3.6 Summary and implications for the study

This chapter has examined constructivist learning theory as a theoretical framework to guide most of the study activities, including the process of designing, developing, and implementing of the curriculum materials and teachers' learning in PD workshops. The review has explored the potential of constructivist theory in the teaching and learning of science through its emphasis on the role and importance of students' prior knowledge in the construction of new knowledge and the active engagement of learners in the teaching and learning process. The theory clearly articulates the need to shift the teacher's role from transmissive teaching to a facilitative mode of teaching when working in the constructivist learning environment.

The chapter also presented activity-based teaching and learning as a constructivist approach which suggests that effective learning is accomplished best when students learn by experimentation, and not by being told what will happen. Students are left to make their own inferences, discoveries, and conclusions which will reinforce inquiry learning. An inquiry-oriented, activity-based approach to science instruction stimulates the natural curiosity and theory-building inclination of students, while providing a solid conceptual framework for supporting the development of accurate concepts. However, findings from research studies (Anderson, 2002; Jeanpierre. *et al,* 2005; Llewellyn, 2005; McNeill, & Krajcik. 2007) have pointed out various challenges associated with the implementation of constructivist classroom instructions such as inquiry-oriented and activity-based instructions which included: teachers' content knowledge and the demands on teachers' pedagogical skills.

Teachers' subject content knowledge. Inquiry teaching can make significant demands on teachers' content knowledge. By including students in decision-making and encouraging them to ask questions, debate and negotiate. A teacher must rely even more heavily on his/her expertise in subject knowledge, knowledge of resources and materials, and the ability to think critically. According to Stoll *et al.,* (1996), teachers who are insufficiently qualified are rigid in their teaching styles and stick closely to the prepared notes or textbook with minimal teacher-student interaction. Carr *et al*., (1994: 148) adds that, "teachers who are themselves insecure in their knowledge of science can find the uncomplicated transmission of knowledge attractive". Teaching science in this manner overlooks both students' prior knowledge and their active involvement which are central in constructivist learning theory.

Demands on teachers' pedagogical skills. Teachers' pedagogical skills are crucial in inquiry-based instructions which are designed to engage students in the processes of formulating predictions, organising and interpreting data, and communicating results using science terminology. This is even more critical if the teacher lacks sufficient classroom equipment and materials. This approach has great potential to excite and motivate students but requires preparation and forethought to implement successfully (National Science Teachers Association -NSTA, 2009). For students to be actively involved there is a need for adequate equipment and textbooks. However, most schools in the Sub-Saharan Africa have inadequate or no equipment at all due to governments' low funding of education sectors (Fabiano, 1998). In the Tanzanian situation, different studies Bathlomew (2008); Mafumiko (2006) indicated similar findings. Environments like these can make it difficult for teachers to implement constructivist practices.
The above scenario suggests that, without teachers' skills including teachers' content knowledge and pedagogical roles such as facilitative teaching, helping students to develop elements of curiosity and creativity in asking questions, designing experiments, analysing and interpreting data, and drawing conclusion, could wreak havoc in secondary science classrooms (Jeanpierre *et al*, 2005). Therefore based on the evidence this study aimed at developing an effective professional development strategy to enhance science (biology) teachers' learning, and practice a constructivist activity-based approach supported by the 5Es instructional sequence in their daily lesson planning and teaching. This was thought to be a favourable intervention to support biology teachers' improvement of classroom instructional approaches, which in turn could improve student learning outcomes.

Chapter 4

Development of the PD Programme

4.1 Introduction

This chapter discusses the knowledge base for developing the biology teachers' professional development (PD) programme that supported implementation of the activity-based approach and 5Es instructional sequence in Tanzanian secondary schools. Section 4.2 discusses the perspectives on what counts as professional development and its operationalisation in this study. Section 4.3 discusses teachers' learning through PD. Section 4.4 analyses PD models. Section 4.5 presents the characteristics of effective PD. Section 4.6 discusses the rationale and the process of designing a PD model for the study. Section 4.7 illustrates the evaluation of a PD programme, and Section 4.8 presents the summary of the chapter.

4.2 What counts as professional development?

The literature casts a wide net for what might be included as PD for teachers. Little (1993: 491) described it as 'any activity that is intended partly or primarily to prepare paid staff members for improved performance in present or future roles in school districts'. Moving beyond discrete activities such as workshops, local, and national conferences, courses, special institutes, and centres, are the newer, more complex and broad-based views on how to conceptualise teachers' PD that have begun to emerge over the past decade. Fullan (1991) defined PD as the total of formal and informal experiences throughout one's career from pre-service teacher education to retirement. PD can be visualised as a 'system' (Borko, 2004: 4). In this context a 'system' is a set of connected elements in which processes occur with facilitators who guide teachers as they construct new knowledge and practices; the PD programme; teachers who are the learners in the system; and the context in which the PD occurs.

This study had characteristics described by Borko (2004) as *Phase 1* research activities. The focus of these activities is on an individual PD programme at a single site. The research is labour-intensive with the designer of the PD programme also being the researcher. The goal of *Phase 1* research activities is to create an *existence proof*, that is, to provide evidence that a PD programme can have a positive impact on teachers' learning. As *Phase 1* research provides evidence that, a high-quality PD programme can help teachers deepen their knowledge and transform their teaching Borko (2004), it formed the basis of the PD of this study. While *Phase 1* research activities generally study the relationship between a PD programme and teachers as learners, and relationship between teachers' participation and their learning, it does not have a component linking teachers' learning and student outcomes. The PD programme for this study went beyond the parameters of *Phase 1* research as it collected students' performance and attitude data in order to investigate what could be determined about the relationship between teachers' PD and student learning outcomes (Section 7.6). The model of teachers' PD used in this study was created to enhance teachers' pedagogical practices which in turn were expected to result in the improvement of student learning outcomes.

This study differentiates between the 'event' PD (typically one-day workshops or seminars, off-site, and without follow-up) and 'transformative' PD (process-driven, extended time frame, and on-site) as described by (Porter *et al.,* 2000). Although event PD is necessary to meet certain demands, the literature clearly demonstrates that transformative PD is more effective in developing teachers' knowledge, changing teachers' practice, and improving student outcomes (Basista & Mathews, 2002; Cohen & Hill, 2000; Desimone *et al.*, 2002). Based on the aforementioned description, PD in this study is therefore explained as professional learning that is an observable positive change in teachers' practice, or in other words, a transformation of teachers' practice which has impact on student learning. Implicit in this definition is the assumption that increased teachers' knowledge will improve teaching practices and in turn improve student learning outcomes (Meiers & Ingvarson, 2005). The ultimate aim is to improve what students know and they can do to improve knowledge and skills, and their dispositions to learning and to persist in their demonstration of this learning (Kennedy, 1999). Guskey (1986: 5) described teachers' PD as attempts to bring about 'change in the classroom practices of teachers, change in their beliefs, and attitudes, and change in the learning outcomes of students'.

4.3 Teachers' learning through PD

The constructivist conception of teachers and teachers' role holds that: teachers create and orchestrate complex learning environments, engage students in appropriate instructional activities so that students can construct their own understanding of the concepts being studied, and working with students as partners in the learning process (Schnell, 1996). Bransford *et al.*, (1999) and Putnam and Borko (2000) argued that learning in individuals, including teachers, is a constructive and iterative process in which people interpret events on the basis of their existing knowledge, beliefs and dispositions. Thus 'what' and 'how' teachers learn is shaped and filtered through the lenses of their existing knowledge, beliefs and practices. Helping teachers to learn through professional development opportunities is critical if they are going to move successfully towards new visions highlighted in reform initiatives (Guskey, 2003). Borko and Putnam (1996) suggested five features that facilitate teachers' learning in professional development opportunities, these are:

i) Teachers' pre-existing knowledge and beliefs;
ii) Enhancing teachers' subject matter knowledge and pedagogical content knowledge;
iii) Treating teachers as learners with an eye towards the principles of adult learning;
iv) Grounding teachers' learning and reflection on classroom practices; and
v) Ample time and support for reflection, collaboration and continued learning.

The following sections illustrate each of the mentioned features.

4.3.1 Addressing pre-existing knowledge and beliefs

Teachers come to the PD opportunities with a number of expectations, knowledge and beliefs that serve as a filter in their efforts to acquire new ways of learning. According to Borko and Putnam (1996), this filtering of learning experiences occurs from a very general level of what learning teachers expect to get from educational opportunities, to more specific aspects of their beliefs about teaching and learning of particular topics.

Teachers' current classroom practices usually are influenced by their pre-existing knowledge and beliefs. Therefore, it is crucial that PD opportunities explicitly address teachers' pre-existing knowledge and beliefs. One way to do this is to enable teachers to reflect upon and make explicit their knowledge and beliefs, attitudes and concerns about teaching, learning, learners and the subject knowledge (Borko & Putnam, 1996). Teachers can be assisted by creating contexts in which they could examine and change their knowledge and beliefs. For example the model of PD for this study (Section 4.6.2, Figure 4.3) bears a component (theory exploration) which explicitly provides opportunities for teachers to discuss the methods used to teach biology, and how they are related to students' learning and understanding.

4.3.2 Enhancing teachers' subject matter knowledge and pedagogical content knowledge

Science education reform initiatives demand a strong conceptual understanding of the subject knowledge of a teacher. Teachers must have a rich and flexible understanding of the subject matter in order to teach in ways that are responsive to students' thinking, and which foster learning with understanding (Borko & Putnam, 1996). It is from this emphasis that Shulman (1986; 1987) categorised the knowledge base of teachers as: Content Knowledge (CK); Pedagogical Knowledge (PK); and Pedagogical Content Knowledge (PCK). Content Knowledge is a discipline perspective which is based on the breadth and depth of the subject knowledge (Shulman, 1996). Researchers have regarded a flexible, thoughtful conceptual understanding of subject knowledge as being critical to effective teaching (Borko & Putnam, 1996; Darling-Hammond, 2005). Pedagogical Knowledge which has been the focus of most teaching research consists of general knowledge of learning and learners, knowledge of principles of instruction, knowledge and skills relevant to classroom management, and knowledge and beliefs about the aims and purposes of education (Grossman, 1990). How teachers blend Content Knowledge and Pedagogical Knowledge to determine the most effective means to teach particular topics or problems consistent with students' interest and ability is what is referred to as Pedagogical Content Knowledge (Shulman, 1987).

4.3.3 Treating teachers as learners with an eye towards principles of adult learning

Successful PD projects treat teachers as learners in ways that are consistent with the perspectives on student learning (Borko & Putnam, 1996). Similarly, evidence in brain research and cognition by Bransford, Brown & Cocking (1999) has shown that adults as much as children are constructors of knowledge. They need to be supported as they learn new material, they need to be able to engage in trial and error, they need to be able to practice skills, and receive feedback from respected others. It is important that teachers experience learning environments where the subject matter and learners are treated in a new way before they try to successfully translate them into their own classrooms. Borko and Putnam (1996) caution educators not to overlook the important differences between setting goals of student and teachers' learning (i.e. simply providing the same learning activities for teachers and students wrongly assumes that teachers and students need to learn the same things and bring similar qualities to their learning). PD is a type of adult learning and is affected by inherent adult characteristics. The literature on adult learning, advocates that honouring adults' wisdom and autonomy are essential for the effectiveness of PD programmes (Smith, 1981; Zemke & Zemke, 1998). When teachers work together as colleagues in a focused, collaborative inquiry, they are likely to be successful at substantively changing their practices, the ultimate goal of most educational innovation and professional development (Wenger, 1998).

4.3.4 Grounding teachers' learning and reflection on classroom practices

Teachers must have opportunities to learn about and reflect on new instructional strategies and ideas in the context of their own classroom practices (Borko & Putnam, 1996). This principle is based on the premise that knowledge is situated in a particular context where it is acquired and used. Putnam and Borko (2000), found evidence that PD programmes can successfully address this issue by systematically incorporating multiple contexts for teachers' learning such as introducing theoretical and research-based ideas in workshops and provision of on-going school support as teachers attempt to integrate the ideas into classroom practices. A professional development team could provide demonstrations, feedback and opportunities for reflection during visits to classrooms as well as to organise follow-up workshops for further exploration of issues regarded as necessary. Putnam and Borko (2000) suggested that a combination of approaches in a variety of contexts holds the best promise for fostering powerful multidimensional change in teacher thinking and practices.

4.3.5 Ample time and support for reflection, collaboration and continued learning

Findings from most PD programmes suggest that teachers need to be provided with sustained time and support for learning complex skills and acting differently in their classroom in their early stages of implementation of any change (Borko & Putnam, 1996; Guskey, 2000; 2002; Joyce & Showers, 2002). This support should allow the teachers involved in the difficult processes of implementation to lessen the anxiety and be able to cope with intended changes. Similarly, Borko and Putnam (1996) and Loucks-Horsely *et al.*, (2003) asserted that teachers must be provided with ample time for practice, reflection, and collaboration with their colleagues. It is unfair to expect too much from those involved in the implementation, therefore, PD must be seen as a process and not as an event (Garet, *et al*, 2001). One way to support teachers' learning is through curriculum materials designed to be educative to teachers (Ball & Cohen, 1996).

Curriculum materials such as textbooks and teachers' guides (whether supplied by publishers or designed by researchers) are used by teachers to support student learning, i.e. to plan and structure student activities (Ball & Cohen, 1996). Ball and Cohen (1996) found that development of such materials can put teacher learning at the centre of the effort to bring about educational change. Additionally, Van Den Akker, (1998) identified key areas that materials should address which included lesson preparation, subject content, pedagogy, and assessment of learning. Wormstead *et al.*, (2002) reported about the design of teacher support materials for science teachers. Curriculum materials in their research focused on a better understanding of scientific concepts and methods, and ensured that these concepts and methods were presented to students in ways that are motivating and engaging. They identified and recommended a set of design criteria for such materials which are similar to Van Den Akker's key areas, including classroom management practices for inquiry-oriented learning. Similarly, Schneider and Krajcik (2002) designed teacher support materials that address teacher learning as well as student learning. The materials included information explaining content and pedagogy, as well as specific information about strategies, representations, and student ideas. Their research findings indicated that curriculum materials enhanced teachers' pedagogical content knowledge (Davis & Krajcik, 2005).

It is therefore evident that curriculum materials are important as they illustrate to teachers what effective classroom practices look like. Development of such materials is essential in helping teachers bring about changes in classroom practices that will fulfil the requirements of constructivist approaches (Schneider & Krajcik, 2002). In the present study the researcher, is developing biology curriculum materials integrated with the activity-based approach and the 5Es instructional sequence (Sections 3.4.3.1 and 6.2.2) which focuses on supporting teachers in lesson planning and teaching biology in their respective classrooms in the ways suggected in the constructivist approaches, i.e. that will consider students prior knowledge, active involvement of students in the construction of their knowledge and maximise interaction among students, materials and their teachers.

4.4 An overview of PD models

In the context of staff development Ingvarson (1998) used the term 'model' as a design for learning which embodies a set of assumptions about where knowledge in relation to teaching practice comes from, and how teachers acquire or extend their knowledge. PD models according to Ingvarson are specific processes and opportunities that are planned to provide PD to teachers from the beginning of their preparation. Kennedy (2005) held that PD can be structured and organised in different ways and for different reasons. Nevertheless, most PD experiences might be considered as a means of introducing or enhancing knowledge, skills and attitudes. Kennedy (2005) identified 9 models of PD which are categorised into three main groups based on their purposes, (i.e. transmission, transitional and transformative).

i) Transmission models include: the training model, the award bearing model, deficit model, and cascade model;

ii) Transitional models include: the standard-based model, the coaching/mentoring model, and community of practice model;

iii) Transformative models include: action research model, and transformative model.

To show how this will inform the design of the PD model of the present study the researcher has described below one model from each category: training model (transmission), coaching/mentoring model (transitional) and transformative model (transformative).

4.4.1 The training model

The training model has been recognised as the form of the PD of teachers which provides teachers with the opportunity to update their skills in order to be able to demonstrate their competence (Little, 1993; Kelly & McDiarmid, 2002). The new knowledge and skills are generally delivered to teachers by an 'expert' with the agenda determined by the deliverer, and participants placed in a passive role. The training can take place within the participants' institution, but it is can be delivered off-site and hence there could be a lack of connection to the participants' classroom context (Kennedy, 2005). The training model includes other forms of PD commonly termed as 'traditional', such as workshops, seminars, institutes and conferences. They are all regarded as an effective means of introducing new knowledge and skills (Hoban, 2002).

The training model has been criticised as being 'one-off' experiences providing no follow-up. However, given the new understanding of PD as an on-going process of growth and learning there are some cases that show that when this model of PD accompanies other types of PD opportunities, it can be quite successful (Garet *et al.*, 2002). An example of such an approach is that reported by Zeegers (1995) based on a series of three one-day workshops offered to teachers in New Zealand as a first phase of a PD programme designed to prepare teachers to teach the new National Science Curriculum. These workshops were followed by supplementary supportive and informative visits from in-service facilitators, the results of which were positive i.e. the new science curriculum was successfully integrated in teachers' routine. Joyce and

Showers (2002) training model (Section 4.6, Figure 4.2) is an example of teachers' PD models with most of the characteristics addressed in the abovementioned examples.

4.4.2 The coaching/mentoring model

The coaching/mentoring model covers a variety of PD practices that are based on a range of philosophical premises (Kennedy, 2005). The distinctive feature of this model is that of working on a one-to-one relationship with equally or more experienced teachers to improve teaching and learning through a variety of activities including classroom observation and feedback (Loucks-Horsley & Stiles, 2001). According to Loucks-Horsley & Stiles this strategy helps teachers to translate new knowledge into practice by, engaging teachers to draw on their knowledge base to plan instruction and improve their teaching. The mentoring or coaching relationship can be collegiate, for example 'peer coaching' Kennedy (2005) which is a process by which a colleague who is "a critical listener/observer, asks questions, makes observations and offers suggestions that help a teacher grow and reflect and produce different decisions" (Harwell-Kee, 1999: 28).

In order to be successful, coaches and mentees need to have a good working relationship; they need some skills in communication and observation and they need time to develop an understanding of each other's strengths and try out new practices (Loucks-Horsley *et al.,* 1998). Glatthorn (1995) adds that there must be a meaningful collaborative school support and, teachers must receive some training on how to implement this model effectively. In an experimental study involving peer coaching, Joyce and Showers (1998) designed training that began with modelling practice under simulated conditions, followed by classroom practice supported by feedback from a more experienced colleague. The purpose of these initial studies was to look at whether coaching facilitated the use of new skills. Following 30 hours of initial school-wide training in a new instructional strategy, the treatment group engaged in on-going peer coaching improved their skills while the control group did not. The findings indicated that, the coached teachers practiced the new strategy more frequently, adapted them to other contexts and used them more appropriately than uncoached teachers. In addition, students of coached teachers were more likely to understand the new concepts and used them independently.

The purpose of mentoring is to help teachers focus on, and improve their practice by discussing it with other individuals (Loucks-Horsley *et al.*, 2003). There is considerable research evidence to suggest that the more meaningful a programme is, the more likely it is to positively affect teachers' retention (National Research Council, 2000). Teachers, who had a helpful mentor from the same field and other components such as common planning time, and opportunities to collaborate with other teachers, were more likely to stay in the teaching profession (Ingersoll & Kralik, 2004).

4.4.3 Transformative model

The transformative model of PD involves a combination of a number of processes and conditions which are drawn from other models (Kennedy, 2005). This model recognises the range of different conditions required for transformative practices. According to Hoban (2002) this perspective of professional development is regarded as a means of supporting educational change. He suggested that the effective integration of the positive aspects of PD models together with awareness of power/tension exerted by requirements of each model can contribute to successful outcomes (Kennedy, 2005). Stein *et al.*, (1999) found that, the idea of integration of models is both helpful and challenging to the PD planner because each model has different characteristics and serves different purposes. Therefore, different models might be logically used at different stages of PD (Loucks-Horsley *et al.*, 1998). For example, the training model strategies can be used at the beginning of the change process because they help participants develop awareness of the new concept. Thereafter, employing strategies that allow participants to explore and try the new concept, and finally, coaching strategies to reinforce the adoption of the new concept.

4.5 Characteristics of effective PD

The concept of 'effective' PD is necessarily linked to positive effects on student outcomes through three main stages: teachers' learning, teachers' practice, and student outcomes (Garet *et al.*, 2001). Traditional approaches to teachers' PD described as 'something external to the on-going work of teaching, and something that one 'does' or that is 'provided' in the form of activities and events' are no longer appropriate for *transformational* change Little (1999: 246). Rogers (2007) stated that the new paradigm of PD had moved away from short-term teacher-training events where information is transmitted by an expert to a group of participants to a more constructivist model. This constructivist model is thought to be more effective as it is based upon the recognition that learning takes place over time and that active learning requires opportunities to link previous knowledge with new understandings (Cochran-Smith & Lytle, 2001). Researchers have composed checklists and guidelines for what constitutes effective PD, (e.g. Guskey, 2003; Hawley & Valli, 1999; Sykes, 2002). Characteristics of effective PD are useful in choosing and justifying a particular PD approach, and may be used to influence the design and method of evaluation of a particular PD programme. Hawley and Valli (1999) summarised research about the conditions that foster professional learning that relate to improved student learning outcomes. Their list of nine principles for the design of effective professional learning has underpinned many later studies (e.g. Ingvarson, 2005; Lieberman & Pointer Mace, 2008; McRae, 2003). The nine principles recommended that PD should:

i) Have a content focus upon what students are to learn and the ways in which different problems students may have in learning the material may be addressed;
ii) Be an analysis of the differences between the actual student performance and goals and standards for student learning;
iii) Involve teachers in the identification of what needs to be learned and in the development of learning experiences in which they will be involved;
iv) Be primarily school-based and built into the day-to-day work of teaching,
v) Be organised around collaborative problem solving;
vi) Be continuous and on-going, involving follow-up and support for further learning;
vii) Incorporate evaluation of multiple sources of information on outcomes for students, instruction and other processes that are involved in implementing lessons learned through PD;
viii) Provide opportunities to gain understanding of the theory underlying the knowledge and skills be learned;

ix) Be connected to a comprehensive change process focussed on improving student learning.

Guskey (2003), synthesised 13 lists constituting a fairly representative sample of principles developed in the United States (produced by organisations and agencies such as Educational Research Service and Educational Testing Services, American Federation of Teachers; National Partnership for Excellence and Accountability in Teaching, and the United States Department of Education). His intention was to distil a shortlist of the most frequently mentioned characteristics of effective professional development. The shortlist Guskey (2003), in order of frequency of inclusions comprised:

i) Enhancement of teachers teaching content and pedagogical knowledge;
ii) Provision of sufficient time and resources;
iii) Promotion of collegiality and collaborative exchange;
iv) Inclusion of specific evaluation procedures;
v) Alignment with other reform initiatives;
vi) Modelling of high quality instruction and school or site-based.

The above-mentioned list of characteristics of effective PD may be useful in framing the intent and content of PD activities as well as to enhance the quality of the PD programmes and activities (Guskey, 2003).

4.6 Developing a PD model for the study

The PD model for this study was developed based on the characteristics of transformative model by combining different aspects of training and coaching models. Joyce and Showers (2002) suggested a training model of effective PD which comprises four critical components which are: theory, demonstration, practices and feedback and, coaching, and follow-up as illustrated in Figure 4.2

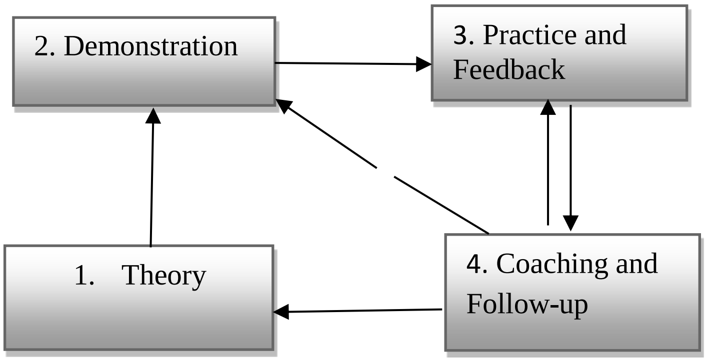


Figure 4.2 Training model, from Joyce and Showers (2002)

Description of the components

Theory. This is the first component which focuses on knowledge and consists of an exploration of theory about the content/topic or rationale through discussion, readings and lectures which are necessary for an understanding of the concept behind a skill or strategy and the principles that govern its use. The teacher must understand the underlying research base and rationale for the new instructional strategy, skill or concept being presented. According to Armbruster and Osborne (2002), only those ideas supported by scientific research as capable of improving student achievement should be included. This component is similar to what Guskey and Spark (2002) termed *content characteristics* of effective PD which refers to the '*what*' of professional development i.e. the knowledge and skills, and understanding which are the foundation of any PD effort. Effective PD emphasises the overriding importance of *what* teachers learn, as opposes to *how* they learn it (Ingvarson, 2005; Kennedy, 1999). Knowledge is the key particularly when it leads to deeper understanding of the concepts and skills that participants are to learn.

Demonstration. This component provides the teacher with an opportunity to observe a model of what is being taught. This demonstration may be provided with actual students in the training setting or through videotape. Demonstrations can be mixed with explanations and modelling to facilitate the understanding of the underlying theories by illustrating them in action (Joyce & Showers, 2002).

Practice and feedback. This is the opportunity provided to teachers to practice what has been demonstrated within the training session followed by immediate feedback. Practice of skill can take the form of peer teaching sessions as well as micro-teaching. This component has been described by Guskey and Sparks (2002) as a 'process' variable which refers to the '*how'* of the PD and is concerned not only about the type and form of the PD activities, but the way those activities are planned, organised, carried out, and followed up. Garet *et al.,* (2001) described these variables as '*core'* features of PD, and stressed the importance of active learning and fostering coherence among various opportunities for teacher learning and development. According to Joyce & Showers (2002), simpler skills or those more similar to those previously developed will require less practice to consolidate than those that are more complex or different from the participants' current repertoire.

Coaching and follow-up. This is the collaborative work of teachers to solve the problems or questions that arise during implementation. It begins during training and continues in the workplace. According to Joyce and Showers (2002) and Murphy (2000) this component ensures that the teacher is likely to retain the strategy, skills, or concept and make it a part of his or her repertoire (i.e. planning and developing lessons). The feedback provided in the coaching process helps the teacher internalise what has been learned through observation and feedback. Follow-up includes discussions after the coaching sessions and any additional training or support meetings related to what has been learned. Many of the experimental research studies conducted by Joyce and Showers on the effectiveness of coaching and feedback components of training models, found that coaching appeared to have enhanced the transfer of the training (knowledge and skills) in five ways, the coached teachers:

i) Practised new strategies more often and with greater skill than uncoached teachers with identical initial training;
ii) Adapted the strategies more appropriate to their own goals and contexts than did the uncoached teachers who tended to practice observed or demonstrated lessons;
iii) Retained and increased their skill over time while uncoached teachers did not;

iv) Were more likely to explain the new models of teaching to their students, ensuring that students understood the purpose of their strategy and the behaviours expected of them;

v) Demonstrated a clearer understanding of the purposes and use of the new strategies. The frequent peer discussions about them, including lessons and materials design seemed to enable them to think with the strategies in ways which uncoached teachers never showed.

The value of this model for effective PD have been demonstrated over many years of use which revealed its effectiveness on classroom practices (Joyce & Showers, 2002). Table 4.1 shows the training components and attaintment of outcomes in terms of the percentages of the participants likely to attain them when the combinations of components are employed. The findings based on the Joyce and Showers' review study involving 200 In-service Education and Training (INSET) programmes for teachers in the United States.

Table 4.1 Training components and attainment of outcomes in terms of percentages

Training Components	Knowledge	Skills	Transfer
Theory and discussion	10%	5%	0%
Demonstration in training	30%	20%	0%
Practice & Feedback in training	60%	60%	5%
Coaching & follow-up in classroom	95%	95%	95%

Source: Based upon the research by Joyce and Showers (2002).

Table 4.1 demonstrates the effectiveness of a typical training model (Joyce & Showers, 2002) which indicated that when theory and discussions are provided only limited effects on knowledge, skill and transfer in the classroom resulted. As additional training components are introduced, results in knowledge and skill level mildly increase, but not when it comes to actual transfer within the classroom. The final column in Table 4.1, demonstrates the use of coaching and follow-up within the classroom and the accompanying 95% across-the-board indicating effectiveness in the areas of knowledge, skill and use/transfer within the classroom.

4.6.1 The purposes of the PD in the study

The literature reviews conducted by professional developers for the purpose of synthesising evidence across studies that support the design of their PD programmes often tend to eliminate the effects of context or try to decontextualise the data (Guskey, 2000). What works in one situation may not work in another. Therefore, the components of the effective PD mentioned in the above section are relevant and were considered in this study, but some features may not be embraced to their fullest extent because of the contextual constraints such as promotion of coaching and mentoring. In the context analysis of the study (Section 2.5.1) it was revealed that there is an acute shortage of science teachers in Tanzanian secondary schools and those present are overstretched with teaching loads, and due to lack of infrastructure and culture of collegiality for promoting professional collaboration in schools, the effective adoption of coaching and mentoring would be challenging to teachers..

The overall purpose of the PD of this study was to support teachers to integrate the activity-based approach and the 5Es instructional sequence (Table 6.1) in the preparation and teaching of biology lessons. Specifically, the design process was geared towards:

i) Developing teachers' awareness towards using the activity-based approach supported by the 5Es instructional sequence;
ii) Developing an understanding of the new knowledge and skills in the science teaching and learning and connecting it to their prior experiences;
iii) Supporting teachers in practising and implementing the new approaches with a goal of becoming fluent at recognising various problems in a particular domain so that appropriate solutions can easily retrieved;
iv) Supporting teachers to develop the ability to reflect on, and, recognise when misconceptions and misunderstanding occur in the instructional context;
v) Building teachers' knowledge, skills, and attitudes towards using the new approaches;

vi) Supporting teachers' in receiving feedback from others and engaging in peer collaboration.

4.6.2 Details of the PD model of the study

The PD model for this study was developed with the purpose of improving teachers' classroom instructional practices which in turn, would improve student learning and understanding of biology. The model integrates the components of Joyce and Showers' training model, curriculum materials, a supportive school environment, and is guided by inherent characteristics of effective PD such as: *on-going* (an extended period of time i.e. a school term); *on-site* (based at the school site with teachers working in their classrooms); *on-target* (specifically linked to student outcome) and *refining* (an iterative process that develops during the programme). Figure 4.3 shows the professional development model used in this study.

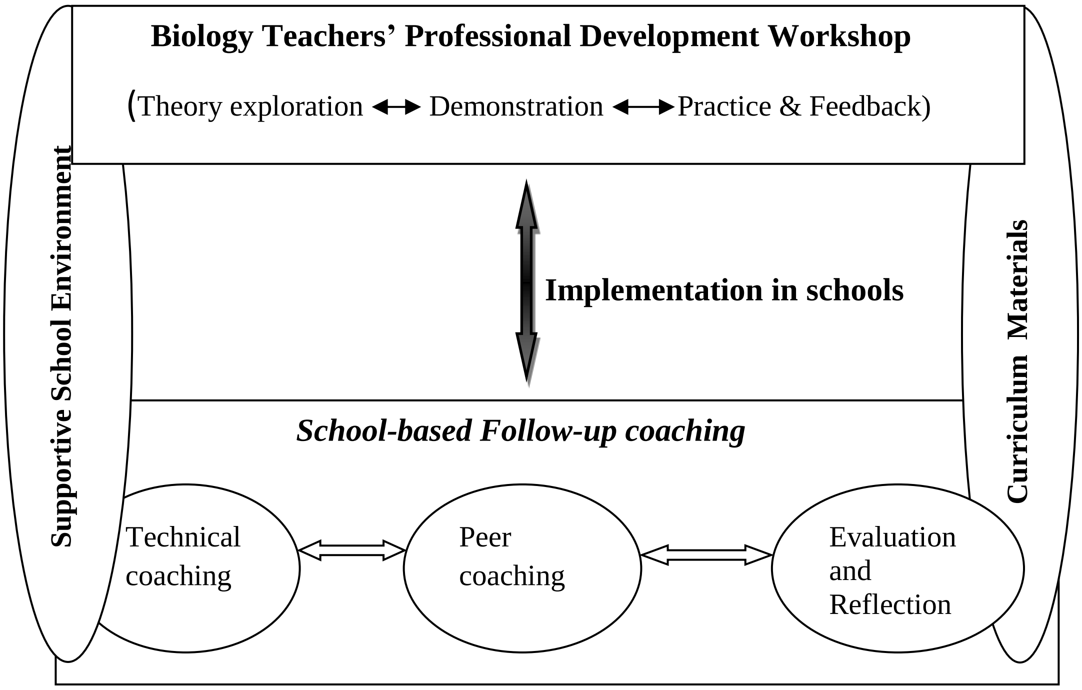


Figure 4.3 A model of the PD programme in the study adapted from Joyce and Showers (2002)

4.6.2.1 Description of the main components of the PD model

The workshop. This component of the PD model for this study provided opportunities for biology teachers to learn and practice new knowledge and skills (i.e. the activity-based approach and the 5Es instructional sequence). The activities at the workshop included theory exploration, demonstration, and practice, and feedback (Joyce & Showers, 2002).

Theory exploration. The activities focused on teachers' learning new knowledge and skills guided by constructivist learning theory and characteristics of effective PD. Teachers were given opportunities to examine their expectations and prior conceptions about teaching and learning methods and how they relate to student learning approaches. The activities took the form of discussion, studying, and facilitation of how the major aspects of constructivist theory such as use of prior knowledge, conceptual change, and collaboration enhance meaningful learning. This included the rationale for adopting an activity-based approach and the 5Es instructional sequence which facilitates skills acquisition and increases understanding of the concepts. The explicit goal was to familiarise teachers with the new approaches and help them construct a conceptual framework within which to understand it.

Demonstration. This provided opportunity for teachers to observe the implementation of the activity-based lesson taught by the researcher to the invited students. The aim was to show the practicality of the new approaches with actual students.

Practice. In this aspect of the workshop teachers were given the opportunity to explore and practice the activity-based lessons illustrated in the exemplary curriculum materials. This provided both the content and procedures to follow during implementation in the classroom with students. Teachers worked in groups to develop lessons which were taught by one of the teachers from each group in the form of micro-teaching with a small number of students.

Feedback. Teachers were provided with the opportunity to reflect during a plenary session on the practiced lessons and to provide their perceptions and suggestions on the practiced skills.

Curriculum materials. Curriculum materials are tools that help the teachers implement curriculum or innovation in the classroom (Ball & Cohen, 1996). These materials influence teachers' pedagogical decisions, and help in structuring their lessons, as well as providing sources of teachers' learning and practice (Schwarz *et al.*, 2008). Curriculum materials for this study (Appendix A2) included five biology activity-based lessons for teachers to experience the flexibility of an activity-based approach. This was supported by the 5Es instructional sequence in the teaching and learning process (Table 6.1). Joyce and Showers (2002) and Kennedy (1998) held that curriculum materials, when systematically embedded in the PD process could strengthen some of the training components and peer collaboration activities in schools.

School follow up coaching. This included organisation of school-based coaching activities in the form of technical and peer coaching which were initiated and guided by the researcher to help teachers transfer the workshop experiences to their respective classrooms to facilitate effective adoption of the new approaches (Section 7.4). Based on the PD strategies, technical coaching focused on incorporating the new curriculum or instructional techniques into teachers' routine (Ackland, 1991; Becker, 1996; Showers & Joyce, 1996). The technical coaching in this study embraced Glickman's (1990) model of developmental supervision that advocates provision of formative feedback to teachers for the purpose of helping them improve their instructional approaches

Peer coaching is an interactive process between two or more teaching professionals that is used to share successful practices through collaboration and reflective practice in order to bring about a better understanding of the best practice (Baker, 2001). According to Baker, peer coaching reduces the isolation among teachers, and creates a forum for addressing teachers' classroom instructional problems and challenges.

A supportive school environment. In this study this aspect was regarded as an essential element of the context of teachers' PD. According to Loucks-Horsley *et al.*, (2003), the context constitutes factors like the needs and nature of the students, the needs and teaching responsibility of teachers, the resources available, community support, organisation, expectations, and current demands of schools. Throughout the implementation of the PD of this study the researcher ensured the smooth collaboration and support from each school administration and teachers in terms of materials, resources, and time for effective preparation of lessons and implementation (Section 7.5.1)

4.7 Evaluation of the PD programme

The evaluation of the teachers' PD programme in this study is based on Guskey's (2000) five levels of evaluating teachers' PD. Guskey's evaluation framework has been used in the United Kingdom to evaluate Continuing Professional Development (CPD) Muijs & Lindsay (2004), and extensively within the United States of America (Loucks-Horsley *et al.,* 2003). For example the development of the *Standards for Staff Development* published by the *National Staff Development Council* (2001) and the *No Child left Behind Act* (U.S Congress, 2001) that demanded teachers' PD programmes were evaluated based on specific measures of student learning. The present study is significant in that it evaluated the impact of the teachers' PD programme in both teachers' classroom practices as well as student learning outcomes. According to Guskey this type of evaluation is summative with a purpose of providing information to make judgements about the programme's overall merit or worth. The evaluation framework consists of specified levels arranged hierarchically from simple to more complex whereby, the process of gathering information in each succeeding level requires more time and resources. The focus of each level is outlined as follows:

- Level 1) Participants' reaction: measuring initial satisfaction with the experiences;
- Level 2) Participants' learning: measuring new knowledge and skills of participants;
- Level 3) Organisation support and change: measuring the organisation's advocacy, support, facilitation and recognition;
- Level 4) Participants use of new knowledge and skills: measuring degree and quality of implementation;
- Level 5) Student learning outcomes: measuring student learning outcomes, in terms of the cognitive (performance and achievement), affective (attitudes and dispositions), and psychomotor (skills and behaviour).

Guskey's framework illustrates the complexity of the PD. McRae (2003), when describing measures of the effectiveness of PD, cited four pertinent measures for evaluating the success of PD activities, these are:

i) Level of participation;
ii) Levels of satisfaction with the activity;
iii) Change to professional practice as a result of participation in learning activities;
iv) Improvement of student learning outcomes.

Data on the level of participation and participants' satisfaction are relatively easy to collect, however they provide no valid inferences about consequential changes in teachers' practice. Where data related to changes in practice are sought, self-reflections are most widely used, for example in the Commonwealth Government's Quality Teachers Programme (QTP) projects 2000 to 2009, 75% of participants claimed that their practice had changed as a result of their PD (McRae *et al.*, 2001). There had been little triangulation with these observed and reported practices, hence the validity of these data is questionable. In terms of improved student learning outcomes, there is little focused data to support any impact of the PD on student learning or the degree of change of student learning (Ingvarson, 2005). Given the number of contextual and other variables this is unsurprising.

Guskey (2005: 16) introduces a strategy to address the relationship between teachers' PD and improved student learning outcomes called 'backward planning'. "Backward planning" limits the intruding variables upon the relationship between teachers' PD and improved student learning outcomes. According to Guskey (2000: 208) "improvements of student learning outcome are likely, only when PD endeavours focus specifically on learning and learners" i.e. the process begins with a focus on, and goal setting for student learning outcomes to be achieved and measured (level 5).

In the present study the backward planning can be illustrated as follows:

Level 5) The goal was to engage students in doing lesson activities for *excitement* and improve their involvement in the learning and understanding of biology;

Level 4) The instructional approach based on the constructivist learning theory and teachers' use of the activity-based teaching and learning approach upported by the 5Es instructional sequence;

Level 3) The organisational support required which included: teaching and learning resources, peer and collegiate support, and school recognition of the participating teachers;

Level 2) The knowledge and skills required included: the constructivist learning theory (cognitive and social constructivist learning perspectives), the activity-based approach supported by 5Es instructional sequence;

Level 1) The experiences for participants based on their engagement in the training components of the PD model for this study (Figure 4.3) included understanding and adoption of the activity-based approach and the instructional sequence.

Guskey's (2005) evaluation model was used as a framework for evaluation of the PD programme for this study so that any conclusions could be as valid as possible. However, recognition needs to be given to the fact that obtaining information about teachers' use of new knowledge and skills (level 4) and improvements in student learning outcomes (level 5) may not be immediately evident, rather, evaluating these outcomes should be delayed due to the take-up time required before evidence can be found. For example, teachers required time to use new knowledge and skills, to gain confidence and to be assured that their students will not be disadvantaged. Furthermore, students also required time to internalise new techniques of learning, and in some cases 'unlearn' previous learning techniques. In this study the time for activities in these two levels was 12 weeks (a school term) before summative evaluation.

4.8 Summary of the chapter

This chapter produces information and insights on what constitutes effective teacher PD, as well as the knowledge base and requirements for the implementation process. The lessons learned indicate that the current conceptions of learning and teaching, and teachers' learning through PD, are very demanding for teachers in specified contexts. Teachers have to adopt new roles, need to be invested with new understanding about learning, subject knowledge, and pedagogical content knowledge. Such a change is a complex process and its implementation demands guiding teachers through an effective PD process that is well informed and adapted to the unique features of users' context. Thus, the PD for this study used workshops, curriculum materials, school follow-up coaching, and evaluation of teachers' practices of the new approaches and student learning outcomes. These components were systematically integrated in the PD programme for teachers in ways that developed teachers' awareness, enhanced their knowledge base for teaching biology, and helped them to translate and implement the new knowledge and practice in their classrooms.

Chapter 5

Research Methodology

5.1 Introduction

The present study requires a methodology that can focus on the design, implementation, and evaluation of a PD programme to support activity-based biology teaching and learning in Tanzanian secondary schools. The aim of the PD programme was to support teachers' learning and implementation of the activity-based approach supported by the 5Es instructional sequence (Table 6.1) which in turn could contribute to the improvement of their instructional practices and student learning and understanding of biology. The study attempts to answer three research questions:

1) What are the characteristics of an effective professional development programme that adequately supports learning and teaching of biology in Tanzania?
2) How can a professional development programme be practically designed and implemented to enhance Tanzanian biology teachers' pedagogical knowledge and skills effectively?
3) What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?

Different research designs and methodologies were considered in answering the research questions. The literature suggests that studies involving innovations in classroom practice require a methodological approach that engages teachers as co-investigators and forges strong teacher-researcher collaboration (Richey & Nelson, 1996; Richey *et al.*, 2004). Brown (1992) claims that approaches for measuring learning success such as skills acquisition, test measurements, or inventories, commonly used in the psychological tradition as a single measure, are inappropriate for advancing our understanding of how to design for change in educational settings. Findings from these approaches may not account for the influence of contexts, i.e. the nature of learning in the real world situations (Collins *et al.*, 2004). An approach that leads to a holistic understanding of the processes, and impact of educational innovation on classroom practice and student learning, may be conducted using a mixed methodology that employs both qualitative and quantitative measures, and works within a framework of having teachers as co-investigators (Brown, 1992; Collins *et al.*, 2004).

In this chapter, Section 5.2 presents an overview of the research methodology of the study. Section 5.3 describes design-based research, its characteristics and justification - as a methodology in an education context. Section 5.4 discusses the quasi-experimental design. Section 5.5 presents the research location, the study population, sample, and sampling procedures. Section 5.6 describes the data collection methods, instruments, and their administration. Section 5.7 discusses research validity and reliability issues and the techniques used in this study to ensure quality and trustworthiness. Section 5.8 illustrates data analysis procedures for the study. Section 5.9 discusses ethical issues, and Section 5.10 presents a summary of the chapter.

5.2 An overview of research methodology used in the study

The methodology used in this study has been influenced by Design-Based Research (DBR). Other research approaches such as action research share some characteristics of Design-Based Research. Action research can be defined as the form of “self-reflective inquiry” by participants, undertaken in order to improve understanding of their practices in a context with a view to maximising social justice (Carr & Kemmis,1986: 162). It has a spiral element of planning-acting-reviewing, and evaluating, which allows teacher-researchers to constantly refine practice (Carr & Kemmis, 1986; McTaggart, 1991). These elements and this cyclic process of intervention are also present in this study.

DBR resembles action research in that it identifies real world problems accompanied by subsequent actions to improve the *status quo*, and practitioners such as teachers are highly involved in the research process. However, DBR is distinct from action research with respect to their goals (Reeves *et al.*, 2005). Researchers with DBR goals conduct their studies through the design, development, and testing of interventions that focus on teaching, learning, and performance problems (McKenney & Reeves, 2012). Educational researchers with action research goals often seek to improve professional practice, usually their own, and sometimes in collaboration with others. Furthermore, embedding the pursuit of theoretical understanding in the design and development of educational interventions is what sets DBR apart from action research as well as other research approaches (McKenney & Reeves, 2012). The theoretical understanding emerging from DBR can be descriptive, explanatory, predictive, or prescriptive in nature:

i) Descriptive: focused on portraying specific aspects of education, such as; engagement of learners in a specific type of learning environment;
ii) Explanatory: an attempt to explain the meaning or implication of phenomena related to teaching and learning, performance, social interaction, and other educational factors;
iii) Predictive: focused on testing hypotheses related to theories of teaching and learning, assessment, social interaction, and other educational factors;
iv) Prescriptive: aimed to guide future development efforts.

Researchers with action research goals focus on a particular programme, product, or method, usually in an applied setting, for the purpose of describing it, or estimating its effectiveness, and worth. While action researchers may contribute to knowledge production Elliott (1991), they are not fundamentally concerned with constructing, and testing theory, models, or principles to describe, explain, or predict a certain phenomenon, nor deriving prescriptive principles/guidelines that may guide the design initiatives of others (McKenney & Reeves, 2012).

DBR methodology is concerned with both the development of the learning environment and a systematic study of the forms of the learning generated in these learning environments (Brown, 1992; Cobb, 2003; Wang & Hannafin, 2005). Scholars engage in DBR to better understand how to orchestrate innovative learning experiences among students in their everyday educational contexts, as well as simultaneously develop new theoretical insights about the nature of learning (Bell, 2004). It also entails a continuous process of testing and revision to refine the designed learning environment.

It is this emphasis on designing an innovative learning environment and using mixed methods to inform the findings that influenced the design of this study and the consequent alignment with DBR methodology. The following section presents a rationale for the DBR methodology.

5.3 Design-Based Research (DBR)

Design-Based Research is a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration between researchers and practitioners in real-world settings and leading to contextually-sensitive design principles and theories (Wang & Hannafin, 2005). This methodology has roots in the field of educational psychology. In proposing this methodology researchers e.g. Brown (1992) and Collins (1992) refer to the term 'design experiments' for studies of classroom-based interventions where the purpose of the research is to actively participate in the design and implementation of innovation in order to test and develop instructional theories.

DBR projects have two major goals: i) the empirical investigation, and ii) development of high quality interventions to solve complex educational problems and the accompanying set of well-articulated design principles (Linn, Davis & Bell 2004; Van den Akker, 1999). These principles show how the intervention works in practice, the effect of using the intervention, and an explanation of the working mechanisms. Design-based researchers carefully combine design and research activities in order to develop research-based solutions for complex problems in educational practice (McKenney & Reeves, 2012; Van Den Akker *et al*., 2006). To support the dual goals of DBR, Barab and Squire (2004: 6) held that:

> DBR requires more than simply showing a particular design works, but demands that the researcher generates evidence-based claims about learning that address contemporary theoretical issues and further the theoretical knowledge of the field.

5.3.1 Justifications for DBR methodology

Numerous motives for DBR have been cited in the literature, many of them speak to the long-standing criticism that educational research has a weak link with practices (Design-based research collective 2003; Kelly, 2004; Reeves *et al*. 2005). In combination with other social science research approaches, DBR has potential to help in the development of educational interventions, and to offer opportunities for learning during the research process (e.g. in this study teachers' participation in the validation and implementation of the PD programme aimed to enhance their understanding of effective instructional approaches). In the drive for better understanding of teaching and learning, the belief that context matters leads to the conclusion that research paradigms that simply examine the learning process as isolated variable within laboratory settings will necessarily lead to an incomplete understanding of their relevance in more naturalistic settings (Barab &Squire, 2004; Barab & Leuhmann, 2003). For example, naturalistic settings such as classroom environments are complex hence required multiple methods that possess high degree of ecological validity, i.e the methods, materials and settings must approximate the real life situation under investigation (Brewer, 2000).

The field of DBR was introduced with the expectation that researchers would systematically adjust various aspects of the designed intervention so that each adjustment served as a type of experimentation that allowed the researchers to test and generate theory in naturalistic contexts (Barab & Leuhmann, 2003). For example, during prototyping approach (Chapter 6) the formative evaluation was designed to involve several levels such as experts and users appraisals, try-out with teachers and sudents, panel diacussions with experts and field implementation. The essence of having each of the mentioned levels was to improve the quality of prototypes before implementation in the target schools.

5.3.2 Characteristics of DBR

DBR has been described as:

i. Pragmatic;
ii. Grounded;
iii. Interactive, iterative, and flexible;
iv. Integrative;
v. Contextual (McKenney & Reeve, 2012; Wang & Hannafin, 2005).

The following section illustrates each of these characteristics.

The first characteristic of DBR is that it is pragmatic, because its goals are to solve current real-world problems by designing interventions, as well as extending theories, and refining design principles (Design-Based Research Collective, 2003; Van den Akker & *et al.*, 2006).
In traditional educational research, existing theories are usually tested through artificial treatments in controlled contexts (Reeves *et al.*, 2008). People engaged in these experimental approaches hope to be able to design instruction based on the principles that the theory and associated experimental results support (Edelson, 2002). However, in DBR the goal is not testing whether or not the theory works (Van Den Akker, 1999) rather both design and theory are mutually developed through the research process. Therefore, researchers use design to enact and refine theories continuously (Edelson, 2002) so that the theories "do the real work" in practice Cobb *et al.*, (2003: 10) and eventually lead to substantial change in educational practice (Van Den Akker, 1999).

The second characteristic of DBR is that it is grounded in both theory and the real-world context (Wang & Hannafin, 2005) i.e. DBR uses theory, along with empirical findings, and local expertise as inputs to create interventions that solve real-world problems. Through research embedded in the intervention development process, DBR produces theoretical understanding as an output (McKenney & Reeves, 2012). In addition, DBR is conducted in real-world contexts replete with the complexities, dynamics, and limitations of authentic practice.

The third characteristic in terms of the research process is that DBR is interactive, iterative, and flexible.

DBR requires interactive collaboration among researchers and practitioners in order to refine the designed intervention. For example, in the current study the researcher worked with experts, biology teachers, and students at different stages of development of the intervention. Without such collaboration, interventions are unlikely to effect changes in the real world context (Design-based Research Collective, 2003; Reeves *et al.*, 2005; Wang & Hannafin, 2005).

The insights and the interventions of DBR evolve over time through multiple iterations of investigation, development, testing, and refinement (MacKenney & Reeves, 2012). Furthermore, MacKenney & Reeves argue that within one research study, several sub-studies often take place, each with its own complete cycle of inquiry and chain of reasoning. For example, the current study used cycles within three stages (Section 5.3.3) to portray the overall process of the study i.e. the preliminary analysis stage had two cycles of context analysis including field based investigation and a literature review; the design or prototyping stage had up to four cycles of prototypes (refer to Figures 6.1 and 6.2); and the field implementation and evaluation stage had two cycles, i.e. implementation of the PD workshop, and implementation of new approaches in the experimental schools.

DBR procedures usually take a long period of time because theories and interventions tend to be continually developed and refined through an iterative design process from analysis to design to evaluation and re-design (Design-Based Research Collective, 2003; Wang & Hannafin, 2005). This on-going recursive nature of the design process also allows greater flexibility than traditional experimental approaches.

The fourth characteristic of DBR is that it is integrative. Researchers need to integrate a variety of research methods and approaches from both qualitative and quantitative research paradigms, depending on the needs of the research (Section 5.6).

The integrative use of multiple methods in the research process results in data from multiple sources, which serves to confirm and enhance the "credibility" of findings (Wang and Hannafin, 2005: 8), and shows the connection between the processes of enactment and outcomes. This aspect of methodology was explicitly implemented when the intervention was enacted with experimental school teachers and students for a period of a school term during the third stage of the study. This stage provides an opportunity to use a quasi-experimental design (Section 5.4) with experimental and control groups, as well as pre-test and post-test comparisons for the measurement of teachers' classroom practices, students' attitudes toward biology, and the teaching and learning methods.

The fifth characteristic of DBR is that it is contextualised because research results are "connected with both the design process through which results are generated and the setting where the research is conducted" (Wang & Hannafin, 2005: 11).
It is imperative that design-based researchers keep detailed records during the design research process concerning how the design outcomes (e.g. guidelines or principles) have worked or not, how the innovation has been improved, and what kind of changes have been made (Van Den Akker *et al*., 2006). Through this documentation, other researchers and designers who are interested in those findings can utilise them in relation to their own context and needs. In order to increase the "adaptability" of the findings in the new settings, guidance on how to apply those findings is also required (Wang & Hannafin, 2005: 12). The following summarises the three stages of the study.

5.3.3 An overview of the three stages of the study

The three main stages of this study are: preliminary analysis, design , and implementation and evaluation (Chapter 1 Figure 1.1).

Stage 1. The preliminary analysis entailed the problem identification, diagnosis, and initial recognition of design requirements. The researcher was involved in the activities such as conducting context analysis, field-based investigation, and a literature review. The preliminary analysis stage contributed to both practical and theoretical outputs. From a theoretical perspective this stage generated a clear understanding of the problem as well as specifications of long range goals, (i.e. the overall aim of the intervention, based on the analysis and exploration which have shaped an understanding of both the problem at hand and teachers' needs and wishes). In addition, tentative design requirements were determined and initial design guidelines were generated based on contextual insights. Practically, this stage produced a descriptive and analytical understanding of the identified problems as manifested within a context.

Stage 2. The design and empirical testing stage generally takes place through prototyping approach (Section 6.3) where successive approximations of desired solutions for the identified problems in the context are re-created. Each prototype of the research, i.e. the curriculum materials and PD programme was reviewed by experts, and teachers, tried out by teachers and students, and finally reviewed by experts. The process was iterative in nature which involves design, formative evaluation, analysis, and revision/refinement (Sections 6.3, Figure 6.1 and Section 6.4, Figure 6.2). Findings from each cycle through formative evaluation were used to improve the validity and practicality of prototypes.

The overall results from the design and empirical testing stage from practical perspectives included the intervention which was conceived and assembled with the most successive prototypes.

Stage 3. Implementation and evaluation of the PD programme. According to Smith and Ragan (1999), the purpose of evaluation of implementation of the PD programme is to determine the effectiveness of the revisions made during the prototyping stage and ascertain any problems that might arise in the administration of the intervention.

From practical perspectives, the activities in the third stage lead to ideas for conclusions about how the intervention is to be implemented more widely. From a theoretical perspective the knowledge and pedagogical skills produced by the combined activities contribute to a broader theoretical understanding of the intervention.

The following section discusses the quasi-experimental design which guided research activities (e.g. student learning outcomes) during evaluation of the PD programme.

5.4 The quasi-experimental design

The third research question of the study asks: *What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?* Answering this question requires an experimental design concerned with measuring the effect of the new intervention to teachers' instructional practices and students' learning.

According to Cohen *et al.,* (2007) experimental research investigators deliberately control and manipulate the conditions that determine the events in which they are interested. Furthermore, Borg and Gall (1983) add that experimentation involves making a change in the value of one variable, called the independent variable, and observing the effect of that change on another variable, called the dependent variable. Quasi-experimental research focuses on questions where researchers have some control of subjects but can only work with an intact group (Demert & Towner, 2003). Shadish, Cook and Campbell (2002) held that quasi-experiments lack random assignments of units (e.g. teachers and students) to conditions, but have similar purposes and structural attributes to randomised experiments.

Quasi-experimental designs are commonly employed in the evaluation of educational programmes when random assignment is not possible or practical and allow for use of existing groups without disruption (Muijs, 2011; Ross *et al*., 1999). In the current study quasi-experimental design is used to examine the impact of the PD programme on student cognitive and affective learning outcomes (Chapter 7).

Robson (2002) and Shadish, Cook and Campbell (2002) provide a range of quasi-experimental designs, for example: one-group-post test only, one-group-pre-test post-test, post-test non- equivalent control group, and pre-test post-test non-equivalent control group.

For this research, one-group post test only design does not show students' attitudes towards biology and the teaching and learning methods before implementation of the PD programme. The lack of pretest makes it difficult to know if the observed changes in students' attitudes would be a result of the intervention, and it may be that students' attitudes don't change at all after implementation of the intervention.

One-group pre-test/post-test design is considered to be appropriate for this research as it aims to discover whether the changes in students' attitudes toward biology and the teaching and learning methods were due to the implementation of the new approaches.

5.4.1 Limitation of quasi-experimental design

There is an argument that quasi-experimental research simply seeks associations between treatment and outcomes and that no further information or reasoning is required about why and how outcomes are linked (Demert & Tower, 2003). This research used questionnaires and interviews to triangulate with the quasi-experimental research design to help elucidate more effectively the changes in the students' attitudes toward biology and teachers' classroom instructional practices.

Another limitation of quasi-experimental approach is time constraints. In order to generate a detectable impact, a certain amount of time is required. However with increased time there is also an increasing possibility of experimental problems such as history, mortality, and maturation among the comparison groups (Krathworhl, 1998). These problems together with other experimental threats to internal and external validity are discussed in Section 5.7 and summarised in Table 5.3.

5.5 The research location

DBR is typically context-bound research and therefore the nature and conditions in which the activities are carried out are critical (Richey & Klein, 2007). Different settings have different cultures and sets of conditions that can have a profound impact on the design and development activities occurring there (Richey & Klein, 2007). Other factors may have an even greater impact on DBR activities such as variation in materials and resources that shape the work being done by teachers and students, or aspects of organisational climate. It is with these features in mind that this study was conducted in Tanzanian school settings. Eight secondary schools were purposefully selected because they had a wide range and availability of teaching and learning resources, and teachers who could teach biology. These schools were located in four Tanzanian regions and used in all three stages of the research for different research activities, as shown in Table 5.1.

These activities include: preliminary analysis which was conducted before the researcher embarked on this study in order to ascertain the research problem in science teaching and learning in Tanzanian secondary schools (Section 2.8). Users' appraisal and tryout stages involved the design and formative evaluation of exemplary curriculum materials and PD programme in order to improve their validity and practicality before implemented in the field (Sections 6.3 and 6.6). Field test involved implementation of the PD programme in the experimental schools and its evaluation. The study selected government secondary schools for the following reasons:

i) Smooth monitoring of implementation of the intervention without causing any disruptions to the school or teacher's timetable. These schools used a similar biology syllabus, and they had similar school routines as directed by the Ministry of Education; and
ii) It was easier to have an access to research participants as required, because the permission to implement research activities in the schools was granted by the Ministry of Education through respective Regional Education Officers and headmasters.

Table 5.1: Secondary schools involved in the study.

Secondary School	**Region**	**Research activities**
1	Dar es Salaam	Preliminary analysis
2	Dar es Salaam	Preliminary analysis
3	Dar es Salaam	User appraisal and try-out of the PD workshop and curriculum materials
4	Dar-es Salaam	Try-out of the curriculum materials
5	Iringa	Field test (Experimental group)
6	Iringa	Field test (Experimental group)
7	Morogoro	Field test (Control group)
8	Morogoro	Field test (Control group)

5.5.1 The study population, sample and sampling procedures

A research study population is a group of individuals' possessing one characteristic that distinguishes them from other groups (Creswell, 2008). The target population is defined as the individuals in a population that a researcher can actually access; it is also called a "sampling frame" (Creswell, 2008: 393). The study sample is the segment of the population (group of people, objects) that is selected for investigation (Bryman, 2001;

Richey & Klein, 2007). The sample should be representative of the population to ensure that the findings can be generalised from the research sample to the population as a whole (Bryman, 2001). This study involved biology teachers and their students from the eight government secondary schools in Tanzania Mainland (Table 5.1), experts, and biology student teachers.

Teachers. Biology teachers were the key sample of the study. They provided the professional and pedagogical support required by the study including the validation and implementation of the PD programme. The aim of including teachers as practitioners in this study was to develop their understanding of the theoretical perspectives on teaching and learning which underpin the PD (Van Den Akker *et al.*, 2006). Similarly, Driver *et al*. (1994) argued that, since teachers are aware of the students and the environment in their workplace, such approaches will give teachers the opportunity to reflect and generate useful ideas, which will modify their practices.

Students. The study involved all students who were learning biology from the eight schools and in their respective classes (i.e. from the Form I – IV). In Tanzanian Ordinary secondary schools, biology is one of the core subjects (refer to Section 2.4) and these classes provided an environment in which the new activity-based approaches were tried, implemented, and evaluated.

Experts. The study involved experts in the field of education, i.e. people who by definition have knowledge and experience that the novices (intended participants) should not possess (Tessmer, 1993). The current study used University lecturers from the field of biology subject knowledge and methods, science education, curriculum development, and teachers' PD. They performed an expert review of the biology teachers' PD programme including curriculum material prototypes. The focus was to verify validity and the initial practicality of the teachers' PD programme including curriculum materials before they were implemented in the users' (biology teachers and students) context.

Student teachers. The study involved Postgraduate Certificate in Education (PGCE) student teachers during the initial stages of the study, i.e. design and development of the teacher support curriculum materials. They were requested to review the first draft of the curriculum materials and verify the clarity and content validity of the activity-based lessons.

Table 5.2 presents the study sample for different research activities.

Table 5.2: The study sample and data collection instruments

The Main Research Stages and Duration	Research Activities	Participants				Total	Data Collection Instruments
		Teachers	Students	Experts	Student Teachers		
Preliminary analysis (*April–August 2010*)	Context analysis and literature review	3	-	-	-	3	- Documents - Unstructured classroom observations - Field notes
Design/ Prototyping (September – *December 2010)*	Experts' review	-	-	3	-	3	Guiding questions
	Users' review	12	-	-	7	19	Open-ended questionnaires
	Tryout with teachers and students	12	123	-	-	135	- Observation checklists - Semi-structured interviews - Evaluation questionnaires - Focus group discussions - Field notes
Field implementation and evaluation *January–May 2011)*	Field implementation and evaluation	7 experimental schools (Schools 1 and 2)	413 (experimental schools), and 139 (control schools- schools 3 and 4)		-	559	- Classroom observation checklists - Semi-structured interviews - Evaluation questionnaires - Focus group discussions - Field notes - Achievement tests

5.5.2 Sampling procedures

This study used purposeful sampling procedure to select participants as well as the setting (Patton, 2002). The participants were selected in order to match the criteria of the study (Rudestan & Newton, 2001). According to Patton (2002: 230) the goal of purposeful samplings, is to select cases, which are "information-rich" to develop an understanding of the situation being studied. The researcher identified the sample composition presented in Table 5.2 because they can provide the required information for the implementation of the research activities.

5.6 Data collection methods

In DBR, the type of data collected are related to description of key research components i.e. the preliminary analysis, design (prototyping), implementation, and evaluation.

This study used mixed methods as a procedure for data collection and analysis (Creswell 2007; Tashakkori & Teddlie 2003a). The requirements of the research questions for this study provided the grounds for mixed methods because they have elements of descriptive and explanatory research (Singleton & Straits, 2005).

Different methods and approaches for data collection were particularly useful at different stages of the study because the results from one stage were used to inform the development of the following stage (Richey & Klein, 2007). Van Den Akker *et al.,* (1999) argued that the methods and techniques for data collection in DBR are usually attuned to follow the quality criteria, for example, validity can be adequately evaluated through *experts* and *user reviews*, practicality via *try-outs* and *effectiveness* in the field implementation. The methods of data collection in the former phases are qualitative (i.e. using interviews, documents, and unstructured classroom observations) with fewer participants compared to the later phases which are more quantitative, with an increasing number of participants (i.e. using questionnaires and achievement tests).

The qualitative and quantitative data were collected at different stages of the study with a rationale of:

i) Instrument fidelity (i.e. maximising the appropriateness and/or utility of instruments used in the study);
ii) Treatment integrity (i.e. mixing the qualitative and quantitative data in order assess the fidelity of intervention);
iii) Significant enhancement (i.e. mixing qualitative and quantitative techniques in order to maximise researchers' interpretations of data) (Greene, 2007).

The major purpose of mixing qualitative and quantitative approaches and methods of data collection for this study was to seek confirmation of the research findings in order to increase their validity and credibility (Greene, 2007; Bryman 2008). The study adopted triangulation in order to seek convergence and corroboration of findings from different sources and methods which study the same phenomenon for the purpose of obtaining complementary data (Creswell, 2007). When results from triangulation provide consistent or convergent information, then the confidence in inquiry inferences increases.

5.6.1 Data collection instruments and administration

DBR tends to use a wide variety of data collection instruments (Richey & Klein, 2007). This displays the critical role which data collection instruments play in a design research project, specifically because of various evaluation levels. Data collection instruments for this study involved: documents, questionnaires, interviews, classroom observations, teachers' log book, and achievement tests. Some instruments such as questionnaires, interviews and curriculum profile classroom observation checklists were used more than once i.e. during prototyping and field implementation and summative evaluation (Table 5.2).

5.6.1.1 Documentation

Documents are written or printed materials that can be read, have not been produced specifically for the purpose of research, and are relevant to the concerns of social research (Bryman, 2008). Documents usually, carry content in terms of words, images, plans, ideas and patterns which reveal something about an underlying social reality. According to Bryman (2008: 526) they are "windows onto social and organizational realities". One of the strengths of using these documents is due to their "non-reactivity" as the fact that documents are collated, usually for other purposes (Bailey 1982: 303). The authors of the documents are unlikely to assume their future use in research hence the researcher is not in a position to bias subjects, and studies (Bryman, 2008).

The advantages of using documents as data collection instruments are:

i) They enable a researcher to obtain the language and words of the participants;
ii) They can be accessed at a time convenient to the researcher (as an obtrusive source of information).

On the other hand, the documents bear the following limitations: they may not be authentic, i.e. there may be some missing or incomplete data and inaccuracies in the material; they may be protected information, unavailable to public or private access and sometimes require transcription (Creswell, 2009).

This study used a number of documents during the preliminary analysis stage (context analysis and literature review) in order to obtain information about science teaching and learning in Tanzanian secondary schools, teachers' PD, and theoretical inputs that helped the understanding of the research problem and gain insights of the design requirements of intervention. The documents used in this study included: Tanzania Education and Training Policy, Teacher Education Master Plan (TEMP), Secondary Education Master Plan (SEMP), Secondary Schools Curriculum Framework, biology syllabus, biology teachers' lesson plans and schemes of work, and National examination results for science subjects.

5.6.1.2 Questionnaires

Questionnaires are research tools through which people are asked to respond to the same set of questions in a predetermined order (Gray, 2009). The questionnaire is a widely used and useful instrument for collecting survey information, providing structured, often numerical data, which can be administered without the presence of the researcher, and often being comparatively straightforward to analyse (Oppenheim 1996; Cohen *et al.,* 2007).

Questionnaires can be "structured, semi-structured or unstructured" Cohen *et al.,* (2007: 320) depending on the sample size, e.g. when having a larger sample the questionnaires tend to be more structured and closed with numerical components; while for smaller sample, the questionnaire becomes less structured, more open and word-based.

This study used a semi-structured questionnaire with open-ended questions in order to obtain teachers' and students' opinions and perceptions on the various parts and functions of the intervention. The open-ended questions are useful if the possible answers are unknown, or if there are so many categories that a closed question would contain an extremely long list of options (Bailey, 1992). The respondents are provided with spaces to write their answers in as much detail as they could in their own language (Oppenheim, 1996). The advantage of open-questions is the potential for richness of responses, some of which may not have been anticipated by the researchers (Gray, 2009). On the other hand, these questions can lead to irrelevant and redundant information (Cohen *et al.,* 2007). They may be too open for respondents to know the kind of information required and at the same time they require much more time for both the respondents to answer and for researchers to analyse (Oppenheim, 1996).

The questionnaires used in this study were:

i) A biology teachers' expectation questionnaire (Appendix C1) used to explore teachers' prior experiences with PD and expectations about participating in the PD workshop;
ii) A workshop evaluation questionnaire (Appendix C2) which examined Biology teachers' opinions and experiences regarding the workshop activities, including what they learned and practiced;

iii) A student evaluation questionnaire (Appendix C6) which provided information about students' perceptions and experiences relating to the activity-based approaches adopted by their teachers during Biology lessons;

iv) A student attitude questionnaire (Appendix C3) which examined students' attitudes toward Biology and the teaching and learning methods before and after implementation of the PD programme in the experimental schools;

v) A school support questionnaire (Appendix C9) exploring Biology teachers' opinions and perceptions on how supportive their schools were during the implementation of the PD programme;

vi) A school-based follow-up questionnaire (Appendix C12) for assessment of teachers' perceptions and experiences following their participation in the school-based coaching sessions.

Appendices C1 and C2 were used during the Try-out stage and field implementation of the PD workshop**.**

5.6.1.3 Interviews

A research interview involves gathering data through direct verbal interaction between individuals and, it can represent people's words and actions as the data of the research inquiry and this requires methods that allow the researcher to capture language and behaviour (Kvale, 1984). Interviews can be used to gather in-depth information about a person's knowledge, values, preferences and attitudes, and can be used in conjunction with other research techniques, such as surveys, to follow-up issues (Gray, 2009: Oppenheim, 1996). The common types of interviews discussed in the literature are structured, unstructured, semi-structured and focus group interviews (Kvale, 1994; Gray, 2009).

Structured interviews. Structured interviews are used to collect data for quantitative analysis in which the questions are formulated beforehand and asked in a specific manner (Sommer & Sommer, 1997). The structure is provided to obtain consistency from one situation to the next. Response categories are fixed and prescriptive, serving to reduce interviewer bias to a minimum and achieve the highest degree of objectivity and uniformity (Sarantakos, 2005).

Semi-structured interviews. These are non-standardised interviews Gray (2009) containing elements of both structured and unstructured interviews. The degree to which the interview is structured depends on the research objectives as well as the types of information sought (Sarantakos, 2005). When conducting semi-structured interviews all respondents are asked the same questions, but the order in which they are asked may differ from one person to the other, in some cases even the manner in which they are asked varies, for example changing the wording or sentence structure to better fit the respondent or the situation. This arrangement may be more suitable for obtaining in-depth information (Bryman, 2008).

Unstructured interviews. Unstructured interviews lack the predetermined order or specified wording of the questions, leaving room for improvisation on the part of the researcher. The structure of the interview is highly flexible, and the restrictions are minimal, in most cases taking the form of guides rather than rules (Sarantakos, 2005). The main goals of an unstructured interview are to explore all the alternatives in order to pick up information, to define areas of importance that might not have been thought of ahead of time, and to allow the respondent to take a lead to a greater extent (Sommer & Sommer, 1997).

Focus group interviews. This is a form of group interview that collects data through group interaction on a topic determined by the researcher (Morgan, 1996). This technique locates the interaction in a group discussion as a source of data and acknowledges the researcher’s active role in creating the group discussion for data collection purposes. Group size ranges from eight to twelve people and sessions last from 30minutes to 45 minutes to allow full exploration of the topic (Sommer & Sommer, 1997).

Participants interact with each other rather than with the interviewer such that the views of the participants can emerge, and hence collect extensive data (Creswell, 2008). One of the disadvantages of focus group interviews is that it sometimes requires the researcher to find consensus on questions, so one explanation can be recorded for all individuals in the group. In addition, some individuals may dominate the conversation leading to responses that do not reflect the group (Creswell, 2008).

Limitation of interviews. Interviewing as a data collection method is prone to subjectivity and bias on the part of the interviewer due to the human interactions during the interviewing (Sarantakos, 2005; Kvale, 1996). Oppenheim (1996) suggested some of the causes of bias during interviewing which may be associated with:

i) Sampling which is created by the researcher without adhering to sampling instructions;
ii) Poor rapport between interviewer and interviewee;
iii) Changes to question wording and alterations to the sequence of questions; poor prompting and biased probing; and
iv) Poor use and management of support materials (such as cards) and poor handling of difficult interviews;

Semi-structured and unstructured interviewing are time-consuming and expensive types of data collection techniques (Oppenheim, 1996). The reason is that, interviewers need to follow respondents in their natural setting (for effective interviewing) and sometimes they are scattered over a wide geographical area. The quality of data depends on the quality of the interaction during the interviewing process and proper recording of information. The interviewer is expected to possess considerable skills, experience and commitment (Kitwood, 1997).

The study employed semi-structured and focus group interviews to support and extend information obtained from questionnaires and classroom observations. The following are the interviews used in the current study:

i) A biology teachers'reflective interview (Appendix C5) enabled the researcher to assess how teachers perceived and later put into practice the activity-based approach supported by the 5Es instructional sequence, i.e. a constructivist framework with five instructional stages, i.e. *Excitement, Exploration, Explanation*, *Elaboration* and *Evaluation* (Table 6.1).

ii) A teachers' Level of Use interview (Appendix C8) provided information about the depth of individual teachers' new knowledge and skills acquired from the PD workshop and the extent of implementation in their classrooms.

iii) A students' focus group interview (Appendix C7) examined students' perceptions and experiences about their teachers' classroom practices following the implementation of activity-based approaches;

iv) A teachers' focus group interview (Appendix C10) explored teachers' perceptions about how supportive their schools were during the implementation of the new approaches.

Appendices C5 and C7 were used both during the try-out of curriculum materials and implementation of the new approaches in schools.

5.6.1.4 Classroom observations

Observation in the research context involves the systematic viewing of people's actions and the recording, analysis and the interpretation of their behaviour (Saunders *et al.,* 2000). The distinctive feature of observation as a research process is that, it offers an investigator the opportunity to gather "live" data from naturally occurring social situations (Cohen *et al.,* 2007: 398). According to Morrison (1993) cited in Cohen *et al.,* (2007) observations enable researchers to gather data on the physical setting, human setting, and interaction setting. There are two types of research observation according to Patton (2002) and Saunders *et al*., (2000) these are: structured and unstructured/ participant observations. Structured observation is very systematic and enables the researcher to generate numerical data from observations, which in turn facilitate making comparisons between settings and situations, and frequencies, patterns and trends to be noted or calculated. An observer adopts a passive, non-intrusive role, merely noting down the incidence of the factor being studied (Cohen *et al.,* (2007; Gray, 2009). Usually, observations are recorded on an observation schedule or form (Gray, 2004).

The unstructured or participant observation is largely qualitative Saunders *et al.,* (2000), and it occurs in two forms; the 'complete participant' form where a researcher takes an insider role in the group being studied and may or may not declare that he/she is a researcher, or a 'participant as an observer' form where the researcher becomes a part of the social life and take notes what is happening for research purposes (Cohen *et al.*, 2007).

Problems with using observation as a method of data collection include:

i) The individuals or groups observed may change their behaviours when become aware that they are being observed. The use of observation in that situation may introduce distortion, i.e. what is observed may not represent their normal behaviour;

ii) There is always a possibility of observer bias if the observer is not impartial she/he can easily introduce bias and there is no easy way to verify the observations and inferences drawn from them;

iii) The interpretation drawn from a single observation may vary from one observer to another.

This study employed both unstructured and structured observations. A participant as an observer form of unstructured observation helped to explore the teaching and learning of biology in the secondary schools during the preliminary field-based context analysis stage of the study (Section 2.8). Structured observations were conducted with the assistance of a curriculum profile classroom observation checklist (Appendix C4) during the prototyping and field implementation stages of curriculum materials and the PD workshop. A curriculum profile is a set of statements about the teachers' roles and students' classroom activities during lesson observations (Van den Akker & Voogt, 1994). This instrument was developed by the researcher by considering the requirements of the proposed innovation, i.e. the 5Es instructional sequence (Table 6.1) adapted by the study to support implementation of the activity-based lessons. The first part comprised of action statements organised under each of the 5Es, i.e. *Excitement, Exploration, Explanation, Elaboration, and Evaluation* to indicate specific teachers' roles and students' activities during the lesson. The second part comprises the open-ended questions on specific instructional practices not included in the checklists. This procedure allowed the observers to pay more attention to the specific intentions of the designer and the specific interpretation in classroom operations by teachers and students.

5.6.1.5 Researcher's log book

This instrument is used to document precisely the nature of tasks and decisions made during the various stages of the study (Richey *et al,* 2007). In this study the researcher's log book was used to maintain a record of activities and observation notes associated with teachers' implementation of the activity-based approaches from the preparation sessions, and in the classroom with students. Field notes can be defined as the researchers' written accounts of what they hear, see, experience and think in the course of collecting data and reflecting on their data (Fraenkel & Wallen, 2008). The researcher in this study manually documented the experiences of teachers at different stages of implementation of the curriculum materials, the difficult areas and how they organised and monitored students' activities. The notes included the general response of the students in performing lesson activities. A researcher's log book was maintained throughout the field implementation stage for monitoring and reflection purposes.

5.6.1.6 Achievement test

This is an instrument used to measure the proficiency level of individuals in a given area of knowledge or skills (Fraenkel & Wallen, 2008). It is mostly used in schools to measure learning or effectiveness of the instruction. In this study, the achievement test was used to measure student learning and understanding of the topic of 'c*lassification of living things'* to form II students in both experimental and control schools. The achievement test (Appendix C11) was constructed by the researcher (Section 7.6.1) because, usually it is difficult to obtain standardised tests which are directly aligned with the purposes of the PD programme being investigated or developed (Kennedy, 1999: Meiers & Ingvarson, 2005).

5.7 Validity and reliability

Quality and trustworthiness of research are often associated with the measures of validity and reliability.

Validity has been defined as the appropriateness, correctness, meaningfulness and usefulness of the specific inferences researchers make based on data they collect (Fraenkel & Wallen, 2008). According to Hoadley (2004: 204) validity of a study refers to the "likelihood that our interpretation of the results accurately reflects the truth of the theory and hypotheses under examination". Reliability points to the "degree to which a measurement can be replicated" (Hoadley, 2004: 204).

Reliability implies that repeated measurements of the same phenomenon are able to produce consistent results.
Qualitative and quantitative studies tended to rely on different sets of criteria for establishing validity and reliability of their research (Johnson & Christensen, 2004: Cohen *et al*., 2007).
In quantitative research quality and trustworthiness concerns are primarily related to the following four types of validity (Cook & Campbell, 1979):

i) Internal validity or causal validity: the validity with which it is inferred that the relationship between two variables is causal;
ii) External validity or generalisation: the extent to which results of a study can be generalised to and across populations of persons, settings, outcomes and treatment variations;
iii) Statistical conclusion validity: the validity of which it can be inferred that two variables are related and the strength of that relationship; and
iv) Construct validity: the extent to which theoretical construct is accurately represented in a particular study;

On the other hand, qualitative researchers are often not concerned with exploring causal relationships between variables, and their notion of validity of research outcomes tends to rely on a different set of criteria (Guba & Lincoln, 1989). Qualitative researchers prefer to use terms such as plausible, credible, trustworthy, and defensible to describe their research outcomes. However issues of validity are important to qualitative researchers as well. Maxwell (1996) identified three types of validity that are applicable to qualitative research:

i) Descriptive validity: refers to validity of settings and events;
ii) Interpretive validity: refers to the validity of the statements about the meanings or perspectives held by participants; and
iii) Theoretical or explanatory validity: refers to the validity of claims about causal processes and relationships;

Qualitative researchers need to be aware of the threats to the credibility of their research due to the influence of “researcher bias” which results from ‘allowing one’s personal view and perspectives to affect data interpretation and how the research is conducted (Johnson & Christensen, 2004: 249). However, most of qualitative researchers are not concerned about the subjectivity associated with their research Denzin and Lincoln (2000), and often they use “reflexivity” as a means to achieve credibility. Johnson and Christensen (2004: 249) define “reflexivity” as “a self-awareness and critical self-reflection by the researcher on his or her potential biases and predispositions as these may affect research process and outcomes”. Qualitative research methods employ a range of techniques including triangulation, peer review, member checking, and participants’ feedback to enhance their trustworthiness of research outcomes.

DBR treats the notion of quality and trustworthiness differently from purely qualitative and quantitative research. Van Den Akker *et al.,* (2006: 85) argued that DBR “typically triangulates multiple sources, and kinds of data to connect intended and unintended outcomes to process of enactment”. They also point out that the reliability of findings and measures can be promoted through triangulation from multiple data sources, repetition of analysis across stages/cycles of enactment, and use (or creation) of standardised measures or instruments.

DBR is not concerned with a broad generalisability of research outcomes, and as such ignores the issues related to external validity. Hoadley (2004: 205) argues that “universality is rare in educational phenomenon and because methods take tentative steps by first examining individual context, design based researchers generalise their findings only tentatively" because, researchers are involved in the process of intervention as participant observers and because they play an active role in manipulating the environment they study. Hoadley (2004) points out that it becomes imperative for them to describe and monitor ways in which results may be influenced by their own agenda. For this matter design based researchers like others from different approaches not only document their perspective or starting point, but also document any plausibly relevant interventional strategies used by participants and researchers.

In this study the researcher has taken particular care to present the design and intervention as a narrative that describes the practices of participants and the researcher, and the context within which this intervention is located. This study has involved a number of participants and care was taken to document the practice in an on-going manner for example, the iterative activities at the three stages of the study, i.e the preliminary analysis, prototyping and implementation of the intervention in the field. Similarly, participants' feedback, review, (e.g. participants who were involved in the try-out stage provided feedback of their classroom practices) and presentation of the research to seminar(s) and conference(s) helped the researcher to document the practice in detail and at the same time the researcher was able to clarify the personal perspective and the possible effect it could have on outcomes in a reflexive way. The information kept in the researcher's log book throughout the field work enhanced reflection on both the researcher's and teachers' practices.

Another technique for ensuring rigour in DBR is its reliance on multiple methods and multiple sources of data (Cobb *et al.,* 2003). This effect rests on the premise that the weakness in each single data source, method, evaluator, and theory or data type is compensated by counterbalancing the strength of another (Miles & Huberman, 1994; Patton, 1990). This study employed triangulation design in order to corroborate findings from qualitative and quantitative methods employed in the answering of the research questions. The study adopted the convergence model of triangulation Creswell & Plano Clark (2007) whereby, the researcher collected and analysed qualitative and quantitative data from different sources separately for each research question. Thereafter, the two datasets were merged or converged (by comparing and contrasting the different results) during the interpretation of the findings so that a complete analysis could be developed from both datasets.

The study also used a quasi- experimental design during field implementation of PD programme and evaluation (Table 5.2) to gain a better understanding of the impact of the intervention on student learning outcomes. The quasi-experimental design followed the criteria of internal validity and causal validity but it was not the concern of this research to address generalisability because the goal was to gain an understanding of the intervention as it unfolded in a particular setting, and to develop tentative theories applicable to the particular context. This helped to maximise *ecological validity,* i.e. the method, materials, and setting of the study must approximate the real life situation under investigation (Van Den Akker *et al.,* 2006). Table 5.3 illustrates experimental threats to internal validity and how this study tried to eliminate/reduce them.

Table 5.3 Experimental threats to internal validity

Threats	**Authors' explanations**	**Elimination/reduction of the threats in the present study**
History	Specific events which occur between the first and second measurement that could cause the observed outcomes (Shadish, Cook & Campbell, 2002).	The experimental and control school teachers had the same headmasters in the same school but teaching different classes. Students were taught by the same teachers in their respective classes.
Mortality	Loss of respondents to treatment or to measurement can produce artificial effects (Shadish, Cook & Campbell, 2002).	In the present research sample neither teachers nor students dropped out.
Instrumentation	The changes in the instrument, observers, or scorers which may produce changes in outcomes (Robson, 2002)	The participants (students) and the instruments, i.e. Appendices C3 was the same during pre-testing and post-testing.
Maturation	Naturally occurring changes over time that could be confused with a treatment effect (Shadish, Cook & Campbell, 2002).	Students in the control group had a similar experience as experimental students (e.g. use the same syllabus and class levels and teachers had the same education level, i.e. Diploma)
Selection	There may be preliminary differences between the control and experimental groups before involvement in the study (Robson, 2002)	Students were matched based on their respective class levels such as: Form I, II, III and IV. There might be other events which the research would have had no control.

Other techniques employed to maximise the validity and reliability are:

i) Using the assistant researcher during the evaluation stage to assist in classroom observations, i.e the researcher and assistant researcher independently observed the teachers' classroom practices guided by the classroom observation checklist (Appendix C4). This helped to improve internal reliability of findings from classroom observations;

ii) Piloting of the data collection instruments during the prototyping stage of the study in order to ensure the validity of the instruments in collecting the intended information during the field implementation and evaluation stage (Chapter 6, section 6.5).

5.8 Data analysis procedures

The study collected both qualitative and quantitative data to answer the three main research questions. For each question both qualitative and quantitative data were analysed separately and merged during the interpretation of findings in order to gain an in-depth understanding (Creswell & Plano Clark, 2007).

5.8.1 Quantitative data analysis procedures

The quantitative data from the 5-point Likert scale questionnaires (e.g. Appendices C2, C3, C6, C9 and C12) where 5 = strongly agree and 1= strongly disagree, were analysed statistically with the help of a computer-based statistical programme SPSS version 18, to compute descriptive statistics by using *mode, frequency*, and *percentages*, and displayed data by using tables. Each level on the scale was assigned a numeric value from which the individual responses were treated as ordinal data (Jamieson, 2004; Muijs, 2011). Furthermore, it cannot be presumed that participants perceive the difference between adjacent levels equally (i.e. the difference between 'agree' and 'strongly agree', the same as they might be between 'agree and neutral').

The inferential statistics for data from the 5-point Likert scale questionnaire (Appendix C3) used a non-parametric statistic test, i.e. Wilcoxon Signed Ranked Test (z *value)* which is designed for use when there are repeated measures at different occasions in order to determine whether participants change significantly across occasions (Green & Salkind, 2008). This statistical test works best when data are ordinal because it compares the medians of the two measurements, i.e. whether there is a statistical difference in the median values on different occasions (Pallant, 2010).

The quantitative data from classroom observation checklists were analysed through quantitative content analysis which involved the transformation of the statements from the checklists to numeric values (for example, the observed behaviour = 2, behaviour not well represented = 1, and behaviour not represented = 0) which allowed computation of percentages for each stage of a lesson (Appendix C4b-c). The rationale of assigning numeric values is to offer the opportunity of weighing the relative importance of different statements and the stages of a lesson.

Quantitative data from achievement test (Appendix C11) were analysed statistically by using a parametric statistic, i.e. independent samples *t-test* which compares the mean scores on the continuous variables for two different groups (Pallant, 2007). The independent samples *t-test* determines whether there is a statistically significant difference in the mean scores of the two groups.

Findings from inferential statistics were associated with the ‘effect size’ Pallant (2007: 207) which is defined as a statistic to provide an indication of the relative magnitude of the difference between the groups. The effect size values are calculated by using SPSS outputs and guideline scales proposed by Cohen (1988) for a specific statistical test. For example, in this study the effect size for a non-parametric test such as Wilcoxon Signed Ranked Test (z *value*), i.e. correlation *r*, ranges from: 0.1 = small effect size; 0.3 = medium effect size; to 0.5 large effect size.
The effect size for parametric test such as independent samples *t-test*, i.e. *eta squared,* ranges from: 0.01 small effect size; 0.06 medium effect size; to 0.14 = large effect size.

5.8.2 Qualitative data analysis procedures

Qualitative data from interviews, documents, unstructured classroom observations, field notes, and open-ended questions from questionnaires were analysed through content analysis.

Content analysis is a systematic and objective means of describing and quantifying phenomena Bryman (2001). It can be used with either qualitative or quantitative data, and in an inductive or deductive way, depending on the purpose of the study. Inductive content analysis involves the process of discovering the patterns, themes, and categories in one's data, while deductive content analysis is the process of analysing the data based on the pre-existing framework or categories (Miles & Huberman, 1994; Patton, 2002). This study used both inductive and deductive qualitative content analysis. Inductive content analysis was used to analyse data for research question one, because the themes were derived from the raw data (Weber, 1990). Deductive content analysis was used to analyse data for the second and third research questions because the themes were predetermined issues examined by the study and addressed by the research questions (Table 5.4). The study adopts Guskey's (2000) five levels of evaluating PD (i.e. teachers' reactions, teachers' learning, the nature of school support, teachers' level of use of the new approaches, and student learning outcomes) as a framework to guide data collection and analysis. This framework was used for the second research question on the practicality of the PD workshop, and the third research question about the impact of the teachers' PD programme on teachers' pedagogy and students' learning of biology (Chapter 7). Data from different sources were categorised along themes related to Guskey's framework (see Section 4.7).

In this study interviews and some of the classroom observations were audio recorded. The audio recordings collected were transcribed, and the information from each participant or classroom observation was summarised and used to enrich the researcher's field notes. The preliminary content analysis was undertaken through a manual method of analysis and reviewed several times by referring to the field notes and listening to the audio recordings in order to ensure all the required information had been considered for each question. The second stage involved data organisation whereby the categories were created from the summarised findings (e.g. research question one) or the data were coded according to the predetermined themes (e.g. research questions 2 and 3). The predetermined themes were modified in the course of analysis as new themes emerged inductively. The final stage involved analysis and interpretation of the findings.

According to Patton (2002), when presenting qualitative content analysis a researcher should strive for a balance between description and interpretation, i.e. “sufficient description allows the reader to understand the basis for an interpretation and sufficient interpretation allows the reader to understand the description” Patton, 2002: 503-504). Table 5.4 illustrates emergent and pre-determined themes for each research questions

Table 5.4: The emergent and pre-determined themes for each research questions

Research questions	Qualitative Instruments	The Main Themes
		1) Emergent Themes
1. What are the characteristics of an effective PD programme that adequately supports learning and teaching of biology in Tanzania?	Documents Unstructured classroom observations Field notes	- Science teaching and learning methods; - Students' involvement in the lesson; - Students' achievement in science subjects; - Availability of teaching and learning materials; - Lesson planning and presentation; - Science teachers' preparation; - Provision of in-service teachers' training; - Constraints in the science teaching; - Constraints in teachers' preparation and in-service training.
	Literature review	- Theoretical framework of the study; - Knowledge base for developing effective PD programmes and curriculum materials
		2) Predetermined Themes
2. How can a professional development programme be practically designed and implemented to enhance biology teachers' pedagogical knowledge and skills?	Experts' guiding questions Open-ended questions from questionnaires Interviews Focus group discussion Field notes	i) The content of the curriculum materials and the PD programme. • Relevance of the materials and PD programme to the targeted sample • Sequence of the components • Process/presentation • ii) Practicality of the materials and programme. • Resources, e.g. teaching and learning materials, teachers' support materials; • Sufficient time for preparation and implementation; • Teachers' and students' competencies in working with the innovation. iii) Improvement of materials and the PD programme. • The content;

		• The structure/ components; • Organisation; • Presentation modes.
3. What impact does this professional development programme have on teachers' pedagogy and students learning of biology?	Open questions from questionnaires Teachers' interview Level of use interview Focus group discussion Field notes	i) The content of the PD programme • Relevance of the PD components • Sequence of activities • Presentation modes ii) Feasibility of the PD programme • Resources/ materials support; • Collegiate/Peer support; • School leadership support; • Sufficient time for implementation process; • Teachers' and students' competencies in working with the innovation.

5.9 Ethical issues

Ethical considerations are an important part of any research and several ethical issues may confront researchers (Cohen *et al.,* 2007). The goal of considering ethical issues in research is to ensure that the participants will not be harmed at any stage of the research process (Flick, 1998). In this study the researcher was concerned with obtaining access to schools and avoiding any act of unethical behaviour. Ethical clearance was obtained from the University of Southampton, School of Education Ethical Committee prior data collection (Appendix D1). Permission to access schools was processed at the University of Dar es Salaam for local clearance which allowed implementation of the study and ensured maximum support from teachers and students (Appendix D2).
The researcher ensured that participants:

i) Were well informed about the purpose of the research they were being asked to participate in and how the information they provided would be used;
ii) Understood risks they may face as a result of being part of the research;
iii) Understood the benefits that might accrue to them as a result of participating; and
iv) Felt free to make independent decisions without fear of negative consequences;

During interview sessions with teachers and students the researcher allowed the interviewees to ask questions at any time, which made them feel respected as important participants in the study and they were re-assured that they could withdraw at any time. According to McQueen and Knussen (1999), interviews work better when participants are given initiatives and are invited to participate effectively in the study. In addition, the researcher established clear procedures that reduced risks and maximised confidentiality by assuring anonymity through the use of pseudonyms together with professional confidentiality during and beyond the research process. For example, each of the distributed questionnaires indicated (in the introductory part) that the information provided by participants was confidential and used only for the purposes of the research study. Furthermore, the validity and reliability issues discussed in Section 5.6 are also part of ethical aspects of research. Finally, participants will be provided with access to the outcomes of the completed research.

5.10 Summary of the chapter

This chapter presents the rationale of adopting Design-Based Research methodology which guided the development of learning environments and a systematic study of the form of learning generated in these environments. The Design-Based Research employed mixed methods in order to acquire in-depth understanding of findings and their interpretation . This was achieved through convergent triangulation design whereby the researcher collected and analysed qualitative and quantitave data separately for each research question and later merged during the interpretation of findings in order to maximise their validity and credibility.

The chapter also describes the aspects of research population, sample, sampling procedures, data collection instruments and their administration.

The chapter illustrates validity and reliability issues; quantitative and qualitative data analysis techniques; and ethical considerations associated with this research.

Chapter 6

Design and Formative Evaluation of the Curriculum Materials and Professional Development Programme

6.1 Introduction

This chapter presents the design and formative evaluation of the curriculum materials and professional development (PD) programme. It includes the description of the collaborative design of the curriculum materials and professional development workshop prototypes and how they were piloted before implementation in the field. The chapter ends with an outline showing improvements of the curriculum materials, PD workshop and data collection instruments based on the try-out findings.

The chapters on context analysis, theoretical framework of the study and development of teachers' PD programme, provided background information from which important design guidelines and specifications for teachers' support curriculum materials and PD programme were formulated. The context analysis provided a clear image of the current status of secondary science teaching and learning as well as teachers' PD in Tanzania which include:

i) The predominant use of traditional teaching and learning methods;
ii) Continued failure of O-Level secondary school students in their final national examinations;
iii) Teachers' lack of content knowledge and pedagogical knowledge and skills;
iv) Shortage of teaching and learning materials and equipment;
v) Inadequate in-service teacher training (i.e. most is externally funded, not focused on students' learning, lacking evaluation or follow-up measures and not sustainable (Sections 2.5.1 and 2.6.4).

Based on these problems and challenges the literature highlighted the arguments for designing teachers' PD programmes that integrated an activity-based approach supported by the 5Es instructional sequence (Table 6.1). The study recognises that embracing the activity- based teaching and learning approach was not an easy change for teachers because it was an unexpected innovation, i.e. teachers had to assume new roles and understanding, and change related beliefs about their identity (Borko & Putnam, 1996). Taking this into consideration the study tackled these challenges by designing a PD programme that comprises curriculum materials, a PD workshop, school follow-up coaching, and a supportive school environment (Section 4.6.2). These components were geared towards supporting teachers' learning of the activity-based approach and the 5Es instructional sequence for student improvements in the participation and understanding of their lessons.

The design and research activities discussed in this chapter are guided by the second research question: *How can a professional development programme be practically designed and implemented to enhance biology teachers' pedagogical knowledge and skills?*

6.2 Designing the biology curriculum materials

The advantages of carefully designing curriculum materials include a theoretical understanding of goals combined with informed outlooks about best practices (Davis, & Krajcik 2005). It is relatively straightforward to design materials that help teachers add new ideas to their repertoires. More challenging is to help them connect those ideas to their experiences; and harder still, is helping them to use their new knowledge to engage in the discourse and in their teaching. According to Davis and Krajcik (2005: 8) there are three factors which may limit the effectiveness of the curriculum materials, the first one is the "base" - curriculum materials must be of high quality in terms of content and pedagogy. The second factor is the characteristics of the teachers themselves such as their knowledge, beliefs, and dispositions toward reflection and improving their own practice. The third factor is the fact that the curriculum materials may be more effective if used in conjunction with other forms of support such as PD workshops.

This study adapted the methodological guidelines of Design-Based Research for designing curriculum materials suggested by Van Den Akker and Plomp (1993) and refined in the studies of Ottevanger (2001) and Stronkhorst (2001). This methodology includes:

i) Selection of exemplary themes or topics;
ii) Standardisation of the structure and design of lessons;
iii) Anticipation of potential implementation problems of teachers;
iv) Provision of the procedural specifications; and
v) Systematic and efficient formative evaluation.

In line with these guidelines, the design of the materials for this study reflected the problems and challenges raised in the context analysis (Chapter 2) which contributed to the following guidelines for the curriculum materials:

i) *Subject matter (biology) learning goals:* Each lesson in the curriculum materials has concise and clear information about the central elements, a list of instructional objectives that clearly specify the desired outcomes of a given lesson, an outline of the key concepts, activities, and possible questions;

ii) *Pedagogical support*: Reflections on the challenges facing Tanzanian secondary school biology teachers in terms of pedagogical knowledge and skills revealed in the context analysis (Chapter 2). Curriculum materials intended to support teachers in the implementation of the activity-based approach supported by the 5Es instructional sequence in:
    - Lesson preparation;
    - Lesson execution;
    - Assessment of students' learning during instruction;
    - Information on students' learning difficulties, preconceptions, and misconceptions;

- Specific instructional strategies that would promote and support students' involvement in the learning process;

iii) *Active learning through engaging students in doing lesson activities*: The lessons focus on student-centered approaches and learning for understanding. Curriculum materials were designed to involve students actively in inquiry learning processes through hands-on activities;

iv) *Alignment with the current curriculum*: Curriculum materials were designed and developed to support teaching and learning of biology by using the existing curriculum and the lesson planning format. Users (biology teachers and students) of the materials must believe that the materials will become part of the established curriculum and that it is not a waste of time. In this way the legitimacy of the new approaches could be established;

v) *Flexibility and active learning environment*: Curriculum materials provided flexibility for teachers to integrate theory with hands-on activities and promote more interaction among the students and with their teachers.

vi) *Fit with the school timetable*: Curriculum materials had lesson activities that could be carried out within the normal school/lesson timetable where a single biology period takes 40 minutes and double periods take 80 minutes.

The curriculum materials for this study integrated the 5Es instructional sequence (Table 6.1) with a focus on supporting biology teachers in the lesson planning (procedural specification) and implementation (i.e. very concrete 'how-to-do-it' advice). The 5Es instructional sequence begins with the e*xcitement* stage which replaces the *engagement* stage in the Bybee's (1997) 5Es model (Section 3.5).

The *excitemen*t stage emphasises the use of short stimulating lesson activities at the beginning of the lesson that are intended to capture students' attention, get students thinking about the concepts at hand, raise questions in students' minds, stimulate curiosity, and access students' prior knowledge.

During the *excitement* stage, the teacher should appeal to the interest of the student through introductory activities such as, oral presentations, or thought provoking problems to prepare students for the instructional content (Morrison *et al.*, 2001). Introductory activities should be fun, and engaging for the students, because fun activities can positively influence the attitudes towards both instruction and instructional content. Furthermore, the introductory activities should be appropriate for the students so that they can all participate.

Thought-provoking problems are useful for relating new instructional content to cognitive ability and building problem-solving skills (Meyer, 1988). Before introducing the new content the teacher should consider the students' current skills and knowledge by providing a reference to knowledge the students should already possess (Gagne, 1985). The teacher should encourage students to think of previous experiences relating to the current content, or provide examples of experiences to stimulate prior knowledge.

6.2.1 The topics and rationale

Five lessons were developed from the four topics that appear in the current version of Tanzanian Ordinary Level biology syllabus (MOEC, 2005). The topics are:

- i) Classification of living things (two lessons);
- ii) Cell structure and functions;
- iii) Transport of materials in living things; and
- iv) Balance of nature.

The selected topics were among those for which teachers claimed the need for pedagogical support (MOEVT, 2007). Several topics were included because biology teachers might be at different levels in terms of teaching experience and pedagogical knowledge which require different amounts of support from curriculum materials. Collopy (2003), Lloyd (1999) and Remillard (2000) held that, individual teachers interpret, use, and learn from curriculum materials in different ways and it stands to reason that any group of teachers will vary in their use of curriculum materials. Therefore, including various subject contexts may establish relevance and flexibility in the integration of the activity-based teaching and learning approaches.

6.2.2 The structural specifications of curriculum materials

The structural specifications of curriculum materials are guidelines with specific advice on how to plan and execute the activity-based lessons and deal with typical teachers' implementation problems associated with lesson preparation, subject content, pedagogy, and assessment of learning. Structural specifications provide teachers with an orientation to the intended changes or improvements, and support them in performing aspect of tasks that could be difficult to accomplish successfully (Van Den Akker & Voogt, 1994).
The structural specifications of the curriculum materials given to the teachers included the following components:

i) **Lesson preparation:**

- **A brief lesson description of what the lesson looks like**: This aims at providing the general overview of the lesson including specific activities and instructional strategies.
- **Lesson objectives**: Indicate learning outcomes expected to be achieved by students by the end of the lesson
- **Materials and resources:** These are teaching and learning aids required for the lesson activities and in the facilitation process. Possible alternative materials and resources are encouraged depending on the context and availability.
- **References**: These are the suggested possible textbooks and reference books that a teacher may refer to, to enrich his/her subject content knowledge and may guide students' assignments.
- **Lesson timing**: This part indicates the possible timing for each stage of a lesson and activities.

ii) **Lesson development activities:** This part is guided by the '5Es' with the description of teachers' roles and students' activities in a logical manner, i.e.

Excitement, Exploration, Explanation, Elaboration and *Evaluation* as summarised in Table 6.1.

Table 6.1: The 5Es instructional sequence

Stages	**Summary of teachers' roles and student activities**
Excitement	The teacher to use short activities that generate students' curiosity, create interest, raises questions, and elicits responses that uncover what the students know or think about the concept/topic.The activities should make connections between the past and present learning experiences, expose prior conceptions, and organise students' thinking toward the learning outcomes of the current activities. The instructional objectives should be provided by the end of this stage.
Exploration	Exploration experiences provide students with a common base of activities (with minimum supervision from the teacher) within which current concepts, misconception, processes, and skills are identified and conceptual change is facilitated. Students may complete the activities (laboratory, or outdoor) that help them to use prior knowledge to generate new ideas, explore questions (inquiry), and possibilities, design, and conduct preliminary investigations.
Explanation	The explanation phase focuses students' attention on particular aspects of their excitement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviours. It also provides opportunity for teachers to directly introduce/facilitate a concept, process, or skill. An explanation from the teacher may guide students towards a deeper understanding which is a critical part of this stage.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept to new contexts by conducting additional practical activities.
Evaluation	Evaluation occurs throughout the lesson. It provides an opportunity for students to demonstrate and check their understanding of the concepts. The evaluation stage encourages students to assess their understanding and abilities and provide opportunity for teachers to evaluate student progress towards achieving lesson objectives. The joint-students and teacher's reflection of all important concepts, skills, and processes may conclude the lesson.

Source: (Bybee *et al.*, 2006)

iii) **Suggestion of homework ideas**: These are the assignments (in the form of questions or activities) with a purpose of extending and applying the concepts or skills learned from the lesson. Students may accomplish them at home, after the lesson, or part of it may be done in the classroom/laboratory if the teacher finds it relevant. The teacher should monitor the evaluation of these assignments and ensure immediate feedback is given in order for students to realise its contribution to the understanding of the taught concepts.

iv) **Teachers' notes**: This is the summary of important ideas or concepts a student is required to learn from the lesson (the teacher may decide the best ways to present the class summary notes).

v) **Remarks:** This part could be used by the teacher to explain what has been learned from the lesson or some important observations, suggestions, and comments from the current lesson which may be valuable for the following lesson

6.3 Prototyping and the formative evaluation of curriculum materials

In this study the term evaluation is the systematic investigation of the merits and worth Guskey, (2000; 2002). This can take a form of formative evaluation or summative evaluation on the basis of its aims and the stage of the subject being evaluated. The focus of evaluation in this chapter is formative in nature because it aimed at improving the quality of the curriculum materials and the PD programme before being implemented in the field. Formative evaluation of the curriculum materials was strengthened with an evolutionary prototyping approach, which the study adopted in the development of the curriculum materials and PD programme. Nieveen (1999) described a prototype as a preliminary version of the whole or a part of an intervention before full commitment is made to construct and implement the final product. In the prototyping approach empirical data are needed to gain an insight into the quality of the tentative intervention and design principles, therefore formative evaluation is a crucial feature of each prototype as it provides an insight into the potential of the intervention and its key characteristics. Results from the formative evaluation give ground for both improving the prototype of the intervention towards high-quality functionality and sharpen up the underlying tentative design principles.

The curriculum materials had four prototypes each with a higher degree of iteration through a development cycle including design, formative evaluation, analysis, and revision, and participation of the potential users such as experts and users (i.e. teachers and students). The focus was to identify the characteristics of high quality curriculum materials that could adequately support teachers in using the activity-based teaching and learning approaches. With this central focus the overall formative evaluation was designed to include several stages aimed at improving the quality of curriculum materials.
These stages include experts' appraisal, users' appraisal, try-out and field test, as in Figure 6.1.

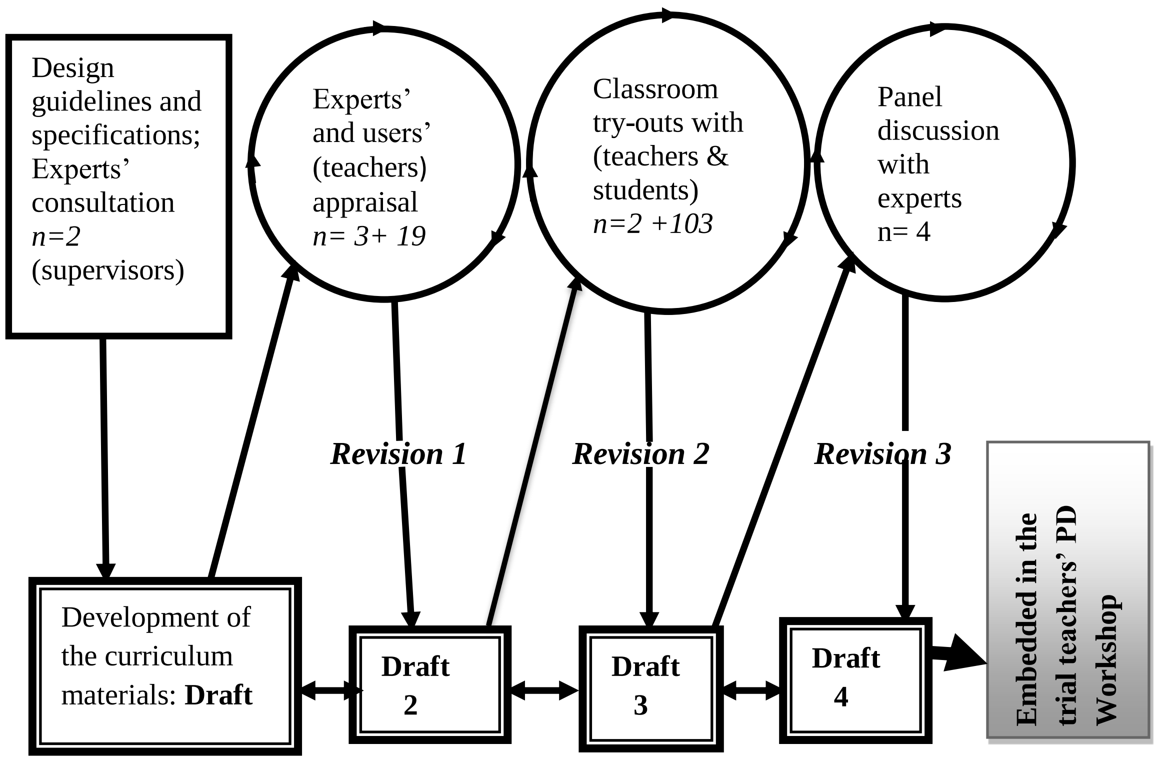
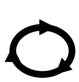


Figure 6.1 Evolutionary developments of curriculum material prototypes
Note: '***n'*** represents the number of participants: **PD** = Professional development

 Represents the cyclic developmental character of prototypes with processes such as Design-Formative evaluation-Analysis. The outputs from each cycle were used to guide the revision of prototypes.

Descriptions of the developmental activities at each prototype and the anticipated outcomes are illustrated in Table 6.2

Table 6.2 Descriptions of prototyping stages

Prototype levels	**Development activities**	**Participants**	**Outcomes**
First draft	Problem identification and design requirements with reference to context analysis and theoretical inputs from the literature.	The researcher/designer 2 Supervisors	Improved validity of the curriculum materials (Sections 6.2 and 6.3)
Second draft	Review of the first draft and to conduct a formative evaluation.	- 7 PGCE student teachers at Southampton University - 3 experts in Tanzania (i.e. the context of the study) - 12 biology teachers in Tanzania.	Improved validity and the initial practicality of curriculum materials in Tanzanian secondary school classrooms (Sections 6.3.1.1 and 6.3.1.2)
Third draft	Review of the second draft and to conduct a formative evaluation.	2 biology teachers in two schools 103 students in two classes.	Improved practicality of the curriculum materials (Section 6.3.2)
Fourth draft	-Review of the third draft and to conduct a formative evaluation -Embedded curriculum material to the trial PD workshop (Section 6.4)	3 Experts in Tanzania and the researcher.	Improved validity, practicality, and the initial effectiveness of the curriculum materials (sections 6.4.2.5 and 7.3.1.4)

The essence in the development of each of the four prototypes was to increase their quality as development progressed and was delineated by the criteria of validity, practicality, and effectiveness (Nieveen, 1999). These criteria are all related to the typology of the curriculum representation expounded by Goodlad, Klein and Tye (1979), and adapted by Van den Akker (1999), as summarised in Table 6.3.

Table 6.3 Illustrations of the curriculum representations

Curriculum Representations		
INTENDED	*Ideal*	Reflects the original ideas and intentions of designers underlying the curriculum
	Formal	Reflects the concrete curriculum documents such as syllabus, lesson materials, teachers' guides, and textbooks.
IMPLEMENTED	*Perceived*	Represent curriculum as interpreted by its users such as teachers
	Operational	Reflect the actual teaching and learning process in the classroom; it is also curriculum-in-action
ATTAINED	*Experiential*	Reflect learning experiences as perceived by learners in the classroom situation
	Learned	Reflects the learning outcomes of students as a result of classroom experiences, i.e. their reactions and outcomes.

Source: The typology of curriculum representations adapted from (Van den Akker, 1999)

This typology was applied in this study to understand the relationships and discrepancies between representations of curriculum materials in practice and clarify the notion of quality of curriculum materials (Nieveen, 1999). Table 6.4 presents the summary of links between curriculum representation levels (Table 6.3) to illustrate the framework of the quality of curriculum materials; this is followed by the description of quality aspects of the materials.

Table 6.4 Quality aspects of curriculum materials

Quality aspects	**Validity**	**Practicality**	**Effectiveness**
Descriptions of representations	Intended (*ideal* + *formal*) - State-of-the-art - Internally consistent	Consistency between: - Intended + Perceived - Intended + Operational	Consistency between: - Intended + Experiential - Intended + Learned

Source: (Nieveen, 1999)

According to Van den Akker (1999) and Nieveen (1999) the first characteristic of high quality curriculum materials is *validity,* i.e. the intended vision and intentions embodied in the curriculum materials worthy of consideration. Validity is attained when there is an internal consistency between:

i) The curriculum materials and the state-of-the art- knowledge (content validity); and
ii) The different components (construct validity).

The consistency between the intended and the perceived curriculum, and the intended and the operational curriculum, describe the second characteristic of curriculum material, *practicality.* Practicality is attained when the users, i.e. teachers and students consider the materials appealing and usable in their normal situations in the way that is largely compatible with the developers' intentions.

When there is consistency between the intended and experiential curriculum, and the intended and the learned curriculum, then the materials can possess the third characteristic, *effectiveness*. Effectiveness is indicated when the experiences with materials result into desired improvements, e.g. students appreciate the learning programme and the desired learning takes place. A prototyping approach can be used to explore and improve the quality of curriculum materials through successive approximations until a satisfactory product is obtained.

Based on the stated characteristics, the curriculum materials and PD programme for this study passed through various levels of evaluation before implemented in the field stage. Data collection methods during formative evaluation included: interviews, open-ended questionnaire, curriculum profile classroom observation checklist, and field notes.

Findings of the different sources and instruments were summarised with respect to the quality aspects of curriculum materials, i.e. the validity of curriculum materials, the practicality of curriculum materials, and the suggestions for improvement.

These findings were used to:

i) Refine both the theory (i.e. activity-based approach and the 5Es instructional sequence) and teachers' classroom instructional practices;

ii) Identify the initial problems and challenges associated with implementation of the new approaches (activity-based approach and the 5Es instructional sequence);

iii) Generate ideas to guide revision decisions and improvement of the successive prototypes.

6.3.1 The validity of the curriculum materials

Experts' and users' appraisal activities were conducted to gain insights of the validity of the curriculum materials. In this study 'validity' refers to the curriculum materials that contain state-of-the-art knowledge, which is relevant to student learning and has components that assure internal consistency (e.g. subject content, pedagogy, and assessment) in an integrated and logical way.

6.3.1.1 Experts' appraisal

The first draft of the curriculum materials was appraised by three experts. The appraisal was guided by five questions (Appendix A1). The experts' input at this level provided a clear direction for the design of the materials on the relevance of the content, the structure and presentation of the materials. Findings of experts' appraisal suggested:

i) Replacement of the *'Engagement'* stage (refer to Section 3.5) with an *'Excitement'* stage in the 5Es instructional sequence (Table 6.1) which seem to fit the Tanzanian context, where students' motivation and enjoyment to learn science subjects are thought to be a prerequisite for students' involvement and achievement in these subjects. Findings of context analysis (Section 2.5.1) indicated that the number of students who are specialising in science subjects in the advanced secondary schools and higher education is declining yearly, because most of O-Level secondary school students who are studying science subjects failed in their final national examinations;

ii) Re-organisation of the curriculum materials in order to suit teachers' professional knowledge. Experts criticised the presented format (i.e. tabular format) because it looked like a conventional lesson plan which can be taken for granted by teachers without critical analysis of other lesson activities or methods which may suit the same situation. This finding suggested that the curriculum materials on their own should bear the content knowledge including examples of activities to support teachers' change of practice in the context of their classrooms;

iii) The introductory part of the curriculum materials should emphasise the need for teachers to consider evaluation as an integral component in the teaching and learning process and not only in the concluding part of a lesson.

Following the experts' appraisal, the above improvements were made to the curriculum materials (Appendix A2) before the second appraisal by users (biology teachers and student teachers).

6.3.1.2 Users' appraisal

A second prototype of curriculum materials was subjected to users' appraisal which involved 7 PGCE student teachers in the School of Education, University of Southampton, and 12 biology teachers in Tanzania.
Generally, findings of the teachers' evaluation questionnaire (Appendix B) suggested the following:

i) Using short practical activities at the *excitement* stage of a lesson in order to capture students' attention and become curiosity;
ii) Including of peer marking across different group activities in order for students to learn from each other and reduce the time required for teachers to mark each group activity. This may also motivate students to learn in the lesson;
iii) Restructuring of a homework question in lessons 2 and 4 in the materials in order to reflect on the performed lesson activities (Appendix A2);

iv) Including a content of *mass flow* process in animals with teachers' notes in lesson 4, in order to support teachers with content knowledge;
v) Removing a part of the *lesson 5* content about the *nature of the environment* from Form III to Form II according to the current Tanzanian Ordinary Level secondary biology syllabus.

However, findings of Tanzanian teachers' questionnaire (Appendix B) indicated that eight of the 12 teachers would use the activity-based approach and the 5Es instructional sequence in the planning and teaching biology due to the following reasons:

i) The approach encourages active participation of students in doing lesson activities and hence they will become self-motivated;
ii) The approach assists teachers with techniques to identify students' prior experiences and misconceptions;
iii) The approach provides opportunities for students to evaluate their own understanding of the taught concepts.

Furthermore, two of the teachers could use the new approaches to teach only short topics because the activity-based approaches required teachers' competencies in the planning and executing lesson activities (which they may not have). The remaining two teachers were doubtful about its practicality, i.e. they thought that the new approaches would require a lot of teachers' time for preparation and teaching, and the fact that those teachers were not using lesson activities before. They felt that it would be difficult to use the activity-based approaches in the big classes (i.e. with more than 45 students) because teachers cannot supervise practical lessons with so many students.
Generally, the challenges which Tanzanian teachers foresee in the adoption of the new approaches included:

i) Time consuming in both teachers' preparation and teaching;
ii) Inadequate knowledge and skills to plan and organise lesson activities in the classroom;
iii) Lack of laboratories and other teaching and learning materials.

6.3.1.3 Revision decisions following users' appraisal

The experts' and users' appraisal have been instrumental in improving the validity of curriculum materials by generating valuable suggestions and recommendations. Many of the suggestions were incorporated into the third prototype and a few (e.g. time estimates) were considered during the try-out stage. The designer did not change the amount of time indicated for each stage of the lessons before practising the materials. The problem which the designer foresees was with teachers' and students' unfamiliarity with the new approaches compared to the traditional lecture-style method.

6.3.2 The practicality of implementation of the curriculum materials

The aim of the try-out stage was to identify teachers' and students' experiences, and the initial problems, and challenges with the practicality of implementing the curriculum materials.

The implementation of the curriculum materials was carried out during the try-out stage. Two teachers who were previously provided with initial training by the researcher participated in the implementation of the activity-based lessons, as suggested in the curriculum materials. The profile of the two teachers is shown in Table 6.5

Table 6.5: The profile of teachers who participated in the try-out of the lessons

School	Teachers	Gender	Education	Teaching Experience	Class Size	Teaching Sessions per Week
1	A	F	Bachelor of Education in Science	7 years	55	28
2	B	F	Diploma	16 years	48	24

Findings of the try-out of the curriculum materials were organised into three categories:

i) Teachers' implementation of the trial lessons in the classroom settings;
Teachers' perceptions and experiences with the new approaches; and

ii) Students' experiences with the teaching approaches adopted by their teachers.

6.3.2.1 Implementation of the trial activity-based lessons

The curriculum profile classroom observation checklist (Appendix C4) was used to record teachers' and students' classroom interactions during the implementation of the trial lessons. According to Ottevanger (2001), curriculum profile reflects the central parts of the curriculum innovation, and indicates what the designer of the materials would like to see happening (or not happening) in the classroom. The curriculum profile for this study was based on the information from the state-of-the-art knowledge review. The literature review has revealed that the activity-based approach could be realised when supported by the 5Es instructional sequence. The profile focused mainly on the features of the 5Es instructional sequence, i.e. e*xcitement, exploration, explanation, elaboration,* and *evaluation* (Table 6.1). This provided a framework for teachers to scaffold their developing expertise in structuring a learning environment that facilitated students' interaction with a learning context in a critically reflective and analytical way.

Each profile statement could be scored as *'Yes'* indicating the activity was observed, *'Partly'* indicating the activity was partially executed, and *'N/A'* indicating the activity was not observed. The scoring statements marked *'Yes'* = 2, *'Partly'* = 1 and *'N/A* = 0. The scores for statements of individual lesson stages were added and expressed in percentages of total profile practice scores for each stage. Since the checklist has five stages, each stage was analysed and presented separately (for example, Appendix C4b).

Teacher A taught a lesson on the characteristics of the *Kingdom Protoctista* and teacher B taught a lesson on *classification systems*. The time for each lesson was 80 minutes.

The researcher kept field notes on teachers' and students' classroom instructional behaviours and the physical environments, which could not easily measured by the curriculum profile classroom observation checklist. Table 6.6 presents the classroom observations scores for the two teachers in percentages.

Table 6.6: The try-out stage classroom profile practice scores (i.e. 100% = all items for each stage were met in full)

Lesson stages	**Teacher A scores in %**	**Teacher B scores in %**
Excitement	40	45
Exploration	88	84
Explanation	86	69
Elaboration	50	71
Evaluation	58	51
Average scores	**66**	**64**

Note: The average profile practice score is 50%

Findings in Table 6.6 show that the average profile practice scores for teachers A and B were satisfactory. The two teachers had lower profile practice scores, i.e. 40% and 45% in the *excitement* stage. This finding suggested that the two teachers were not competent in the implementation of lesson activities at this stage in comparison with the suggestions in the curriculum materials. Findings of the teachers' reflective interviews (Appendix C5) reveal that the two teachers had never engaged their students in the lesson activities at the beginning of their instruction in order to elicit students' prior knowledge and create lesson interest or curiosity. The teachers declared that they used to ask one or two questions based on the previous taught lessons so that students can remember the content already covered.

The following section provides the descriptive analysis of the teachers' practices at each stage of their lessons.

During the *excitement* stage both teachers had activities that related to their previous lessons as well as the new lessons. Teacher A used short and closed questions which did not provoke students' curiosity or prior knowledge to any extent, i.e. *Name the kingdoms of the living things.* Teacher B guided small group discussions about the *importance of grouping living organisms.* Students looked unfamiliar with small group discussions despite the fact that their teachers had encouraged them to do so. However, both teachers did not give students sufficient time to provide their own ideas before they started explaining the new lessons. In both cases students showed little interest in the lesson and they were unfamiliar with the lesson activities. Findings of the teachers' reflective interview (Appendix C5) provide evidence that the two teachers were unfamiliar with the instructional practices at this stage .These could be possible reasons why these teachers had low profile practice scores in the *excitement* stage, (i.e. teachers A = 40% and teacher B = 45% respectively).

Students were provided with a common base of lesson activities during the *exploration* stage. Both teachers introduced lesson activities and students were told what and how to do them by using their prior experiences, e.g. to form groups and discuss the questions (teacher A) or to conduct observations of animal specimens and draw their features (teacher B). Findings in Table 6.6 show that teacher A scored 88% and teacher B scored 84% which was regarded as a positive indicator of improvement of teachers' instructional practices at this stage. However, neither teacher took into consideration the amount of time required to accomplish a specific lesson activity. For example, students were observed interested in doing activities and they would have liked to interact with the lesson materials for longer by continuing with these activities.
Despite the poor arrangement of desks and chairs teachers maintained their facilitative role including; moving around the classroom to distribute lesson materials, interacting with groups and answering students' questions. In most cases, neither teacher was particularly

comfortable with group discussions and both were uncomfortable with request for assistance from the students due to the fact that the teaching and learning approaches were new.

During the *explanation* stage both teachers allowed their students to present their observations and the teacher summarised them on the blackboard for other students to reflect on and challenge their peers. The students in teacher B's class were not provided with adequate opportunities to thoroughly discuss and share the results with their group or classmates compared to teacher A's class. The findings in Table 6.6 also support this individual difference in their practices, i.e. teacher A had practice score of 86% compared to teacher B's score of 69%. Furthermore, teacher B lacked the skills to probe the students' ideas based upon their experiences of the lesson activities in order to stimulate students' explanations of the lesson concepts. Both teachers facilitated the lesson concepts after students had demonstrated their conceptual understanding as a result of the lesson activities they performed to verify their prior knowledge. Generally, students were not familiar with learning from the performed lesson activities and they still viewed their teachers' explanations as an exclusive source of the knowledge and skills.

During the *elaboration* stage teacher B provided her students with an alternative activity (i.e. 14 photographs of living things) for the purpose of extending the learned concepts in order to acquire meaningful understanding. This was well implemented as indicated in teacher B's practice score of 71% (Table 6.6) with few students asking for support from their teacher on how to classify living organisms and based their decisions on what they learnt earlier in the lesson. At this point in the lesson teacher A continued with the previous *explanation* stage activities. Findings of teachers A's reflective interview (Appendix C5) indicate that she combined the activities of the *explanation* and *exploration* lesson stages. This was possibly done because the students were not able to apply the acquired knowledge to perform the new activities, they simply completed them as they had done in the *exploration* stage and the teacher was not confident in supporting or furthering students' understanding. This situation was reflected in the observation checklist where teacher A scored 51% in the *elaboration* stage (Table 6.6).

Both teachers attempted to provide students with a general *evaluation* of a lesson based on the lesson activities in which teachers' explanations were followed by a few questions. This stage of the lesson was rather traditional as it was teacher driven and lacked opportunities for students to reflect on the learned concepts and skills. The answers to the questions asked by the teachers only favoured students who provided the correct explanation and students who had not supplied the correct explanation could not find out where they went wrong. In addition, both teachers were unable to complete the evaluation stage successfully because the previous lesson stages had consumed most of their lesson time (i.e. as revealed from the teacher A and B practice profile scores of 58% and 51% in Table 6.6). Furthermore teacher B failed to explain to her students the homework assignment she had indicated in her lesson plan.

6.3.2.2 Teachers' perceptions and experiences with the new approaches

Findings of teachers' interviews (Appendix C5) indicate that the two teachers who participated in the tryout of the activity-based lessons appreciated the new approaches integrated with the curriculum materials as supportive of their teaching as well as students' learning. With reference to how teachers benefited, teacher A held:

> *The 5Es instructional sequence helps me to build my lesson instruction on what students knows and support them through interaction with materials, and other students during group discussion to acquire a meaningful understanding of the lesson.*

Explaining how the new approaches were supportive in making students active participants in the lessons compared to the regular lessons, Teacher B held:

> *Students' participation in today's lesson was different, I think they noticed the changes I made in the teaching of the lesson ...as you have observed they were interested doing practical work and discussing in small groups.*

On the other hand, teachers reported that they experienced challenges in working with the new approaches especially during the initial stages of the lesson (i.e. *excitement and exploration*), and that much of the instructional time was used to support students in the participation and learning from lesson activities. Findings of researcher's field notes reveal that students were unfamiliar with the approaches used by their teachers, which indicated that the trial lessons were taught differently from their regular biology lessons therefore, more time and support would be needed for teachers and students to collaboratively implement the new approaches.

6.3.2.3 Students' experiences with activity-based approaches

Findings of the student evaluation questionnaire (Appendix C6) showed that all students ($n = 103$) liked the approaches used by their teachers during the try-out stage. Students expressed their feelings during the focus group discussion:

> *We liked today's lesson because the teacher was explaining by using live specimens and diagrams in order to make us understand the lesson* (S1, from School A).

Another student who was excited about small group discussions said:
We liked studying in groups for the first time that's helped us to learn from each other (S2, from School B).

Similarly, students were able to explain the differences between the trial lessons and their regular biology lessons by saying that:

> *We observed live specimens for ourselves for the first time this will help us to remember the structure and functions of their body parts* (S3, from school A).

Commenting on how the teacher taught the trial lesson, another student held:

> *The teacher did not talk much in the classroom like in other lessons, this lesson was more practical, and we observed the materials (plant leaves and animal pictures) in groups and present our findings* (S4, from School B).

Responses from the student evaluation questionnaire indicated that 89% (92) students suggested that their teachers should adopt the new approaches. One of the students argued:

> *Our teacher should use this method because it helps us to learn and understand the lesson; we enjoyed doing experiments and discussion* (S5, from School B).

6.3.2.4 Revision decisions following try-out of the activity-based lessons

The major revisions made as a result of the try-out of curriculum materials were:

- Addition of 5 minutes to the *exploration* stage of lesson two, i.e. 30 minutes instead of the previous 25 minutes in order for students to accomplish the indicated activities; and
    - Re-organisation of lesson activities in lesson two (Appendix A2) which would enable teachers to differentiate the two types of classification systems, and be able to explain each type in a logical way.

6.3.2.5 Summary of the practicality of the curriculum materials

It can be concluded that the overall opinions of teachers and students about the implementation of the trial activity based lessons were positive. The tryout stage generated data that indicated the practicality of the curriculum materials. Findings of teachers' reflective interviews reveal that both teachers found the curriculum materials useful to their instructional practices as they gained new knowledge about how to plan and teach the activity-based lessons. Additionally, teachers confirmed that students were more interested to participate in the trial lesson activities than they did in regular lessons. Findings of curriculum profile classroom observation checklists indicated that both teachers attempted to follow the 5Es instructional sequence by starting a lesson with *Excitement* followed by

Exploration, *Explanation*, *Elaboration* and *Evaluation* despite their unfamiliarity with the new approaches.

Results of student questionnaires and interviews revealed that students liked doing lesson activities and working in small groups, i.e. 95 of the 103 students reported improvements in the understanding of the trial lessons. These findings supported findings of classroom observations and researcher's field notes.

Following the revision of the curriculum materials, the fourth draft was embedded in the trial PD workshop (Table 6.2 and Figure 6.1).
The following section presents the prototyping approach of the PD programme.

6.4 Formative evaluation of the PD programme

The development of the PD programme was discussed in Chapter 4 Section 4.6 and its structure illustrated in Figure 4.3. The formative evaluation process involved three prototypes which included experts' consultation, try-out with teachers and panel discussion with experts, as shown in Figure 6.2.

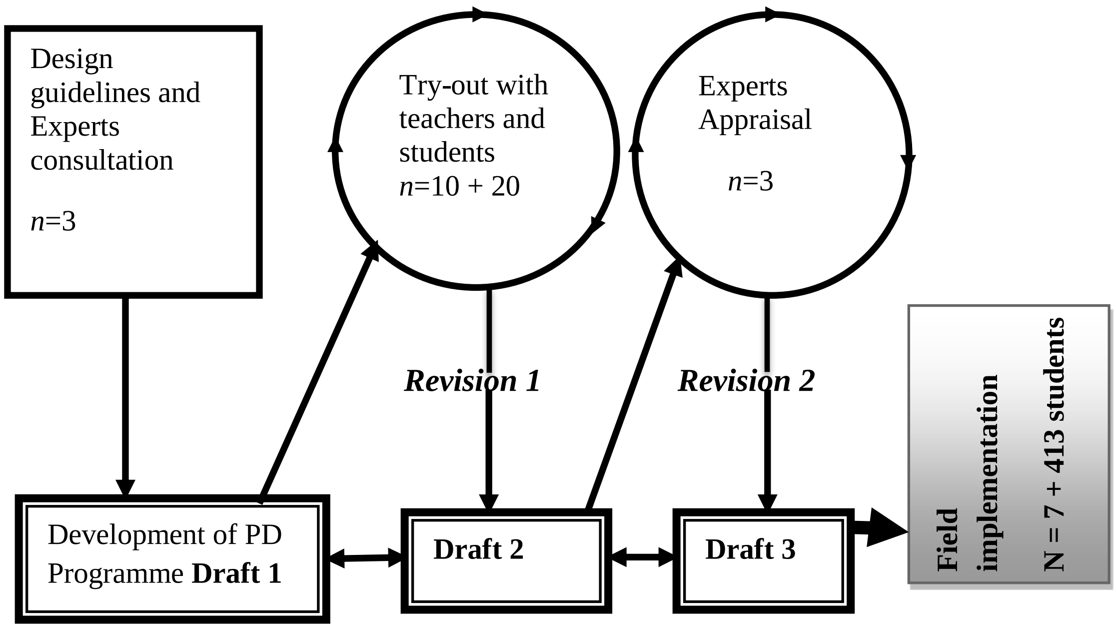
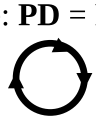


Figure 6.2 Prototyping of the PD programme

Note: **PD** = Professional development: '***n***' = Number of participants

 = Developmental cycle of prototypes,
i.e. Design-Formative-evaluation- Analysis - Revision

6.4.1 The validity of the PD programme

The expert consultation was undertaken to improve the validity of the PD programme in terms of its structure, components, and delivery. The preliminary design of the PD programme took place at the School of Education, University of Southampton with the guidance of two experts (biology education lecturers). The researcher further consulted three experts' in Tanzania (science education lecturers) in the validation of this intervention because of their familiarity with the context of the study. The experts were provided with an outline of the biology teachers' PD programme for review purposes guided by questions (Appendix A1).

Suggestions from the experts' appraisal were summarised and categorised into components of the PD programme, activities of the trial workshop, and components and activities of the main workshop (during the field stage).

6.4.1.1 The components of the PD programme

The experts emphasised that peer collaboration among teachers who were involved in the implementation of the programme during the school-based follow-up coaching in their respective schools, would ensure more sustainable pedagogical changes. Two experts reported that biology teachers may resort to their old teaching practice if there were no strategies to support them and to ensure that they proceed with this intervention.

6.4.1.2 Activities of the trial PD workshop

Two experts suggested an increase of time given to the theory exploration session of the trial workshop (Appendix A3) from 1½ hours to 2½ hours. This extra time could allow teachers to engage in the discussion of their experiences in the teaching and learning of biology, and how the methods used were related or differed from students' learning styles. Teachers' prior experiences were regarded as prerequisite in the understanding of the new teaching approaches.

One of the experts proposed that the designer of the materials should teach a lesson using the activity-based approach as a part of a demonstration session of the workshop, for teachers to observe the implementation process (Appendix A3).

6.4.1.3 The components and activities of the field PD workshop

The experts suggested that it would be an added advantage if the participants were given an opportunity to design a lesson from other topics, not included in the curriculum materials, in order to reflect on the applicability of the new approaches in the teaching and learning of biology. This suggestion complemented the researcher's previous idea of developing the curriculum materials by considering different biology topics in order for teachers to experience the flexibility in using the activity-based approaches in different subject contexts. The implementation in the field study involved all the topics a teacher was teaching because the focus was on the integration of the activity-based teaching approach supported by the 5Es instructional sequence in teachers' lesson preparation and teaching. Following the experts' appraisal, amendments were made to the PD programme before the second appraisal by the users (i.e. the biology teachers).

6.4.2 The practicality of the implementing the trial PD workshop

The aim of the one-day trial workshop was to explore the practicality of implementation, particularly the design, content, and delivery before it could be further implemented in the field study. Ten teachers were invited to attend this workshop as shown in Table 6.7. The workshop sessions and activities are illustrated in Appendix A3.

Table 6.7: The trial workshop participants' background information

Participants	Gender	Qualification	Teaching experience (years)	Teaching load (lesson periods per week)
A	M	Diploma	7	34
B	M	Diploma	9	32
C	F	Diploma	5	24
D	F	Bachelor of Education in Science	5	14
E	F	Bachelor of Education in Science	8	18
F	M	Bachelor of Science with Education	6	32
G	F	Diploma	10	28
H	F	Bachelor of Education in Science	8	24
I	M	Bachelor of Education in Science	12	26
J	F	Diploma	14	24

Data collection and analysis during the trial workshop focused on Guskey's (2000) first two levels of evaluating PD, i.e. participants' reactions and participants' learning (Section 4.7). The two levels guided the evaluation during the trial stage because of their perceived relevance to the implementation of workshop activities and application of the acquired knowledge and skills to practice. Data collection instruments were teachers' expectation questionnaire (Appendix C1), curriculum profile classroom observation checklist (Appendix C4), and workshop evaluation questionnaire (Appendix C2). Both qualitative and quantitative data analyses were conducted to provide information that reflected: teachers' expectations, teachers' reactions of the trial workshop, teachers' learning from the workshop and suggestions for improvement.

6.4.2.1 Teachers' expectations

At the outset of the workshop, teachers were asked to indicate how they expected to benefit from the trial workshop, which aimed to introduce teachers to the activity-based approach and the 5Es instructional sequence. Table 6.8 summarises teachers' expectations.

Table 6.8 Biology teachers' expectations regarding the trial workshop (N= 10)

Teachers' Expectations	**Frequency**
To get information on: • how to use the activity-based approach and the 5Es instructional sequence in their classrooms; • how to plan and organise lesson activities in a class with many students; • how to improve their teaching approaches.	7
To acquire knowledge and skills in using activity-based approach.	2
To explore new teaching methods which lead to improvement of students' understanding of biology.	1

The findings in Table 6.8 show that seven teachers expected to get information about the new instructional approaches, and how these could be used to improve their classroom practices and students' involvement in the understanding of the lessons. Two teachers expected to acquire knowledge and skills about the activity-based approach, and one to explore new teaching methods which could improve students' understanding of biology.

6.4.2.2 Teachers' reactions of the trial workshop

Findings of the teachers' evaluation questionnaire (Appendix C2) show that teachers were positively impressed by the workshop activities, i.e. theory exploration, demonstration, practice, and feedback. Eight of ten teachers found the workshop relevant to their teaching, as they learned the activity-based approach and the 5Es instructional sequence, which they thought could enhance students' participation and understanding of their lessons. Nine teachers indicated that the curriculum materials supported their understanding of the new approaches, by providing examples of the activity-based lessons, and the 5Es instructional sequence, to guide their implementation in the classroom.

6.4.2.3 Teachers' opinions about learning from the trial workshop

The assessment of teachers' learning as a result of attending the workshop was vital in order to gather evidence on the new knowledge, skills, and dispositions that teachers had gained. For this purpose teachers were asked to indicate to what extent they agreed with the closed statements (Appendix C2) related to the acquisition of knowledge and skills, and their decision for implementing the activity based teaching and learning in their schools. Teachers' responses regarding their perceptions are summarised in terms of the Modes and frequencies as shown in Table 6.9

Table 6.9 Biology teachers' opinions about learning from the trial workshop (N = 10)

Teachers' views about workshop activities (Question 7, Appendix C2)	**Mode**	**Frequency**
i) After participating in this workshop my awareness and understanding of the activity-based teaching and learning was enhanced	5	6
iii) Lesson demonstration made me consider practising the activity-based approach	4	8
iii) After studying the activity-based lessons and practicing their design I am convinced that I can practice it in my class	4	8
iv) The micro-teaching and feedback sessions of the PD workshop raised my awareness my own teaching behaviour and knowledge about alternatives	4	9
v) After attending a micro-teaching conducted by a fellow teacher I had the confidence to use the activity-based approach in my class	4	9
vi) Following this workshop I will start teaching my lesson by eliciting students' prior conceptions to make my teaching meaningful	5	6
vii) I will plan and organise biology lessons differently because of this workshop	4	7

Note: 5 = strongly agree and 1 = strongly disagree.

Results in Table 6.9 indicate that teachers gained information about the conception of the activity-based teaching, and the 5Es instructional sequence, and how they can be used in the classroom instructions (Mode = 5). However, responses to the open-ended question of this questionnaire (Appendix C2) indicate that two teachers had varied opinions about how to plan and organise lesson activities in their classrooms particularly with more than 45 students. These teachers showed their concerns about teachers' abilities in the management of students' lesson activities for effective learning outcomes. These findings suggested that teachers would require additional skills on how to implement the new approaches in big classes (e.g. see Section 6.5).

On the other hand, nine teachers indicated that their confidence was enhanced after participating in the micro-teaching session (Appendix A3) which was conducted by their colleague with 20 invited Form II students.

The activity-based lesson for the micro-teaching session was implemented by one of the teachers (Teacher C) due to time constraints (i.e. one day workshop).
The lesson was about *osmosis* and *diffusion* as a part of the *transport in living things*.
Data from the micro-teaching classroom observations were collected and analysed as in the previous part of this chapter (Section 6.3.2.1). The teacher's profile practice scores are summarised in Table 6.10 followed by the descriptive summary of teacher C's practices at each stage of the lesson.

Table 6.10 Teacher C's relative practice scores from the micro-teaching session

Lesson stages	**Teacher C's practice scores in %**
Excitement	74
Exploration	84
Explanation	86
Elaboration	64
Evaluation	58

Note: The average profile practice score is 50%

Findings in Table 6.10 indicate that the micro-lesson taught by teacher C was well implemented and the teacher tried to involve his students in the lesson activities as suggested in the curriculum materials. Teacher C's classroom practice scores at each stage of his lesson were satisfactory and above the average. To a large extent teacher C was confident in using the new approaches and had sufficient lesson materials for students' activities (also supported by his profile practice scores at the *exploration* (84%) and *explanation* (86%) stages.

During the *excitemen*t stage teacher C invited students to perform several demonstrations of *diffusion* and *osmosis* which caught their attention and elicited their prior conceptions which were later connected to the explanation of the new lesson. Students provided explanations of *osmosis* and *diffusion* from the lesson activities such as: W*hat will happen when a fresh water fish is kept in the ocean? How students can smell a perfume which was opened at one corner of their classroom*? The teacher summarised students' explanations on the blackboard and introduced further lesson activities and materials so that students could conduct investigations to illustrate their prior conceptions during exploration stage. This was relevant for them to acquire meaningful understanding of the concepts.

Students worked in small groups and were guided to perform two experiments about *osmosis* and *diffusion* by using provided materials in order to test their prior conceptions. This stage consumed most of the instructional time because the teacher wanted to make sure that students had participated in, and learned from the lesson activities. Each group was encouraged to summarise their findings for presentation.

During the *explanation* stage each group provided findings which included their own understanding of *diffusion* and *osmosis* as a result of their observations and interpretation of their experiments. Most students provided correct explanations for the concepts and this was followed by the teacher's explanation of the lesson facts based on students' presentation in order for students to acquire conceptual understanding.

During the *elaboration* stage teacher C further guided the whole class discussion by questions, e.g. *How can you explain the changes of the volume of water in the beaker with a potato? What do you think about the concentration and distribution of the colour in the measuring cylinder?* These questions challenged students to apply and extend the learned concepts in new situations resulting in deeper understanding. The teacher encouraged students to base their answers on the evidence from the performed activities.

During the *evaluation* stage teacher C was unable to carry out the lesson activities successfully as indicated in his lesson plan due to poor timing. This is also supported by the teacher's profile practice scores in Table 6.10, i.e. 58%. These findings suggested that the teacher as well as students might require more time to work and become familiar with the new approaches indicated in the curriculum materials.

6.4.2.4 Biology teachers' suggestions for improvement of the trial workshop

Findings of the workshop evaluation questionnaire (Appendix C2) showed that the main suggestions for improvement provided by the teachers were based on an increase of time for workshop activities such as theory exploration, and teachers' preparation of the lesson plans for the micro-teaching sessions.

6.4.2.5 General summary of the trial workshop

Findings in Table 6.8 show that seven of ten teachers expected to gain information about the activity-based approach and the 5Es instructional sequence.
Findings of the workshop evaluation questionnaire (Appendix C2) show that the overall impression of teachers about the PD workshop was positive, all 10 teachers indicated that they had acquired new knowledge, and their learning experiences had enhanced their skills, and beliefs about implementing an activity-based approach supported by the 5Es instructional sequence. For example, seven teachers indicated that:

> *I will plan and organise biology lessons differently because of this workshop* (Table 6.9, statement No. viii).

As a result of teachers' participation in the micro-teaching session, eight of ten teachers strongly agreed with the closed statement indicated that '*after studying the activity-based lessons and practicing their design I am convinced that I can practice it in my class'* (Table 6.9, statement No. iv)

The results further show that two of ten teachers had varied opinions about how to plan and organise classroom activities particularly with more than 45 students.

Following the trial workshop, the improvements suggested by teachers were incorporated into the PD workshop outline. The components of the PD programme were further subjected to the second experts' review before its implementation in the field. The researcher provided the experts with a document which described the structure of the PD programme after the trial study. The experts were requested to provide their suggestions and insights before implementation in the field stage. The researcher had a panel discussion with two experts (in Tanzania) in order to share the experiences from the try-out stage, and how the implementation of the PD programme could further be improved.

The experts suggested about the improvements of the demonstration session of the main workshop (Table 7.5). They found that it could be an added advantage for participants if they observe how their fellow teachers had participated in the implementation of the activity-based lessons during the try-out stage. They recommended that the researcher should support the demonstration session with the recorded video showing the implementation of the activity based lesson from the try-out stage, in order to enhance teachers' understanding of the implementation of the activity-based lessons.

Following the second experts' review, the revision decisions were included in the PD workshop. The final version of the teachers' PD programme was compiled (as shown in Chapter 4 Fig. 4.3) and the components, and activities of the field stage biology teachers' PD workshop were delineated as illustrated in (Chapter 7, Table 7.5).

6.5 Improvements following the try-out of the curriculum materials and PD workshop.

The fourth draft of curriculum materials (Fig 6.1) which was implemented in the field (Schools 1 and 2) bears the following amendments:

i) Improved lesson presentation guided by the 5Es instructional sequence with the *excitement* stage being the first stage in order to stimulate students' curiosity and thinking about the new lesson before their engagement in the subsequent stages of the lesson (section 6.2);

ii) Re-structuring of lesson activities, and homework question in lessons 2, 3 and 4 in order to support teachers with techniques to present their lessons in a logical sequence that could ensure student participation and reflection on the lesson activities (Appendix A2);

iii) Addition of the lesson content about the mass flow in animals in lesson 4 in order to strengthen teachers' subject content knowledge;

iv) Addition of time, i.e. 5 minutes to specific lesson stages such as *exploration* in order for students to accomplish the lesson activities successfully.

The following improvements were integrated to the third prototype of the PD workshop (Fig 6.2):

i) Adjustment of the workshop time from one day to two days, in order to provide teachers with sufficient time for the workshop activities (Chapter 7 Table 7.5);

ii) Strengthening of the workshop presentation by a video showing the implementation of the activity based approaches in the Tanzanian classroom context (recorded during the try-out stage) in order to enhance teachers' understanding of the new approaches;

iii) The addition of a component in the *theory exploration* session of the workshop about how teachers can work with an activity-based approach in big classes (i.e. more than 45 students) and sometimes with limited resources. For example:

- Teachers to divide the student groups in a variety of ways and assign various roles to members of each group;
- Providing more chances for students to participate in the lesson activities through individual, paired and group work, and sometimes the whole class;
- Teachers to organise co-operative learning activities including homework assignments, such as think-pair-share, role play, and jigsaw, in order to develop students' comprehensive language competence and cooperative skills;
- Students in groups to demonstrate particular lesson skills for others to observe and encourage students to mark their assignments themselves and across groups.

Based on the findings of the try-out stage the following instruments were amended in order to capture the required information during the field stage of the study:

i) Workshop evaluation questionnaire (Appendix C2), included open-ended questions for teachers to provide additional explanations, or extend the specific perception or opinion they chose for the closed statements of the 5-point Likert scale questions;

ii) The curriculum profile classroom observation checklist was modified to include information about general classroom observation (Appendix C4, part B). Such information was relevant, especially in the field implementation (where the research assistant assisted the researcher in conducting classroom observations) in order to ensure consistency in the evaluation of teachers' instructional practices. The measures included in this part contribute into effective implementation of the activity-based approaches and the 5Es instructional sequence.

iii) The student focus group interview was amended in order to focus only on the experiences from the lessons taught by the new approaches as opposed to their regular lessons taught by traditional lecture-style method (Appendix C7).

6.6 Summary of the chapter

This chapter described the collaborative design and formative evaluation of the curriculum materials and PD workshop which included illustration of how the PD programme and curriculum materials were developed and practically implemented (in the try-out set-up) to enhance teachers' pedagogical knowledge and skills. These activities were achieved through a prototyping approach, whereby a series of prototypes were developed, tried out, and revised on the basis of formative evaluation. The cyclic iteration of the prototypes involved collaboration with key people, including research participants in order to generate ideas useful for improvement of the intervention. The prototyping approach used different levels of evaluation such as; experts' reviews, users' appraisal, and try-out with teachers and students.

Data collection instruments at various levels included interviews, open-ended questionnaires, curriculum profile classroom observation checklists, and field notes. Findings of these instruments were analysed and summarised into categories which illustrate the validity of the materials and the PD workshop, the practicality of the materials and the PD workshop, and suggestions for improvement. The generated ideas and suggestions were used to refine the prototypes as their development progressed. Findings of different levels of evaluation were used to refine both the instructional theory (activity-based approach supported by the 5Es instructional sequence) and teachers' classroom instructional practices, and help the initial identification of problems and challenges associated with implementation of the activity-based approach, and the teachers' PD workshop, in a Tanzanian classroom context. Similarly, the bases for improvement of data collection instruments were sought during the try-out stage before their administration in the field stage.

Teachers' involvement in the prototyping of the curriculum materials enhanced their awareness of the effective science teaching and learning methods. Teachers' participation in the PD workshop activities contributed to their professional growth, and development of local instructional theories that supported the adoption of the activity-based approach and the 5Es instructional sequence. Teachers used the acquired knowledge and skills to develop instructional activities such as classroom discourse, student activities, and specifying learning strategies for a classroom as a whole (e.g. a series of demonstrations, experimentations, brainstorming, or observations, together with a specific support for the teachers and instructional materials).

Chapter 7

Evaluation of the Implementation of the Professional Development Programme and Impact on Teaching and Learning

7.1 Introduction

This chapter presents findings of the evaluation of the implementation of the professional development (PD) programme and impact on teaching and learning. These findings helped to answer the third research question: *What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?*

Teachers' pedagogy in this study refers to teachers' use of the activity-based instructional approaches in the lesson planning and implementation in the classroom. This pedagogy will provide students with different avenues of acquiring understanding of the taught concepts regardless of their difference in abilities. The PD programme in this study comprises a PD workshop, curriculum materials, school follow-up coaching, and a supportive school environment (Section 4.6.2). The programme and teachers' support curriculum materials were designed to improve biology teaching and learning in Tanzanian secondary schools. Formative evaluation of the programme and teachers' support curriculum materials were discussed in Sections 6.3 and 6.4. Guskey's (2000) five levels of evaluating PD were adopted as a framework for guiding data collection, analysis, and their interpretation during evaluation of implementation of the PD workshop and new approaches in schools:

i) Teachers' reactions of the PD workshop;
ii) Teachers' learning from the PD workshop;
iii) The extent of school support for teachers;
iv) Teachers' use of the new knowledge and skills acquired from the PD workshop;
v) Student learning outcomes (Section 4.7).

Each evaluation level had key indicators which were employed in the judgement of the impact of the PD programme as summarised in Table 7.1

Table 7.1: The key indicators for judgement of the impact of the PD workshop and implementation of the new approaches in schools

Guskey's levels of evaluation	**Indicators for judgement of the effectiveness**
1) Teachers' reactions	i) Expectations - teachers' satisfaction that the workshop met their expectations; ii) Content of the workshop - teachers' perceptions about the usefulness and relevance of the different aspects of the workshop such as components, sessions, content, process, and context.
2) Teachers' learning	i) Teachers' opinions about the acquired knowledge and understanding; ii) Teachers' demonstration of understanding of the new approaches (e.g. in the micro-teaching sessions).
3) The nature of school support for teachers	i) Resource/ materials availability; ii) School culture and peer support; iii) School leadership support.
4) Teachers' use of the new knowledge and skills	i) Teachers' Levels of use of the new knowledge and skills; ii) The difference in the teachers' instructional practices.
5) Student learning outcomes	i) Cognitive learning outcomes; ii) Affective learning outcomes.

Table 7.2: A summary of the instruments used to collect the data outlined in Table 7.1

Evaluation levels (Based on Guskey, 2000)	**Stages of data collection**		
	Prior to implementation of the PD workshop	**During implementation of the PD workshop and new approaches in schools**	**After implementation of the new approaches in schools.**
1) Teachers' reactions of the PD workshop	- Expectation questionnaire.	- Evaluation questionnaire.	
2) Teachers' learning from the PD workshop		- Classroom observation checklists; - Evaluation questionnaire; - School Follow-up questionnaire.	
3) The nature of school support for teachers			- School support questionnaire; - Teachers' focus group interview.
4) Teachers' use of the new knowledge and skills	- Pre-test classroom observations.		- Level of Use Interview ; - Post-test classroom observation checklists; - Teachers' interview ; - Student evaluation questionnaire ; - Students' focus group interview.
5) Student learning outcomes	- Pre-test students' attitude questionnaire		- Achievement test; - Post-test students' attitude questionnaire; - Teachers' reflective interview; - Students' focus group interview.

This chapter comprises five main sections with sub-sections. Section 7.2 presents the preliminary procedures prior to implementation of the PD programme. Section 7.3 presents the implementation and evaluation of the PD workshop. Section 7.4 describes the implementation of the new approaches (activity-based approach supported by the 5Es instructional sequence) in schools 1 and 2. Section 7.5 discusses the impact of the new approaches on teachers' pedagogy. Section 7.6 presents the impact of the new approaches adopted by teachers on student learning and understanding of biology. Section 7.7 presents the summary and reflection of the chapter.

7.2 Preliminary procedures prior to implementation of the PD workshop

Prior to implementation of the PD workshop and new approaches (i.e. activity-based approach and the 5Es instructional sequence) to teachers in schools 1 and 2, the researcher administered a pre-test attitude questionnaire to the students in these schools, and conducted classroom observations in order to examine the methods used to teach and learn biology.

7.2.1 Pre-test student attitude questionnaires

The pre-test attitude questionnaire (Appendix C3) was administered to students from schools 1 and 2 (N = 115), in order to determine their behaviour, interests, and perceptions towards biology and methods of teaching and learning before the introduction of activity-based approaches. Findings of the students' pre-test attitude questionnaires are summarised in Table 7.3.

Table 7.3: The modes and percentages of students' pre-test attitudes towards biology (N = 115)

Attitude statements		Mode	Percentages
i)	Biology is very interesting to me	4	42
ii)	Biology is fascinating and fun	4	30
iii)	I am always under terrible anxiety in biology class	4	64
iv)	I have good feelings towards biology	3	32
v)	Biology is the subject I dislike the most	3	67
vi)	I feel more relaxed in a biology class than in any other class	3	44
vii)	Biology makes me feel secure and at the same time stimulating	3	41
viii)	I am very interested in doing practical work in biology	4	38
ix)	It makes me nervous discussing and asking questions our biology teacher	4	60
x)	I enjoyed doing biology lesson activities	2	65
xi)	It makes me nervous doing biology experiments	4	43
xii)	I feel at ease working with biology group activities	2	77
xiii)	Doing group work with my classmates makes me uncomfortable and annoyed	3	50
xiv)	I enjoyed doing with hands than listening to biology teachers' explanations	3	32

Note: 5 = strongly agree; 1 = strongly disagree

Findings in Table 7.3 show that 67% of the students were undecided about whether they like or dislike biology as a subject. With respect to the teaching and learning methods, 38% of the students indicated that they are interested in doing practical work in biology (Statement No. viii). On the other hand, statements x-xii suggested that students were not familiar with practical activities.

7.2.2 Pre-intervention classroom observations

Pre- intervention classroom observations were conducted in November 2010 by the researcher in order to gain insights about how biology was taught in the secondary schools before implementation of the new approaches. Classroom observations focused on the effective teaching practices expected in science classrooms, i.e. with interactions and practical activities (Ottevanger, 2001). The researcher's notes, and teachers' lesson plans, were used in order to provide a descriptive summary of the lesson preparation and teachers' instructional approaches. A total of seven lessons were observed as outlined below:

1) *The process of photosynthesis* – Form II; teacher T1
2) *Kingdom Plantae* – Form II teacher T2
3) *Urinary system and its adaptive features* – Form III; teacher T3
4) *Human digestive system* - Form II; teachers T4
5) *Pollination* – Form III; teacher T5
6) *Mitosis and growth* - Form IV; teacher T6
7) *Cell structure and function* – Form I; teacher T7

The description of the pre-intervention classroom observations for individual teachers is presented in Appendix C4a.

Descriptive analysis of the pre-intervention classroom observations

The qualitative content analysis of the teachers' classroom practices, researcher's field notes and scrutiny of teachers' lesson plans show that the observed lessons tended not to fall into the proposed 5Es instructional sequence because many of the teachers' instructional practices based on the traditional teaching approaches (see the lessons in Appendix C4a). For example, none of the teachers considered students' prior knowledge and experiences at the beginning of their instructions and use these to introduce their new lessons. All seven teachers did not plan or organise hands-on activities for their respective students. They also failed to use techniques to help students to apply or extend the learned concepts to their everyday life. The lessons were teacher-centred and students' activities were limited to note-taking and responding to one or two teacher-led questions at the start and end of the lessons.

The teachers' classroom practices generally followed a teaching sequence of introduction, presentation, and conclusion as described in the following section.

Introduction: This part of a lesson tended to last between five and seven minutes which included a teacher's review of the previous lesson through question and answer. It was at this stage that the teachers prepared their students for the new lessons. For example six teachers asked one or two questions about the previous lessons that were meant to prepare students for the new lessons. However in all these cases students prior conceptions were not associated with the new lesson concepts and activities and students were unsure about the purpose and the content of the new lesson. According to Ausubel (1968), Driver (1989) and Wittrock (1994) such instructional practices are not conducive to productive learning.

On two occasions, teachers T1 and T2 asked questions about the new lessons (Appendix C4a, lessons 1 and 2). For example, teacher T2 asked students to provide their experiences about *the features of the members of the kingdom Plantae* but the teacher ignored the students ideas and went on to the lesson about *kingdom Plantae*. The same teacher could not accept students with alternative explanations for the questions she asked. This indicated that the teacher lacks both the knowledge and skills of why it is important to elicit and use students' prior knowledge including their misconceptions as the basis for planning or developing the subsequent lesson activities.

Similarly, teacher T4 started her lesson by explaining the lesson facts which were not clear to students (Appendix C4a, lesson 4). Her lesson was boring and students were making a noise because they could not follow the teacher's lesson presentation effectively. This situation suggested that the teacher need to dominate the teaching and learning process in a didactic fashion in both the delivery of the subject content knowledge and in disregarding any contribution from students that lead to a disruptive classroom where little learning could take place.

Presentation: This part of the lesson took between 30 to 50 minutes. The major activities common to all teachers were an explanation of the lesson facts with students listening and copying notes and other illustrations from their teachers or the blackboard. Six teachers supported their explanations with diagrams which to a larger extent were not effective in supporting students' understanding of the taught concepts because they were not clearly connected with teachers' explanation. For example, teacher T3 had a diagram illustrating the human *excretory system* which was presented to students to the end of the teacher's explanation of the *urinary system* (Appendix C4a, lesson 3). Therefore, it was difficult for students to reflect on the different parts and their function. On the other hand, teacher T2 explained her lesson without any teaching aid which is an indication of teacher's dominance of the lesson content knowledge and made her students to believe that everything has been already figured out for them to memorise.

The analysis of teachers' lesson plans indicated that two teachers (T1 and T7) would lead the whole class discussion, and students would participate through answering questions but these practices were not performed in their classrooms.

Generally, the presentation part was teachers' driven and students remained passive receivers of the lesson content knowledge and skills from their teachers.

Students were denied opportunities to actively participate in the lesson as there were no practical lesson activities or the materials and resources to maximise students' lesson interaction in order to stimulate their curiosity and acquisition of meaningful understanding of the concepts. The teachers also lacked the skills in using guiding questions that could cross-check whether students had achieved the expected level of understanding.

Conclusion: All teachers ended their lessons differently but this period lasted about five minutes in each lesson. The activities common to all teachers were asking questions about the taught concepts. Teachers seldom posed the type of questions that would require students to reflect on the taught concepts. For example teacher T6 asked her students to *mention the stages of mitosis* and teacher T2 *what are the features of the kingdom Plantae?* (Appendix C4a, lessons 2 and 6). Most of these questions were closed and could be easily answered by students reiterating the teachers' notes on the blackboard. Teachers did not encourage their students to ask questions or to comment on anything during the lessons; this situation may be due to lack of teachers' skills in asking probing questions. The students were merely expected to regurgitate the facts the teachers had provided rather than engage actively in their own learning.

7.2.3 Summary of the pre-intervention classroom observations

Findings of the pre-intervention classroom observations indicate that all seven teachers had similarities in their classroom instructional practices. They all used traditional chalk-and-talk teaching and learning methods. The lessons were dominated by teachers' explanations of the lesson facts, while students remained passive recipients. Student activities included answering a few closed questions posed by their teachers and copying notes from the blackboard. Findings of the researcher's notes and lesson plans indicate that all seven teachers had similar lesson planning formats with a lesson introduction, presentation, and concluding stages. Reflections made from teachers' lesson plans showed that sometimes, teachers' classroom practices were not guided by their lesson plans because the activities mentioned in their lesson plans were not demonstrated during the lessons. Therefore, the observed instructional practices did not always reflect on the teachers' intentions, this could be due to lack of the knowledge and skills to implement students lesson activities.

7.3 Implementation of the PD workshop

The implementation of the PD workshop and new approaches involved seven teachers (T1-T7) as shown in Table 7.4.

Table 7.4 Characteristics of biology teachers involved in the implementation and evaluation of the PD workshop and new approaches in schools 1 and 2

Variables		**Secondary Schools**						
Schools		School 1				School 2		
School Type		A/O-Level				O-Level		
Teachers		T1	T2	T3	T4	T5	T6	T7
Education Levels	Diploma			√	√	√	√	
	Bachelor of Education in Science.	√	√	-	-	-	-	-
	Bachelor of Science with Education.	-	-	-	-	-	-	√
Years of teaching experience		16+	16+	15	16+	16+	5	10
Teaching class/Form		III, VI	III, V	I, IV	I, II	I, III	IV	I, II
Teaching sessions per week		30	28	28	28	28	30	32
Average No. of students in the class		50	50	46	48	55	56	58

The researcher led an introductory meeting at each participating school with biology teachers, school academic teachers (who represented the school administration), and the research assistant four days before implementation of the PD workshop. The aim was to introduce and familiarise teachers with the curriculum materials and to discuss other logistics such as the date of the workshop, the students who will participate in the micro-teaching, and the venue. The workshop was conducted on 10^{th} –11^{th} January, 2011. The two-day workshop components and activities are summarised in Table 7.5.

Table 7.5: The components and activities of the field stage PD workshop

Day/Time	Sessions	Workshop Activities
Day1 9.00-10.00	**Theory Exploration**	i) *Introduction to the workshop* (aims and objectives) ii) *Completion of the teachers' expectation questionnaire* (Appendix C1). iii) *Exploring participants' prior conceptions*; participants were given opportunities to discuss in groups about issues related to biology teaching and learning approaches in their schools. The discussion was guided by the following questions • How do you teach biology? • How your students learn biology? • Is there any relationship between students learning styles and your teaching? Explain your answer • What do you think are the best approaches of teaching biology in your classroom? • What constitutes an effective biology lesson based on the approaches you have mentioned?
10.00-10.15	**Tea Break**	
10.15-12.15	**Theory Exploration**	**iv)** *Theory Presentation*: A brief discussion about participants' experiences and responses to the asked questions followed by a presentation about the current trends in the teaching and learning of science, followed by the rationale of developing the curriculum materials and the integrated activity-based approach and the 5Es instructional sequence. **v)** *Reference materials*: Participants explored the provided materials containing information about teaching science with learners thinking in mind; techniques used to explore students' thinking about aspects of science, how to use 5Es instructional sequence in the planning and teaching of a lesson; advantages of activity-based approaches and techniques for implementation in large classes.
12.15-12.30	*Health Break*	
12.30-1.15		*vi) Curriculum materials*: The researcher provided a description of the 5Es instructional sequence, rationale, theoretical underpinning, and the potential impact on the activity-based teaching and learning approaches.

		vii) Explanation of the structural specifications of the curriculum materials.
1.00-1.45	**Lunch Break**	
1.45-2.45	**Demonstration**	i) The researcher presented one lesson from the curriculum materials with a support of the recorded video (from the try-out stage), i.e. *Kingdoms of living things- Kingdom Protoctista*. ii) Participants observed and provided reflections based on the demonstrated lesson by focusing on the organisation of lesson activities through the 5Es instructional sequence). iii) Plenary discussion of the observed lesson.
2.45-3.30	**Practice and Feedback**	Participants were given the opportunity to study the curriculum materials in two groups (i.e. A and B) and developed a lesson plan for micro- teaching sessions.
Day 2 9.00-1.00		One of the teachers from each group performed the micro-teaching with the invited students (Form II). Other teachers observed the implementation of the lesson. These lessons were recorded and used during the feedback and reflection sessions.
1.00-1.45	**Lunch break**	
1.45-2.00 pm		Discussion of the feedback and reflection from the micro-teaching sessions with a support of the recorded lessons.
2.00-3.00 pm	**Evaluation**	i) Teachers were guided to develop schemes of work for the school-based follow-up coaching sessions ii) Teachers completed workshop evaluation questionnaire based on their experiences of the workshop activities and their perceptions about the acquired knowledge and skills (Appendix C2).

7.3.1 Evaluation of the PD workshop

Findings of implementation of the PD workshop were categorised into three main aspects:

i) Teachers' reactions about the PD workshop, i.e. teachers' expectations and opinions about the relevance of the PD components and activities.

ii) Teachers' perception of their learning from the workshop.

7.3.1.1 Teachers' expectations

The workshop expectation questionnaire (Appendix C1) which was administered at the beginning of the two day workshop sought information about teachers' expectations of attending the workshop, and their prior experiences with PD. Findings of this questionnaire showed that: Four teachers (T1, T2, T5, and T6) had attended regional based workshops organised by the Regional Education Officers on how science subjects can be taught by using local materials and resources, and on the application of participatory methods in the teaching and learning process. Three teachers (T3, T4, and T7) had never attended any in-service workshop. The following were teachers' expectations for the workshop:

i) Four teachers expected to gain knowledge and insights about the activity-based approaches and the 5Es instructional sequence, and the knowledge about interactive student-centred teaching and learning methods (T1, T4, T5, and T6);
ii) Three teachers expected to acquire skills on how to plan and organise lesson activities in the classroom (T1, T2, and T7);
iii) Five teachers expected to acquire information about how to arouse students' interest through practical activities during the excitement stage (T2, T3, T4, T6, and T 7);
iv) One teacher expected to have an opportunity to share the teaching experiences and expertise with other school teachers (T1).

7.3.1.2 Teachers' reactions to the workshop components and activities

Teachers' reactions to the different aspects of the workshop were investigated by the workshop evaluation questionnaire which was administered at the end of the two day workshop (Appendix C2). Findings of this questionnaire show that the teachers' overall impression about the PD workshop was positive (Table 7.6). Table 7.6 summarises teachers' reactions from the 5 point Likert scale by using the modes and frequencies (Section 5.8.1).

Table 7.6: Teachers overall perception of the workshop (N = 7)

Teachers PD workshop	Mode	Frequency
Was according to my expectations	4	6
Was useful to my professional growth	4	5
Was relevant to my teaching practices	5	4
Enhance my awareness of the topic	4	5
Objectives were met	4	5

Note: 5 = strongly agree; 1= strongly disagree

Findings in Table 7.6 show that six teachers indicated that the workshop met their expectations (Mode = 4). Five teachers indicated that the workshop was useful to their professional growth and enlightened their awareness of the topic, and that the objectives were met (Mode = 4).

Teachers' opinions on the extent they valued the five sessions of the workshop are summarised in Table 7.7

Table 7.7: Teachers' opinions about the workshop sessions (N = 7)

	Workshop components	Mode	Frequency
i)	Theory exploration	5	6
ii)	Demonstration and discussion	4	5
iii)	Preparation of micro-lessons: lesson plan development	4	5
iv)	Practice: Micro-teaching with students	5	6
v)	Feedback and reflection	4	5

Note: 5 = very good; 1 = very poor

Findings in Table 7.7 indicate that the overall opinions of teachers about the workshop sessions were good with a high appreciation on pedagogical theory exploration and having an opportunity to put this into practice, i.e. micro-teaching sessions (Mode = 5). Teachers' impression of the demonstration and discussion, lesson preparation and feedback was good

(Mode = 4). Findings of the open-ended question in this questionnaire indicate that the pedagogical theory exploration session provided teachers with additional knowledge about teaching and learning methods such as the activity-based approach and the 5Es instructional sequence which were new or not used in the teachers' instructional practices as it was mentioned by three teachers (T1, T5 and T6) that:

> *During exploration stage the facilitator enhanced my awareness about how the constructivist approaches can be used in the teaching and learning of biology through the 5Es model* (T5).

Furthermore, the provision of the reading materials broadened teachers' knowledge and skills about how to use the new approaches (activity-based approach and the 5Es instructional sequence) in their classrooms.

Discussing the micro-teaching sessions, one of the teachers stated:

> *The micro-teaching session with students was exciting to us, because we observed our colleagues implementing a lesson which we have planned together and observe how students were engaged, and motivated to perform lesson activities.* (T5)

Similarly, five teachers (T1, T2, T4, T6, and T7) indicated that the demonstration of the activity-based lesson supported by a video showing the implementation of the activity-based lesson by one of their colleagues (i.e. during try-out stage) enhanced their thinking about using the new approaches in their classrooms. One of these teachers narrated that:

> *I was quite impressed by a video that show how to put into practice the new approaches we have learned …possibly this can be done in my class* (T2).

Teachers' perceptions about the content, process (delivery), and context of the PD workshop were examined by the closed statements presented in Table 7.8.

Table 7.8: Teachers’ perceptions about the content, delivery, and context of the PD workshop (N = 7)

Workshop content, process, and context	Mode	Frequency
Content		
The knowledge and skills explored in the workshop are useful for improving my teaching practices	5	5
My time in the workshop was well spent	5	6
Delivery		
The workshop activities were well planned and organised	5	5
The activity-based approach supported by the 5Es instructional sequence and the lesson materials are immediately useful to my teaching	4	5
Sufficient time was provided for accomplishment of activities	5	5
The presenter was well prepared	4	6
Context		
The resources and facilities were sufficient and conducive for learning	4	6
The workshop venue was conducive	4	6
The refreshments and lunch were nicely prepared and served on time	4	5
The transport allowance was fair and motivating	4	5

Note; 5 = strongly agree; 1= strongly disagree

Results in Table 7.8 show that most of the teachers regarded the knowledge and skills explored during the workshop useful to their teaching practice (Mode = 5). These teachers agreed that the workshop activities were well planned and organised and that provided them with an opportunity to participate in different activities, as indicated by one of the teachers from School 2:

> *I wish this kind of workshop included all science teachers because the different sessions we have participated can bring changes to our teaching and learning styles.* (T6)

Concerning the workshop setting, six teachers agreed that the workshop environment was conducive in terms of venue, resources, and materials. Similarly, the refreshments, lunch, and transport allowances that were provided to teachers during the two day workshop sessions were highly appreciated (Mode = 4).

7.3.1.3 Teachers' opinions about learning from the workshop

Evaluation at Guskey's level 2 (Table 7.1), aimed at exploring teachers' opinions about what they have gained from the PD workshop in terms of the new knowledge and understanding of the new approaches (activity-based approach and the 5Es instructional sequence). As shown in Table 7.1 the indicators for teachers' learning and understanding that were used to judge the impact of this level were:

i) Acquired knowledge and understanding – teachers' formulation of what they learned from the workshop in their own words, and teachers' verifications of what they gained in terms of new knowledge and enhanced understanding;
ii) Demonstrated understanding – teachers' demonstration of understanding of the new approaches within a micro-teaching set up.

Teachers' opinions about learning from the PD workshop were measured by closed statements in question 7 and open question in the questionnaire (Appendix C2). The aim was to explore teachers' opinions about what they had acquired after attending the two day workshop. Table 7.9 presents the teachers' responses to the closed statements.

Table 7.9: The teachers' opinions about learning from the workshop (N = 7)

Workshop components and activities	Mode	Frequency
After participating in this workshop my awareness and understanding of the activity-based teaching and learning was enhanced	5	5
Lesson demonstration with a video show made me consider practicing the activity-based approach	5	5
After studying the curriculum materials and practising the design of a lesson I am convinced that I can practice it in my own classroom	4	5
The microteaching and feedback sessions raised awareness of my own teaching behaviour and knowledge about alternative methods	5	6
After attending a microteaching conducted by a fellow teacher I am confident to use the activity-based approach with my students	4	6
Following this workshop I will start teaching my lessons by eliciting students' prior conceptions to make my teaching meaningful	5	6
I will plan and organise biology lessons differently because of this workshop	5	7

Note: 5 = strongly agree; 1= strongly disagree

Findings in Table 7.9 show that all seven teachers' strongly agreed to plan and teach biology lessons differently because of the knowledge and skills acquired from the PD workshop (Mode = 5). Teachers' confidence in using the new approaches had improved after studying the curriculum materials and practising the design of the activity-based lessons (Mode = 4). To a larger extent these findings seem to illustrate that the workshop had influenced and altered teachers' previous perceptions about using the new approaches in their classrooms e.g. due to inadequate knowledge and skills to plan and organise lesson activities (Section 6.3.1.2).

Commenting on the efficacy of the new approaches, teacher T2, reported:

> *I learned that the activity-based teaching and learning approaches make students active and participate well in the understanding of the lesson compared to the method I used before.*

Another teacher, (T4) expressed her feelings on how the new approaches aroused lesson interest whilst at the same time involved students in learning from lesson activities. A similar sentiment was reported by teacher (T5):

> *I learned many things from this workshop like: when a teacher uses a simple practical work to introduce a lesson, students become interested and enjoy the lesson; also by using lesson activities such as demonstration and practical work, they may solve the problem I am facing in teaching difficult concepts of a lesson which previously were not clear to students.*

Highlighting the importance of students' prior knowledge and experiences in the teaching and learning process through the 5Es instructional sequence teacher T1, reported:

> *I was quite impressed by the 5Es instructional sequence… the 5Es stages provide opportunities for teachers to start their lesson differently compared to the previous situation. Like today's lesson most of the students were active because they were given a chance to explain their views about the lesson, which helped their teacher identify experiences they brought to the lesson.*

Likewise, all seven teachers reported that they will use the experiences of the PD workshop and curriculum materials to guide implementation of the new approaches in their schools (this finding complemented the last statement in Table 7.9). The following quotes were given by two teachers on how they expected to integrate the new approaches in their daily lesson planning and teaching:

It is challenging when using the new approaches for the first time, but I will use the experiences from the micro-teaching sessions and examples provided in the curriculum materials to plan and teach my lessons differently because now I have to consider students' prior experiences and lesson activities. (T4)

Similarly, teacher T2 indicated the following opinion on how the adoption of the new approaches will be supportive of her teaching:

Yes, I will use these approaches because students in my class will understand the lessons, and hopefully improve their performance because it is not easy for them to forget what they learned by practising.

On the other hand, teacher T6 doubted that teachers would have sufficient time for preparation and organisation of students' activities because of heavy teaching loads, (i.e. 32 lesson sessions per week). The teacher further indicated that their students may not be as active in responding to lesson activities as could be expected by their teachers because this approach could be new to them, and therefore it will take time for them to become active participants.

7.3.1.4 Evaluation of teachers' practices during micro-teaching sessions

Teachers' understanding of the new approaches was measured during the micro-teaching session of the PD workshop with 25 students as a part of the practice session (Table 7.7). Teachers working in two groups (i.e. group A and B) collaborated in developing lesson plans for the two micro-teaching sessions including preparation of the teaching and learning materials. The micro-lessons were implemented by the volunteered teachers (i.e. T1 and T7 from each group which involved one of the lessons from the developed curriculum materials. A curriculum profile classroom observation checklist (Appendix C4) was used to measure teachers' and students' classroom interactions (Section 6.3.2.1). The researcher kept field notes at each micro-teaching session in order to note down teachers' classroom instructional behaviour which could not easily measured by the observation checklist. Teachers' classroom practices were guided by the 5Es instructional sequence (Table 6.1).

7.3.1.5 Description of implementation of the micro-teaching lessons

Group A micro-teaching session. Group A lesson was on '*classification of living things'* taught by teacher T7 to Form IID students (N = 25). Lesson time was 80 minutes.

Excitement (15 minutes) - The lesson started with a surprise demonstration of activities aimed to elicit students' prior knowledge and creating attention to the lesson. Students' were told to collect their biology exercise books and put them on the teacher's table, the teacher then asked a question: *What can you say about these exercise books?* Students hesitated to respond to the teacher's question, but after being encouraged to say anything they thought applicable, one student replied, '*those are biology exercise books'* other students had different answers, e.g. '*the exercise books are different in many ways such as: their length, thickness, and colours of their covers'.*

One student used a *colour of their covers* criterion (and obtained 7 categories) and another used a *length* criterion (and obtained 4 categories). Other students were invited to explain about these activities and encouraged to ask questions. The teacher introduced the concept of *classification of living things* and organised students into 7 groups for further lesson activities.

Exploration - (30 minutes) Students in groups of 6 were given varieties of plants, preserved animals such as insects, birds, small snakes, fish, and rats. The teacher provided guiding questions which required students to name, and group the organisms into different ways as much as they could by using their prior experiences and provided reasons for placing them in groups. The teacher interacted with students in groups by asking questions such as: *how many groups of organisms have you encountered? What can you say about members of each group? Are they similar or not?)* This helped students to focus their observations and at the same time supporting students who asked questions or required explanations as observations continued.

Explanation - (20 minutes) Students presented findings written on the flip charts, some groups had fewer observations than others. The teacher guided students to compare the findings of different groups and ask questions to their classmates in order to share their experiences. For example four students at different times asked their fellows *to provide reasons for assigning living things at each group they presented in the class*. Students were asked to explain the meaning of the *classification* and the importance of classifying living things by using experiences and evidence from their observations. The teacher summarised students' responses on the blackboard, and facilitated the lesson concepts by using examples of organisms in their specific groups and the criteria used to classify them which were presented by students. Four students asked questions requiring additional information from their teacher on how to classify organisms.

Elaboration - (10 minutes) The teacher provided students with alternative lesson activities which required students to demonstrate the classification of living organisms by using the acquired knowledge and skills from the previous stages (e.g. ten pictures of animals set on three manila sheets, i.e. (a *man, bat, butterfly, fish, crocodile, elephant, duck, snail, grasshopper and a bird*). To a large extent students were able to classify the organisms correctly, and provide reasons but sometimes they failed to transfer the learned knowledge and skills from exploration to support their explanations. The teacher somehow lacked skills for probing students to apply the evidence from the performed lesson activities. This suggested that teacher's creativity and confidence are also important factors to ensure effective student support at this stage.

Evaluation (5 minutes) -The teacher summarised the lesson by explaining issues stated in the lesson objectives: the meaning, process, and the importance of classification. However the lesson time was almost over and this part of the lesson was rushed with only two students appointed to answer the questions. The teacher assigned students a homework task to read about the major groups of living things in their biology textbook.

Group B micro-teaching session

Teacher T1 from group B presented a lesson on '*the nature of the environment'* to form IIB students (N = 25). The lesson time was 80 minutes.

Excitement (15 minutes) -The teacher introduced her lesson by asking the students to brainstorm the concept of an environment. Students provided explanations on what they knew about the term 'environment' and gave examples. For example, students said: '*an environment in a place where we can find living things such as a forest'* or, '*an environment is a specified area on the earth such as a town, a lake or playground.* The teacher encouraged other students to compare the answers and provide their views or ask questions. The teacher finally summarised students' explanations on the blackboard and introduced the lesson activities.

Exploration (30 minutes) - Students were introduced to the procedures, and materials to test their conceptions about the environment. The lesson involved doing field study in the school compound. Students worked in groups of 5, and used the field guide to inform the process of recording their observations. The teacher emphasised the safety measures, and the need for each member of the group to participate in the observations. Students were asked to observe all the components encountered in that area, and categorise them into two groups of living and non-living things. They were required to write the different habitats for each living thing. The teacher supervised students in groups in order to monitor their observations and how they were recording the findings by asking questions such as: *how many organisms have you collected? How can you categorise the collected/observed organisms based on their habitats? What type of relationship among the collected /observed organisms have you identified?*

Explanations (15 minutes) - Students in groups were guided to present findings of their observations. The teacher asked other students to comment on the findings of their fellows by making comparisons because each group had different components and habitats. Students were required to define the term *environment* based on their findings. Most students answered correctly by mentioning the components of the environment (*such as* *trees, birds, earthworms, stones, water, human beings, dogs, cows, maize plants, soil, grasses etc.).* The teacher then facilitated the lesson by introducing the meaning of biotic and abiotic components of the environment and led a whole class discussion on the examples of biotic and abiotic components, their importance to the environment and their relationships. Students participated in the discussion by providing their experiences from the previous lesson activities.

Elaboration (10 minutes) - Students were asked a few questions in order to extend and show their understanding of what they learned from the field work e.g. *What is the importance of different habitats you have observed? Explain any relationship you have noticed among the components of the environment?* Most students tried to provide answers to these questions in general but they were not directly connected to what they observed or learned from the fieldwork and teacher's explanation e.g. *plants grow from the soil or animals depend on plants for food and air*. The teacher encouraged students to reflect on the knowledge (from their presentation and teacher's explanations) and experiences acquired from the field work to support the answers for the given questions in order to demonstrate understanding of the taught concepts.

Evaluation (10 minutes) - The teacher ended the lesson by giving students a chance to ask questions about what they learned. One of the students asked: *in what ways do abiotic components of the environment related to biotic components?* The teacher re-directed this question to other students in the class to provide answers and reminded them to use their experiences from the field observations. The teachers summarised the role played by *abiotic c*omponents in the environment and provide individual student homework.

Table 7.10 provides a summary of the two teachers' micro-teaching practice profile scores. The detailed profile practice scores for each stage of the lesson are presented in Appendix C4b.

Table 7.10 Group A and B relative practice scores from the micro-teaching lessons (i.e. 100% = all items for each stage were fully met)

Lesson stages	**Group A scores in %**	**Group B scores in %**
Excitement	69	81
Exploration	73	88
Explanation	69	81
Elaboration	57	71
Evaluation	50	71
Average scores	**65**	**75**

Note: The average profile practice scores is 50%

Results in Table 7.10 show that the two groups of teachers successfully implemented their lessons according to the proposed innovation (the 5Es instructional sequence). They had varied profile practice scores (i.e. Group A = 65% and B = 75%) which could be associated with the unfamiliarity to the new approaches and nature of the topics they taught. Group A had lower scores in the *Elaboration* and E*valuation* stages (i.e. 57% and 50%). These findings suggested that the group A teacher somehow experienced difficulties in the transfer of the new knowledge and skills (from the PD workshop) at *elaboration* and *evaluation* stages to classroom practices with students and therefore, would needed much time and support.

7.3.1.6 The summary of evaluation of the PD workshop

Overall the teachers' perception about the workshop was positive, all seven teachers reported that the workshop content and sessions were relevant to their teaching practices, and felt that their awareness about the workshop content had been enlightened. Teachers indicated that the PD workshop had met their expectations for acquiring new knowledge and skills on how the activity-based approach supported by the 5Es instructional sequence can be used to teach biology in their classrooms. Teachers regarded the theory exploration and micro-teaching sessions as the most effective sessions of the workshop (Table 7.7).

Furthermore, teachers indicated their positive appreciation of the content of the PD workshop, its delivery, and context (Table 7.7).
Findings of the teachers' evaluation questionnaire (Appendix C2) indicate that the PD workshop enhanced teachers' awareness and understanding of the new instructional approaches. Teachers demonstrated their confidence in the understanding of the new approaches during micro-teaching sessions (Section 7.3.1.4) despite doubts about the unfamiliarity and time constraints in the preparation and organisation of lesson activities. Teachers' practice scores in the *excitement* stage were higher (above average), i.e. 69% and 81% (Table 7.10) compared to the previous try-out stage (i.e. 40% and 45% in Table 6.6). This difference might be associated with the PD workshop which provided teachers with opportunities for professional learning and practising the new approaches.

Following the PD workshop, arrangements were made to support teachers to implement the new approaches in their respective schools and classrooms.

7.4 Implementation of the new approaches in schools

Implementation of the new approaches in schools 1 and 2 classrooms was guided by the school-based follow up coaching sessions (Section 4.6). The researcher conducted the follow-up coaching activities for the teachers on a one-to-one basis for three consecutive weeks at each school in order to support teachers' adoption of the new approaches.
The coaching in this study comprised the initial school-based coaching, peer/collegiate coaching, and the final school-based coaching. These activities were carefully guided by the researcher in order to ensure effective implementation of the new approaches in schools 1 and 2. The following sections describe each of the mentioned type of coaching.

7.4.1 The initial school-based coaching

The initial school-based coaching comprised of technical coaching (Section 4.6.2.1) comprised classroom observations and feedback for each participating teacher. Before the coaching sessions, teachers were informed of the purposes, and assured about confidentiality of the observation findings and feedback. Teachers were observed in their normal classroom periods, and discussion sessions were held during the teachers' free periods thus avoiding any disruption to the school timetable. Meanwhile, Glickman's (1990) model of developmental supervision was employed in the organisation of the feedback sessions with teachers whereby the concrete suggestions, and tips from observations were shared with teachers in a nonjudgmental manner. The feedback focused mainly on the salient, manageable issues related the basic tenets of using the activity-based teaching and learning approach and the 5Es instructional sequence.

7.4.2 Peer/collegiate coaching

Towards the end of the third week (January, 2011) the researcher introduced the idea of peer/collegiate coaching to all seven teachers which could support teachers' implementation of the new approaches after the departure of the researcher from the field for the period between February and May, 2011.

The researcher shared with the teachers the collaborative techniques which could be used for the success in the implementation of the new approaches and ensure sustainability. The activities included:

- Co-planning of lessons - this helps teachers to share the ideas of how best they can use the activity-based teaching and learning in their classroom;
- Classroom observations- this includes visiting each other's classroom in order to share their pedagogical knowledge and skills. The feedback may help to improve their instructional practices; and
- Study groups- teachers were encouraged to work in small groups of two or three in order to share the problems and challenges that might emerge as they worked with the new approaches.

Furthermore, teachers were encouraged to help each other, and with students in the preparation of teaching and learning materials and resources for student learning. This collaboration will save teachers' lesson preparation time, and make sure that students had sufficient materials for their lessons (especially for the classes with many students).

7.4.3 The final school-based coaching

The final school-based coaching activities took place towards the end of the school-based coaching at each school (schools 1 and 2) during the fourth week after the implementation of the peer coaching. The coaching session lasted for 1.30 hours. The aim was to enable teachers to reflect on their involvement in the implementation of the new approaches in their respective classrooms. Teachers observed and listened to the recorded lessons from their colleagues and participated in the plenary discussions on how the lessons were executed. The researcher provided an overall feedback on teachers' classroom practices accompanied by particular video or recordings from the previous classroom observations. Such feedback enhanced teachers' confidence in using the new approaches. According to Lave & Wenger (1991) and Wenger (1998) such experiences aim to continuously promote a culture of collaboration and professionalism among teachers. The researcher encouraged the teachers to participate in peer/collegiate collaboration activities in order to improve the individual teachers' competencies in the adoption of the new approaches.

7.4.4 Evaluation of the school-based coaching activities

During the final school-based coaching, teachers were offered the chance to indicate their opinion about participating in the school follow-up coaching sessions. This was achieved with the help of the closed statements and one open question in the school follow-up support questionnaire (Appendix C12). The teachers' responses to the closed statements were summarised in terms of Modes and frequencies in Table 7.11

Table 7.11 Teachers' perceptions of the school-based follow-up coaching (N = 7)

Follow-up statements	**Mode**	**Frequency**
i) As a result of the coaching sessions, I understand the activity-based approaches and the 5Es instructional sequence much better	4	6
ii) Feedback from the researcher's classroom observations contributes to the improvement of my teaching	5	7
iii) Provision of the examples of the activity-based lessons help me to plan and organise students' activities in my classroom	4	6
iv) Sharing of my teaching plans with the researcher and other teachers enhanced my competence to implement the new approaches	5	7
v) The discussion and reflection on my teaching with a researcher inspired me to implement the new approaches	4	7
vi) After implementing the new approaches, I have a better understanding about my role as a facilitator of students' learning.	4	5
vii) I planned and teach biology lessons differently as a result of the support I received during the coaching sessions	5	7

Note: 5 = strongly agree; 1= strongly disagree

Findings in Table 7.11 show that all seven teachers viewed the school-based coaching with individual teachers positively. They highly appreciated many aspects of coaching such as the feedback from the researcher, and sharing of teaching plans with the researcher and other teachers (Mode = 5). Six teachers indicated that they understood the new approaches much better during the coaching sessions (Mode = 4), Similarly, all seven teachers strongly agreed to plan and teach biology lessons differently as a result of the school-based coaching sessions (Mode = 5). Teachers' responses to an open question in this questionnaire (i.e. Explain any changes in the implementation of the new approaches that took place as a result of your participation in the school-based coaching) show that five teachers reported a gain in additional knowledge and skills on how to implement the new approaches in their classrooms, which broadened their insights and reduced their tension on how to plan and organise students' lesson activities. Two teachers (T1 and T4) reported improved sharing of their practices, for example teacher T4 held:

> *The discussion held with my colleagues at the department when developing lesson plans enhanced my understanding about the specific lesson activities at each stage of the lesson.*

These findings suggested that apart from the PD workshop experience, school follow-up coaching sessions provided teachers with additional opportunities to reflect on the new approaches, and enhanced their understanding about their enactment with students.

7.5 The impact of the new approaches on teachers' pedagogy

Following the final school-based coaching, all seven teachers integrated the activity-based approach supported by the 5Es instructional sequence to their teaching routine. The researcher detached herself from the schools for three months until the end of the fourth month when evaluation of the implementation of the new approaches in the two schools took place. This allowed teachers and students to adopt the new approaches in their daily school and teaching and learning routine. During this period the researcher had telephone conversations with teachers once per week in order to support them and ensure effective implementation. The following sections present findings related to the impact of the new approaches on teachers' pedagogy.

7.5.1 Evaluation of the nature of school support for teachers' implementation of the new approaches

Information was sought about the extent to which schools 1 and 2 supported their teachers' adoption of the new approaches in their classrooms. According to Guskey (2000) evaluation at level three (Table 7.1) provides information about school situations, i.e. resources, materials, time, personnel, school culture, peer support and school leadership. Three indicators for support and change were measured in this study:

i) Resources – teachers' opinions that the materials, resources and time were available and helpful for designing and organisation of student lesson activities;
ii) School culture and peer support- teachers' perceptions of school culture and peer support for teaching biology using the new approaches (Section 7.5.1.2);
iii) School leadership support - teachers' perceptions about the role of the headmasters and school administration in their efforts to implement the activity-based approaches.

The extent of school and collegiate support was measured by the school support questionnaire (Appendix C9) and the teachers' focus group interview (Appendix C10).

7.5.1.1 Teachers' perceptions about the extent of resource support

A total of six closed statements in the school support questionnaire were used to assess teachers' opinions and perceptions about the provision of materials and supplies necessary for implementation of the new approaches (Table 7.12).

Table 7.12 Resources support for experimental school teachers (N = 7)

Resources support statements		Mode	Frequency
i)	The physical conditions of school (i.e. laboratory, supplies, classrooms) enhanced my implementation efforts	3	5
ii)	Necessary facilities of schools were made available to me at an appropriate time	3	4
iii)	I had sufficient materials necessary for planning and organising students' lesson activities	4	5
iv)	I had a quiet place to plan and discuss important issues about my work	5	5
v)	I had sufficient time to plan and organise students' lesson activities	4	5
vi)	I had ample time to reflect on the activity based leaching and learning and make appropriate adoption	4	5

Note: 5 = strongly agree; 1 = strongly disagree

Findings in Table 7.12 show that teachers were somewhat satisfied with the physical conditions of their schools including materials for planning, and organising students' lesson activities (Mode = 3). Findings of the focus group discussion indicate that due to the scarcity of funds in their schools, sometimes teachers did not get the required materials or resources for their lessons. Five teachers agreed that they had ample time to reflect on the new approaches (Mode = 4). For example teachers T5 and T6 from school 2 made efforts to improvise some of the teaching and learning materials for their lessons.

7.5.1.2 Teachers' perceptions of school culture and collegiate support

The aspects of school culture explored in this study are those related to the shared understandings about teaching and learning, and commitment to ideas such as the continuous learning of teachers, or collaboration as a means of problem solving (Deal & Peterson, 1994). In this study the measures of peer or collegiate support focused on the extent to which teachers who were involved in the implementation of the new approaches felt that their efforts were valued and honoured by the school administration and colleagues. Table 7.12 summarises findings about the nature of school culture and collegiate support in terms of the Modes and frequencies.

Table 7.12: Aspects of school culture and collegiate support (N = 7)

	Aspects of school culture and collegiate support	**Mode**	**Frequency**
i)	The school encourages implementation of new teaching and learning methods and improving students learning	5	7
ii)	The school administration was open to suggestions for improving instructional practices	5	7
iii)	Fellow teachers shared my enthusiasm for experimenting with new teaching approaches	4	6
iv)	We frequently engaged in conversations about ways to improve our teaching approaches	4	4
v)	Fellow teachers often asked about my improvements with students	4	5
vi)	I had opportunities to visit the classroom of fellow teachers and observe their teaching	2	6

Note: 5 = strongly agree; 1 = strongly disagree

Findings in Table 7.12 indicate that school 1 and 2 encouraged teachers to implement the new approaches in their classrooms (Mode = 5). Their fellow teachers were aware of, and participated in the conversations about how to improve the implementation process as well as how students benefited from doing lesson activities (Mode = 4). With respect to how the teachers' efforts in working with the new teaching methods were appreciated by their schools, teacher T2 from School 1 held:

> *Yes, our headmaster was quite impressed when he found us implementing the new approaches which are student-centred, motivating students to participate in the lesson and inculcating a spirit of hard working in the learning process.*

Furthermore, findings in Table 7.12 show that teachers did not often have an opportunity to conduct peer classroom observations (Mode = 2) apart from the ones conducted during the school-based follow-up coaching (Section 7.4.1). The major reason reported during the focus group discussion was heavy teaching loads, and the fact that such an opportunity was not common in their schools. Due to this aspect, the teachers confirmed that peer meetings were held with members of the biology department only. It was revealed that teachers' engagement in the peer coaching meetings enhanced their implementation efforts of the new approaches as reported by teacher T4 from School 1:

> *Peer meetings provided me with skills of using this method in my classroom, there was a time I discussed with teacher T1, about the problems I faced in the teaching of a lesson on 'cell differentiation' and she was ready to demonstrate the techniques in my classroom while I was observing.*

Emphasising the benefits of sharing teaching experiences during peer coaching, teacher T5 from School 2 held:

> *Because all of us belonged to the biology department, and the fact that we are using the new approaches, we used to meet every Friday, to discuss and share the experiences from each one's class. Sometimes, we worked in collaboration to develop lesson plans, and teaching and learning materials for our lessons.*

7.5.1.3 Teachers' perceptions of school leadership support

The nature of school leadership focused on the characteristics of headmasters as well as school administration in general. These findings were explored with the help of six closed statements in the questionnaire (Appendix C9) and related questions in the focus group interview (Appendix C10). Table 7.14 summarises responses to the closed statements in terms of the Modes and frequencies.

Table 7.14 Teachers' perceptions about school leadership support (N = 7)

	School leadership support statements	Mode	Frequency
i)	The headmaster is the active and enthusiastic leader	4	6
ii)	The headmaster encourages teachers to participate in school-wide decision making.	4	5
iii)	The school administration has schedules that allow you to collaboratively plan and discuss with fellow teachers	2	7
iv)	The headmaster encourages teachers to participate in workshops intended for their professional growth	4	6
v)	The headmaster recognises and honours teachers' success with student achievement	4	6
vi)	You are encouraged to plan lessons collaboratively with your department teachers	2	7

Note: 5 = strongly agree; 1 = strongly disagree

Findings in Table 7.13 show that six teachers agreed that their headmasters were active and enthusiastic leaders, who encouraged them to participate in the workshops intended for their professional growth (Mode = 4). Similar findings were reported by teachers during the focus group discussion. Teachers confirmed to have positive support from their school administration in different ways such as:

i) Encouraged to experiment with new teaching methods which emphasised active student learning (T2, T3, and T4);
ii) Provision of teaching and learning materials when available (T1, T2, T5 and T6);
iii) Putting efforts in the improvement of students' learning and achievement by encouraging teachers to change their teaching styles from transmission to active learning (T1 and T2).

On the other hand, all seven teachers indicated that their school administrations were less supportive in the aspect of teachers working in collaboration with fellow teachers in the departments or the school in general (Mode = 2). Findings of the teachers' focus group discussion confirmed that their schools did not have schedules for teachers working in collaboration. This was supported by Teacher T6 from School 2:

> *There are no specific schedules to work in collaboration in my school ,…. we did it in our own time, mostly free times to discuss and share experiences about the implementation of the new approaches in our classrooms.*

7.5.1.4 Summary of the findings of the nature of school support for teachers' implementation of the new approaches

The extent of school and collegiate support involved aspects such as; resources, school culture and peer/collegiate support, and school leadership. Teachers reported that sometimes they couldn't get the necessary materials and other supplies in time because of lack of funds in their schools. Findings of the school support questionnaire indicate that both schools 1 and 2 encouraged the implementation of the new teaching methods which focused on improvements of students' learning. Teachers' efforts during implementation of the new approaches were recognised and honoured by headmasters and other school teachers. Teachers reported that their school administration does not have schedules that allow them to collaboratively plan and discuss lessons with fellow teachers. Therefore, teachers used their free time to conduct peer coaching meetings in order to share and improve individual teacher competencies in working with the new approaches in their respective classrooms.

7.5.2 Teachers' improvement of instructional approaches

The focus of evaluation at level four (Table 7.1) was to investigate how teachers integrated the new approaches learned from the PD workshop and school-based coaching sessions to improve their daily teaching practices. The two indicators of the use of the new knowledge and skills at level four were:

i) The Levels of Use (Table 7.15), i.e. teachers' Levels of Use and, or adoption of the new approaches in their respective classrooms. This information was sought by the help of the teachers' Level of Use interview (LoU) (Appendix C8);
ii) Change or improvement to teachers' instructional practices, i.e. whether the new teaching practices were really different from what teachers used in the past, i.e. pre-intervention teachers practices. Data collection instruments included the curriculum profile classroom observation checklist (Appendix C4), the field notes and the teachers' reflective interview (Appendix C5), the student evaluation questionnaire (Appendix C6) and the students' focus group interview (Appendix C7).

7.5.2.1 Evaluation of teachers' Level of Use of the new approaches

Levels of Use address the behavioural dimension of change (Hall and Hord, 2001) depicting how teachers act when they become more familiar and skilled in using the intended change. The Levels of Use are directly related to the depth of teachers' knowledge and skills acquired from the PD experience (Guskey, 2000). There are three Levels of Use that define non-users; i) *non-use* level 0, ii) *orientation* level 1, and iii) *preparation* level 2), and five Levels that categorises Users: i) *mechanical* level 3, ii) *routine* level 4A and iii), *refinement* level 4B, iv) *integration* level 5, and v) *renewal* level 6). Table 7.15 provides a description of teachers' instructional behaviours at each level.

Table 7.15: Description of Levels of Use (Hall & Hord, 2001)

Category	Level of Use	Characteristics	Teachers' Instructional Behaviours
NON USERS	0	*Non-use*	Takes no action with respect to the innovation.
	1	*Orientation*	Seeks information about the innovation.
	2	*Preparation*	Prepares for the first opportunity for use.
USERS	3	*Mechanical*	Focuses on day-to-day use, which tends to be disjointed, and superficial with little insights.
	4	*Routine (4A)*	Establishes an appropriate pattern of use with little preparations.
		Refinement (4B)	Varies the level of use within the context to improve the impact on students.
	5	*Integration*	Makes deliberate efforts to coordinate with others in using the innovation.
	6	*Renewal*	Seeks more effective alternatives to the established use of the innovation.

The Level of Use of the new approaches in this study was investigated by using a semi-structured interview (Appendix C8). The teachers were interviewed in order to determine the extent of using the new approaches in the lesson planning and teaching process.
The qualitative content analysis of data from this interview showed that all the seven teachers were users of the innovation (new approaches) but existed at different levels of users: One teacher was at the *mechanical level of use,* three teachers were at the *routine level of use*, two teachers were at the r*efinement level of use* and, one teacher at the *integration level of use.* The following section describes teachers behavioural classroom practices reported at each level of use. These levels complemented the teachers' post-intervention classroom practices demonstrated by individual teachers in Appendix C4d and their e analysis in section 7.5.3.2.

Teacher T3 was graded at the *mechanical level of use (LoU 3).* This teacher reported to use the new approaches in the daily lesson planning and teaching as illustrated in the curriculum materials, but sometimes failed to develop and organise lesson activities in the classroom for some topics (for example Appendix C4d lesson 3). She blamed such inefficiency on the lack of practical skills for carrying out dissection of small animals and plants, and teaching and learning resources. The average practice scores for this teacher during post-intervention classroom observations (Table 7.15) further confirmed the teachers' instructional behaviours.

The majority of users of the new approaches were graded at level 4. Three teachers (T2, T4, and T6) who were graded at the *Routine level (LoU 4A)* reported to make an effort to adapt the new approaches in their classrooms, and confirmed to change their lesson plans formats and lesson presentation styles. For example teacher T2 held:

> *I changed everything I did before, I didn't realise I had active and creative students in my class, until when I followed the 5Es stages which provided me with techniques to motivate students to participate in the lesson from the beginning to the end. This approach gave me the opportunity to learn from students' experiences of which others were misconceptions.*

Teacher T6, who refers to students' participation in the lesson she taught on '*growth in plants'* argued:

> *The adoption of the new approaches made my students believe that they have something to contribute in their learning. During the lesson students were able to perform experiments to test their ideas or hypotheses about the factors necessary for seed germination.*

The two teachers (T5 and T6) who were graded at the *Refinement level (LoU 4B)* articulated their active engagement in the implementation of the new approaches in the ways that suited their lesson contexts. Despite having many students in their classes (i.e. more than 50), they made an effort to involve their students in the lesson activities in order to understand the taught concepts. They used a number of strategies such as; dividing students into fixed small groups in order to avoid wastage of time at each lesson period, and engaged in the improvisation of teaching and learning materials and resources. For example, teacher T5 duplicated the human skeleton model by using hard papers and pieces of wood to enable students in small groups to observe when teaching a lesson on '*movement in animals'* (Appendix C4d, lesson 5). Teacher T6 prepared sufficient materials and equipment for students to use when designing their experiments about seed germination (Appendix C4d, lesson 6).

Teacher T1 was graded at the *integration level of use (LoU 5),* she confirmed to using the new approaches guided by experiences from the PD workshop and school-based coaching sessions. Commenting on the usefulness of the new approaches compared to the previous lecture method the teacher said:

> *There are some topics in biology which are difficult to explain with words such as food tests, genetics, and evolution where it became difficult for students to understand the concepts unless you introduce simple experiments, models, diagrams, or photographs to present the ideas.*

The teacher further reported sharing the ideas of the new approaches and how students benefited from participating and learning from lesson activities to another department such as chemistry (i.e. this teacher was also teaching chemistry). This kind of collaboration has made other teachers interested in using lesson activities in their teaching and learning process. She explained that due to the active participation of students in the lesson activities (such as discussion, asking and answering of questions, and doing field work (e.g. Appendix C4d, lesson 1), the teacher had assigned students to assist in the preparation and preservation of materials and resources during biology club periods. This has not only increased the involvement of the students in their learning but also saved the teacher’s time for planning and organisation of lesson activities.

7.5.3 Differences in teachers' instructional practices

This indicator aimed at substantiating whether the observed instructional practices were truly different from those previously used by teachers (Appendix C4a). This was established by conducting classroom observations before implementation of the PD experience (Section 7.2.2) and after implementation of the new approaches in both schools 1 and 2. Observation data were triangulated by explicitly asking teachers about changes in their practices through interviews as well as collecting students' opinions and experiences of the the new approaches adopted by their teachers via evaluation questionnaires, and focus group interviews.

7.5.3.1 Findings of the post-intervention classroom observations

This section presents a detailed overview of the classroom practices demonstrated by the seven teachers in schools 1 and 2. The teachers' classroom observations in this study focused on the indicators which substantiated the changes and improvement of teachers' classroom practices following the adoption of the new approaches (the activity-based approaches supported by the 5Es instructional sequence). By using these indicators classroom observations could be evaluated to see how well the teachers were operationalising the new approaches in their lessons. These indicators are:

i) Teachers' ability to structure their lessons differently in a way that accommodated integration of the new approaches;
ii) Teachers' use of excitement activities at the starting points of their classroom instruction;
iii) Teachers' ability to elicit students prior knowledge and use this to introduce the new lessons;
iv) Teachers' function more as facilitators of students' learning;
v) Teachers' ability to organise lesson activities that provided students with opportunities for active participation in their lessons;
vi) Students taking active roles in the teaching and learning of biology.

The post-intervention classroom observations were conducted by the researcher in collaboration with the assistant researcher who participated in the teachers' PD workshop. A total of seven lessons were observed which included:

1) *The concept of the environment* –Form II; teacher T1
2) *Drugs and drugs addiction* – Form III; teacher T2
3) *Reproduction in animals* – Form IV; teacher T3
4) *Classification systems* - Form I; teachers T4
5) *Human skeleton* – Form III; teacher T5
6) *The process of Germination* Form IV; teacher T6
7) *Food substances* – Form II; teacher T7

The descriptive analysis of the post-intervention classroom observations for individual teachers is presented in Appendix C4d.

The assessment of the post-intervention classroom instructional practices was guided by the 5Es instructional sequence presented in Table 6.1 and operationalised in the curriculum profile classroom observation checklist (Appendix C4). The classroom observation checklist (developed by the researcher) simplified and guided the observation of teachers' classroom practices (Section 5.8.1).

The teaching of the lesson followed a general sequence of *Excitement, Exploration, Explanation, Elaboration, and Evaluation.* As teaching progressed the researcher and the assistant researcher independently observed and noted teachers' practices which were judged, i.e. to what extent they were in line with the expectations in the observation checklists. After each observation the two observers completed their observation checklists and compared the extent to which the scores were similar. There was an agreement on scoring for each stage in the observation checklist. The mean scores were summarised and presented as percentages as illustrated in section 6.3.2.1 and presented in Table 7.16. The scores for the individual statements at each stage of a lesson are presented in Appendix C4c. These scores supported the qualitative data from the researchers' field notes and the open-ended questions included in the observation checklist. Table 7.16 summarises the post-intervention practice profile scores for the seven teachers as percentages.

Table 7.16 Post-intervention teachers' relative profile practice scores

(i.e. 100% = all items for each stage were fully met)

Lesson stages	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**Average**
Excitement	75	63	46	69	75	69	75	**69**
Exploration	92	85	54	81	88	85	96	**83**
Explanation	94	87	56	62	87	81	81	**78**
Elaboration	79	64	43	64	75	79	79	**69**
Evaluation	92	92	50	75	83	67	83	**77**
Average per teacher	86	78	50	70	82	76	83	**75**

Note; The average profile practice score is 50%

Findings in Table 7.16 show that the profile practice score for all seven teachers were encouraging. Apart from the individual differences in terms of the nature of the lessons they teach (Appendix C4d) and the teachers' Level of Use of the new approaches (Section 7.5.2.1) the practice scores at each stage of a lesson were above the average. These summative findings suggest that most of the teachers' classroom instructional practices demonstrated by individual teacher's in Appendix C4d as well as the observation checklist (Appendix C4c) were in line with the proposed innovation, i.e. the activity-based approaches supported by the 5Es instructional sequence.

The profile practice scores in Table 7.16 do not show large differences among the teachers or across the lesson stages (i.e. the 5Es). Teacher T3 had lower scores in all stages of the lesson which suggested that she was less enthusiastic about the new teaching and learning approaches than the other teachers. This finding complemented the finding from teachers' Level of Use (Section7.5.2.1) where the same teacher reported challenges in using the new approaches in the teaching and learning of some topics such as *reproduction* and *genetics* (e.g. Appendix C4d, lesson 3).

Descriptive summary of teachers' instructional practices during the post-intervention classroom observations

Prior to the post-intervention classroom observations, all seven teachers from schools 1 and 2 had already undergone three cycles of classroom observations during the school follow-up coaching sessions which supported teachers' adoption of the new approaches in their respective classrooms. By looking at teachers' classroom practice trajectories it is hard to miss the gradual improvement of teachers' classroom performance in terms of structuring and delivery of their lessons guided by the 5Es instructional sequence (Appendix C4d), which differed from teachers' pre-intervention classroom practices (Section 7.2.2 and Appendix C4a). For example teachers introduced their lessons differently by not only asking questions to review the previous lessons as they did previously, but also elicited students' prior understanding and experiences by using different techniques including simple and short activities, which aroused students' interest and curiosity. For example brainstorming the lesson content as a whole class which enabled everyone to participate and provide their ideas in the fun and interactive way (Appendix C4d, lessons 1, 5 and 7). The diagnosis of students pre-existing knowledge was important for teachers to plan subsequent teaching activities which supported students to link the new concepts to their experiences.

During the post-intervention classroom observations the teachers provided students opportunities to engage in hands-on activities such as making observations, designing, and planning experiments, doing field work, small group-discussion, problem solving activities, and organising their findings for presentation. In many lessons teachers re-arranged their classroom desks and tables in ways that enabled students to work in groups of not more than six, providing materials and resources as well as focusing on students' activities.

Students were actively involved in working with questions or doing practical activities and communicating their findings to other students in the classroom and with the teachers acting as facilitators to help students to extend and apply the learned knowledge to other contexts in order to acquire deeper understanding (e.g. Appendix C4d, lessons 4, 5, and 7).

With regard to teacher's roles and students' activities, teachers' substituted their traditional dominance as knowledge dispensers (Section 7.2.2) and extended their roles as facilitators for group work activities and as moderators during presentations thus encouraging students to be more responsible for their own learning (Calderon *et al.,* 1996). The teachers used appropriate materials and resources to create learning environments which allowed students to construct their own knowledge rather than depending on their teachers as an exclusive source of the knowledge.

Apart from the above mentioned improvements teachers had some difficulties in following the time indicated in their lesson plans which was caused by delays in starting lesson on time. This forced teachers to miss out the planned lesson activities or rushed to accomplish them. Another reason was teachers' and students' unfamiliarity to the new approaches. Sometimes, teachers were not quite sure with time estimates for particular lesson activities.

7.5.3.2: Analysis and interpretation of findings of the post-intervention classroom observations

This section presents the analysis and interpretation of findings of the post-intervention classroom observations. The analysis is guided by teachers' instructional practices in the five stages of their lessons, i.e. *excitement, exploration, explanation, elaboration and evaluation*, to present the changes in teachers' practices following the intervention, and the underlying reasons for these changes. The pre-intervention observations are presented in Appendix C4a, and the post-intervention observations are presented in Appendix C4d.

Excitement

During the post-intervention classroom observations teachers engaged students in performing short lesson activities such as brainstorming, making observations, carrying out demonstrations, asking open questions and leading discussions in order to elicit students' prior knowledge and generate interest and curiosity. Students' involvement in these activities helped teachers to identify alternative ideas and students' misconceptions at the start of the lesson that could hinder students' acquisition of meaningful understanding of the new concepts (Ausubel, 1968; Mintzes, Wandersee, & Novak, 1998). These instructional practices were new to teachers and not practiced during pre-intervention classroom observations. As indicated in Appendix C4a, the extent of starter activities during pre-intervention lessons was that six teachers asked short questions about the previous lessons to verify the retention of facts. These questions were not connected to the new lessons and therefore, did not help students to build their understanding of the new concepts.

Findings presented in Appendix C4d of the post-intervention classroom observations show that six teachers based their lessons on students' prior experiences which indicated an improvement in their instructional practices. For example, three teachers (T1, T2 and T4) asked questions relating to the current lesson, which required answers or explanations from students' prior experiences based newly performed activities. For example, teacher T1 asked the question: *Explain the meaning of an environment* after students had completed observations and discussion in small groups (Appendix C4d, lesson 1). The other three teachers (T5, T6 and T7) required their students to provide an explanation or illustration of new concepts based on the findings of the newly performed activities or everyday life experiences. For example, in teacher T7's lesson (*Food substances*) students were requested to explain their ideas about the meaning and types of food substances (Appendix C4d, lesson 7).

These findings were supported by the individual teacher's profile practice scores in Table 7.16 which revealed that six teachers had satisfactory and above average scores, i.e. 50%. The small differences among individual teachers' profile practice scores might be due to the nature of the topics they taught and the fact that this approach was new to them. For example, the topics such as *classification systems, drugs and drugs addiction* and *reproduction in animals* (Appendix C4d, lesson 2, 3 and 4) could seem abstract to students and not sufficiently connected to their prior experiences for them to construct their own meaning. Therefore, it demanded the individual teacher's competence and creativity in using practical activities and effective techniques to activate the students' current understanding (or misunderstanding) about the specific topics.

Teachers' diagnosis of students' prior experiences was important in order to plan subsequent teaching activities and help students link the new concepts to what they already know (Ausubel, 1968; Wittrock, 1994). However, teacher T3 did not elicit students' prior knowledge about her lesson, i.e. *reproduction in animals* (Appendix C4d, lesson 3) which indicated little change in her instructional approaches demonstrated at this stage. This teacher's practice scores for *excitement* stage were below the average at 46% (Table 7.16). A more detailed discussion about teacher T3 instructional behaviour is presented in section 7.5.2.1.

Exploration

In the post-intervention classroom observations students had opportunities to carry out hands-on activities in which they explored the concepts and skills. They grappled with the materials and phenomena and described it in their own words e.g. carrying out investigations to experience the phenomenon, collecting evidence through observations, testing their ideas and trying to answer the questions. As they worked in groups, students built a base of common experience which assisted them in the process of sharing and communicating. Six teachers facilitated students' activities in different ways including provision of the sufficient time for students to accomplish the tasks, observing and listening to the students as they interacted, and asking probing questions to re-direct students' investigations when necessary. For example, teacher T1 prepared field guide papers and questions to guide students' observations; teacher T2 guided small group discussions with questions; teachers T4, T5, T6 and T7 used questions and also supported their students to use the equipment and record their observations (Appendix C4d, lessons 1, 2, 4, 5, 6 and 7).

These activities were regarded as an improvement in teachers' instructional practices compared to the traditional approaches, i.e. a theoretical explanation of the lesson facts demonstrated by the same teachers during pre-intervention classroom observations

(Appendix C4a). Students engaged in hands-on activities including discussions, and interacted with materials and phenomena. Haury & Rillero (1994) posit that students can draw meaning and understanding from such experiences, and according to Posner *et al.,* (1982) and Strike & Posner (1992), these kinds of activities allow students to develop thinking processes and begin constructing concepts and developing skills which facilitate conceptual understanding.

Findings of classroom observation checklists (Table 7.16) indicate that the *exploration* stage had the highest average profile practice scores among the teachers (83%). This strengthened the evidence about the extent and quality of teachers' adoption of the activity-based approaches supported by the 5Es instructional sequence.

Explanation

During the post-intervention classroom observations students were provided with opportunities to demonstrate their conceptual understanding of the lesson topics, i.e. they verbalised their understanding from previous activities, identified the patterns in their findings and described what they observed or discussed. All seven teachers supported students' explanations of the lesson activities and findings of small group discussions in order to provide evidence and clarification of their findings, so that students could draw conclusions from the performed lesson activities. In the six lessons (Appendix C4d, lessons 1, 2, 4, 5, 6, and 7) students were encouraged to use specific knowledge, facts, skills and experiences gained from the practical activities and then present their findings to the whole class.

In order to extend the students' knowledge and understanding, six of the teachers asked probing questions that encouraged students to look for patterns or irregularities in their findings, for example teacher T1 who taught a lesson on *the concept of environment* asked: *How many organisms have you observed or collected? Explain the specific areas you have found your organisms, have you noticed any kind of relationship among your organisms*? If the answer is '*yes'*, *can you provide examples of relationships among your organisms*? *How can you explain the meaning of environment from what you have observed* (Appendix

C4d, lesson 1). These questions guided students to focus their explanation on the specific aspects of the lesson which enhanced learning from the lesson activities (Carlton, 2000; Haury & Rillero, 1994; Lumpe & Oliver, 1991).

All seven teachers facilitated the lesson content knowledge after students presented their practical experiences, and referred to students' prior and the current practical experiences in order to help students develop scientific explanations for experiences and representations of their developing conceptual understanding.

Teachers' instructional practices demonstrated at this stage differed from their pre-intervention practices whereby the whole teaching and learning process was dominated by the teachers, as an exclusive source of the subject content knowledge and skills, and ignored students' participation in the understanding of their lessons (Appendix C4a). Instead, during post-intervention classroom observations, teachers adopted a facilitative role and used students' previous experiences as a basis for explaining the lesson concepts and skills. Generally, students were attentive to the teachers' presentation, sometimes asking their teachers questions for further explanation of the concepts and to advance their understanding. For example teacher T5 who taught a lesson on the *human skeleton* was asked: *How a human body performed functions involving bending without tearing or breakage* (Appendix C4d, lesson 5).

The post-intervention profile practice scores for all seven teachers in the *explanation* stage were substantial and above the average (Table 7.16). The observed differences among the individual teacher's profile practice scores could be attributed to the extent they facilitated their respective lessons based on students' prior experiences. For example teacher T3, who scored 56%, did not always base her lesson explanations on students' prior knowledge and experiences, which indicated the teacher's dominance of the teaching and learning process (Appendix C4d, lesson 3).

Elaboration

This stage in the post-intervention classroom observations provided students with opportunities to extend their conceptual understanding and make connections to other related concepts, practices or skills and apply their understanding to the world around them. Findings of post-intervention classroom observations show that two teachers (T1 and T3) used question and answer technique, for example, teacher T1 asked her students: W*hat do you think about the importance of having different environments as observed*? (Appendix C4d, lesson 1). This question made her students think critically not only about the types of environments they had observed, but also why they exist. These techniques enabled the students to achieve higher learning outcomes and use their knowledge and skills to solve problems in their everyday life (Abrams, 1998; Schollum & Osborne, 1985). For example, one student in teacher T1's class explained that:

> *one of the advantages of having different environments is to enhance interaction among living organisms (biotic) and with abiotic components in order to balance the nature and preserved biodiversity.*

Three teachers (T4, T5 and T7) provided their students with alternative practical activities which enhanced the application of the learned concepts. For example after teaching a lesson on *classification systems* teacher T4 provided her students with alternative specimens to classify based on the acquired knowledge and skills from the *exploration* and *explanation* stages (Appendix C4d, lesson 4). Six of the teachers probed and reinforced students' understanding in order to guide them to identify relationships between the concepts learned and other content areas. They sometimes reminded students of the existing evidence and data to support their explanations. For example, teacher T5 after teaching a lesson on *human skeleton* asked her students to explain *how the different parts of skeleton in other animals such as birds and reptiles supported movement in their body* (Appendix C4d, lessons 5).

These instructional approaches were useful at this stage and helped students to correct their persisting misconceptions resulting in deeper understanding whilst also helping the teachers to identify students who had not fully grasped the lesson concepts. For example in teacher T1's lesson two groups described 'an environment' *as an area with living things* (Appendix C4d, lessons 1). Similarly, four students (in two groups) in teacher T4's lesson failed to identify the characteristics of the different groups of organisms they classified even after they learned about *artificial and natural classification systems* (Appendix C4d, lesson 4).

Such instructional practices were neglected in the teachers' pre-intervention classroom practices, where they explained the lesson facts based on their lesson notes and students' activities were limited to passive listening and copying notes and other illustrations from their teachers (Appendix C4a), with an assumption that all students have the same level of background knowledge in the topic and are able to absorb and memorise the concepts at the same pace (Deboer, 2002; Lord, 1999).

Findings in Table 7.16 show the post-intervention profile practice scores for six of the teachers at the *elaboration* stage were satisfactory and above the average. Teacher T3 performed below the average at 43% because she only asked two general closed questions which required short answers from the students and therefore discouraged further reflection about the taught concepts. These questions were: *What are the main parts of the male reproductive system? What are the functions of the female reproductive system?* (Appendix C4d, lesson 3). This finding suggested the teacher's lack of the questioning skills.

Evaluation

The evaluation stage in the post-intervention classroom observations was regarded as an on-going diagnostic process that allowed teachers to determine whether the students had attained understanding of the taught concepts and skills. Students were provided with opportunities to review and reflect on their own learning, new skills and understanding. This was regarded as an improvement in teachers' practices compared with their pre-intervention practices where evaluation (i.e. lesson conclusion) took place at the end of the lesson and just consisted of teacher-led questions. The pre-intervention questions asked were short and closed and did not allow students to reflect on the learned concepts. For example, teacher T1 asked: *Where does the process of photosynthesis occur? What are the conditions necessary for photosynthesis to happen?* Similarly, teacher T5 asked: *What is pollination?* (Appendix C4a, lessons 1 and 5).

During post-intervention classroom observations the teachers employed various techniques to assess students' conceptual understanding and progress towards learning outcomes such as: asking open questions which allowed students to express their opinions and demonstrate their understanding of the concepts. For example teachers (T1, T2 and T4) asked evaluative questions that required their students to demonstrate the specific knowledge and skills learned from their lessons: for example teacher T4 asked: *How does the artificial classification system differ from the natural classification system*? (Appendix C4d, lesson 4).

In addition, teachers T5 and T7 encouraged students to answer questions which were asked by their peers in order to share the lesson experiences and reflect on the learned concepts (Appendix C4d, lesson 5 and 7).

Other teachers observed and assessed students as they applied the learned concepts and skills. For example, students were asked to design experiments on *seed germination* based on their lesson about the *process of germination* (Appendix C4d, lesson 6).

These interactive activities helped teachers to identify evidence that the students have changed (or not changed) their thinking or behaviour, and serve to guide the teachers in further lesson planning which would suggest the need for modification or change of future instructional techniques or lesson concepts and skills.

Findings of the post-intervention classroom observations show that the abovementioned activities were implemented differently among individual teachers. However, time management was a limiting factor because the previous stages consumed most of the time. In four cases (i.e. Lessons 2, 4, 5, and 6) teachers either rushed to accomplish the prepared activities or were unable to do so as observed in teacher T3 lesson (Appendix C4d, lesson

3). Furthermore, all seven teachers were unfamiliar with an interactive lesson evaluation which could enhance joint student and teacher reflection on the important concepts or skills covered in the lessons. These factors might contributed to the differences among the individual teacher's profile practice scores (at the *evaluation* stage) presented in Table 7.16.

Six teachers provided homework assignments at the end of their lessons during post-intervention classroom observations which aimed to extend what students had learned from their lessons, and reinforced in-depth understanding (Appendix C4d, lessons 1, 5, and 7). For example teacher T5 after teaching a lesson on *human skeleton* (Appendix C4d, lesson 5) provided students with homework tasks which allowed them to observe and draw the *thoracic, lumber and sacral vertebrae* and explain how they are adapted to support movement in the human body. These instructional practices were regarded as improvement following the intervention because the homework tasks provided by the same teachers during pre-intervention classroom observations were only aimed at getting students to reproduce the facts or skills provided during the lessons via their lesson notes. For example, teacher T1 assigned her students to write about *the importance of photosynthesis,* and teacher T7 asked: E*xplain the similarities and differences between plant and animal cells* (Appendix C4a, lessons 1 and 7).
Furthermore during post-intervention other teachers (T2, T4 and T6) provided practice homework tasks which aimed to reinforce the newly acquired knowledge and skills. For example teacher T4 asked her students to group organisms of their interest in their environment based on the natural classification system.

7.5.4 Teachers' perceptions about the adoption of the new approaches

This section examines teachers' opinions and experiences following the implementation of the new approaches in their respective classrooms. After each classroom observation the researcher interviewed all seven teachers guided by questions in Appendix C5.
Findings of the teacher reflective interviews (Appendix C5) revealed teachers' positive feelings on adoption of the new approaches. All seven teachers regarded the PD experience

as a supportive device for the implementation of the new approaches in their classrooms. They particularly confirmed that the new approaches they currently embraced increased their confidence in decision- making about effective teaching techniques to improve students' understanding of the lesson. They reported that the curriculum materials were supportive in the specific lesson content knowledge, and provided step-by-step procedures to follow in the classroom, i.e. the 5Es instructional sequence. The teachers further reported that the new approaches encouraged them to use the teaching and learning materials and resources to promote students' participation in the understanding of the lesson. One of the teachers held:

> *It is from the curriculum materials I learned the techniques (e.g. providing alternative activities from the previous ones) to help students transfer the learned concepts and skills to the world around them for a deeper understanding.* (Teacher T2)

Furthermore, all seven teachers reported improved student participation in their lessons which was different from their regular teaching and learning process. Teachers associated this improvement to changes they made in the instructional approaches and the lesson presentation style. Commenting on the changes in the instructional approaches teacher T6 held:

> *Previously I didn't use lesson activities until the time near to the final examinations because students have to sit for practical examinations, but now I am using lesson activities even during the introduction stage of my lesson, these are big changes to me which I hope will make my students perform better in this lesson than before.*

Similarly, Teacher T1 expressed her positive experiences on students' participation in the lessons by saying:

> *Previously, I used a lecture method, sometimes asking a few questions where students depend much on my notes but now, students are playing a larger role in the learning process, they found different sources of the lesson facts including the teacher, students themselves, books, and the lesson activities.*

Addressing on the relevance of using students' prior ideas and lesson activities teacher T2 held:

> *Previously, I used the lecture method throughout of my teaching, but now I am using practical activities and base my lesson explanations on students' prior ideas and experiences, this leads to changes of my role as a teacher to supervisor of students' activities and facilitator of learning.*

The teachers reported the active students' participation in the lesson activities which continually increased with increasing teachers' experiences with the new approaches. Three teachers (T1, T2 and T5) asserted that students were highly motivated to participate in the lesson activities than before because previously there were no practical lesson activities which led to students' dependency on teacher's lecture notes. Two teachers (T1 and T5) found that students were enthusiastic and proud of their involvement in the understanding of the lessons as declared by teacher T5:

> *Student participation in my lesson has increased compared to the previous time… yes, you can see how they asked or answered questions, and how they ask for explanations or assistance when they are performing practical activities.*

However, teachers mentioned the following problems and challenges encountered when using the new approaches in their classrooms:

i) Lack of teaching and learning materials and resources. Four teachers (T1, T2, T5 and T6) declared that sometimes it was difficult to get sufficient materials and resources for students in the classroom (e.g. laboratory equipment and materials) due to lack of funds in their schools (Section 7.5.1.1);

ii) Unfamiliarity of teachers and students with the activity-based approach. Teachers T3, and T7 argued that despite the fact that using lesson activities motivated students to learn, it made teaching of a lesson much longer than if it was taught without them;

iii) Having many students in the classroom (i.e. more than 50) led to ineffective organisation and supervision of lesson activities because it was difficult for teachers to ensure maximum involvement of each student in the lesson (T5, T6 and T7);

iv) Poor mastery of the instructional language, i.e. English language. During the small group discussion some groups failed to communicate their experiences and data due to difficulties in using this language (T1, T2, and T4).

7.5.5 Students' perceptions and experiences with the new approaches

In order to address teachers' changes and improvement in the classroom practices following the adoption of the new approaches the researcher administered a student evaluation questionnaire (Appendix C6) to 145 students from different classes in both schools 1 and 2. In addition, four focus group discussions (each group had ten students) with representative students from each class were conducted in order to triangulate findings of the evaluation questionnaire. The aim was to collect in-depth students' perceptions and experiences about the new approaches adopted by their teachers (Appendix C7). Findings of the focus group discussion were categorised to: students' perceptions of their teachers' role as a facilitator, assessment of students' prior knowledge and experiences, and students' lesson activities. Findings of the student evaluation questionnaire supported explanations for each of the mentioned categories.

7.5.5.1 Students' perceptions of their teachers' role as facilitator of learning

Students' responses indicate that teachers used teaching and learning materials and resources to support students' practical activities. The lesson activities they performed at the beginning of their lessons (i.e. *excitement* stage) created learning environments which allowed many students to provide their prior knowledge and experiences and test their conceptions before teachers' explanations of the new lesson. The following quotes were provided by students about teachers' facilitation:

The teacher (T1) explains the lesson very well by correcting the mistakes we did in the presentation, and encouraged us to ask questions if we didn't understand anything about the lesson. (S2, from School 1)

Another student commented on teachers' support during the lesson:

Sometimes the teacher (T6) provided instructions to follow when doing experiments and tried to ask questions to guide the practical activities, but there are cases whereby our teacher assigned us to conduct experiments to test our ideas, or the hypotheses we propose. (S3, from School 2)

Responses from the student evaluation questionnaire indicated that 134 of 145 students reported teachers' positive responses to the questions they asked in their classrooms. During focus group discussions one of the students held:

Sometimes, our teacher (T5) re-directs the asked questions to other students in the class to provide answers, and finally the teacher may provide explanations and examples. This has provided an opportunity for students to make a self-assessment of the taught concepts and shared the lesson experiences. (S4, from School 2)

7.5.5.2 Assessment of students' prior knowledge and experiences

Students agreed that their teachers used to ask what they know or think about the lesson before providing explanation of the new lesson. For example two students (S5, and S6, from School 1), and one student (S7, from School 2) provided the following illustrations:

Yes, our teacher used various techniques, sometimes she asked students to stay in small groups and discuss what we know about Nutrition in animals (T7); grouping organisms brought into the classroom in order to identify the meaning of classification of living things (T1); observing the pictures and photographs in order explain the basic terms in Genetics (T6); and explain what we think about the provided plants leaves (T4).

These findings suggested that the techniques used by their teachers such as experimentation, observation, brainstorming, and group discussions inspired them to apply their creativity, whilst sharing experiences, and knowledge about the subject. For example, findings in Table 7.17 show that 94 of the 145 students found that when the teacher used lesson activities at the beginning of the lesson to identify their prior knowledge it stimulate their thinking about the new lesson which later enhanced their understanding.

7.5.5.3 Students' lesson activities

Findings of the student evaluation questionnaire (Appendix C6) indicate that students were engaged in the lesson activities. Table 7.17 provides lesson activities favoured mostly by students with sample reasons.

Table 7.17 Students' lesson activities mostly favoured with sample reasons (N = 145)

Activities most favoured by the students	**Sample reasons why they were favoured**
Doing practical work such as experiments, investigations in the field study and observations of specimens and models (N= 108)	-We understood more when involved ourselves in doing practical work because we can see the changes or observed features which enhanced creativity and mastery of the taught concepts. - Made it easier for us to understand the concepts if our teachers showed us the examples of the real things or models -We enjoyed when performing experiments like food test, classification, germination and observe the results from our own work. -Assisted the retention of the taught concepts because we were involved.
Discussion in small groups (N = 82)	-Encouraged sharing of knowledge among students, because during the discussion you can get many lesson ideas from other students -Facilitated understanding of the concepts taught by the teacher when our fellow students explain what they knew about the lesson.
Presentation after discussion (N = 46)	-Made us to share the group ideas with the rest of the class which helped us to learn from other groups, and become confident in the presentation of group findings.
Lesson delivery (N = 94)	-When our teachers started a lesson by an experiment or showed us some pictures and real specimens and ask us to discuss what we know before providing explanation of the new lesson, it encouraged us to start thinking about the lesson, which later helped in the understanding of the new lesson because we can see how the new lesson is connected to our ideas. -The questions asked when the teacher is teaching and the homework activities reminded us what we have learned during the lesson.

Findings in Table 7.17 show that most students favoured doing practical work (N = 108), the newly lesson delivery, i.e. by following the 5Es instructional sequence (N = 94) and discussion in small groups (N = 72). A smaller number of students (N = 46) mentioned their appreciation of doing presentations after discussion. This finding complemented the previous findings of the teachers' reflective interview (Appendix C5) which show that the poor mastery of the instructional language negatively affected student discussions in the small groups and presentation of their findings.

Table 7.18: Lesson activities less favoured by students with sample reasons (N = 14) from Appendix C6

Activities less favoured by the students	**Sample reasons why were not favoured**
Small group discussion (N = 40)	-Other students were not keen in the accomplishment of the given task, they used to disturb others and sometimes they don't know the answers to the questions. -Due to poor arrangement of desks it took time for other students to settle in their respective groups. -Other students were not ready to present their task due to English language problem, but our teacher reinforced every student to participate in the presentation.
Sharing of teaching and learning resources (N = 96)	-Due to lack of resources in our laboratories it was difficult for us to stay in groups of 6 or 7 when doing an experiment like food tests, classification and transport in living things. It was difficult for every student to perform experiments for a given time of a lesson.

Findings in Table 7.18 show that most students (N = 96) indicated that they were not happy with sharing teaching and learning materials and resources during experimentation. Similarly 40 students indicated their disappointments with practicalities involved in managing small group discussion.

Generally, all students (N = 145) reported improvements in doing lesson activities which helped them to understand the concepts taught by their teachers. They reported that the methods used by their teachers enhanced better understanding of the lessons as they learn by practising the tasks, or making observations and engaging in discussion in small groups. These findings indicate that students were involved in the learning process and had opportunities to facilitate conceptual change, i.e. they interacted with other students through discussion, materials and resources through experimentation and observations, and their teachers through answering of the questions and presentation of group activities. These instructional behaviours confirmed teachers' adoption of the activity-based approaches in their teaching and learning process as well as students' involvement in the understanding of their lessons.

Similarly, findings in Table 7.17 indicate increased creativity and lesson interest as a result of doing practical work such as; setting the experiments for investigations, and studying by using different objects such as pictures, diagrams, models and real specimens.

Students' responses from the evaluation questionnaire showed that 85% (123) of the students reported differences between the methods used by their teachers and their regular biology lessons in terms of:

i) Teachers' assessment of what students know about the lesson at the beginning of instruction;
ii) Teachers' use of teaching and learning materials and resources;
iii) Lessons delivery which started with practical activities and engagement in the hands-on activities to test ideas before explanations from the teachers;
iv) Encouragement of students' participation in doing lesson activities such as discussion, practical work, presentation, and question and answer.

Findings of this questionnaire show that 8% (12) of the students did not provide any differences, while 7% (10) of the students did not respond to this question.
Students' responses to question No.5 in this questionnaire about challenges or problems encountered when doing lesson activities were similar to what was suggested by their teachers (Section 7.5.4).

7.5.6 Summary of the impact of the new approaches on teachers' pedagogy

The extent to which the seven teachers from schools 1 and 2 use the new knowledge and skills was explored by using the Level of Use interview. Findings of the teachers' Level of Use interview showed that all the seven teachers were users of the new approaches and were characterised as Levels of Users such as; *mechanical, routine* and *integration*.

Findings of the post-classroom observation checklists indicate that the practice profile scores for all seven teachers were satisfactory and above the average. The descriptive analysis of the individual teachers' post-intervention classroom practices showed changes and improvements from their pre- intervention instructional practices which were based on traditional and expository methods. Based on these differences there is a strong indication that the PD experience and teachers' adoption of the new approaches contributed to improvements in the classroom practices of the teachers.

Furthermore, data from the Level of Use interview and classroom observations were triangulated with teachers' reflective interviews, student evaluation questionnaires, and students' focus group interview. The convergence of data from these instruments indicated that all seven teachers used the new approaches in various degrees of quality.

All seven teachers expressed positive feelings about the effectiveness of the curriculum materials and the activity-based approaches in terms of enhanced knowledge about teaching strategies and lesson presentation. Findings of the teachers' reflective interviews indicate that adoption of the new approaches has contributed to changes in their teaching styles from chalk-and-talk methods where students remained passive listeners of teachers' lesson explanations (Appendix C4a) to the active methods which involved students in learning and understanding (Appendix C4d).

Nevertheless, teachers reported that the lack of sufficient teaching materials and resources were among the constraints in the effective implementation of the new approaches. Other challenges mentioned were the large number of students in the classroom, and teachers' and students' unfamiliarity with the new approaches.

Findings of the student questionnaires and focus group discussion indicate that students perceived the new approaches adopted by their teachers positively. They confirmed that they were actively involved in the lesson activities such as doing investigation in the field study, experimentation, demonstration, observations, presentations, asking and answering of questions, group discussion, and listening of their teacher's explanations. Students commented that their engagement in lesson activities has contributed to better understanding of concepts as well as increasing their creativity, interest, and confidence in biology.

Students indicated the shortage of teaching and learning materials and resources as the major constraints to using activity-based approaches, because sometimes, many students had to share the books and laboratory equipment which affected the acquisition of practical skills. Another problem was wasting time during the formation of groups (especially in big classes) which caused unnecessary student movement in the class instead of participating effectively in the discussions.

7.6 Impact of the new approaches on student learning outcome

This section examines how the implementation of the new approaches benefited students' learning and understanding of biology. Evaluation at level five (Table 7.1), often attempts to link the PD experience to improvements in student learning outcomes (Guskey, 2000; Guskey & Spark, 2002). Students' learning outcomes are broadly defined as the practical knowledge and skills that students are expected to exhibit after a period of study including the entire range of students' goals and indicators of student achievement such as assessment results, scores or grades from standardised examination (Guskey & Spark, 2002). However they may include measures of students' attitudes, study habits, and classroom behaviours (Guskey, 2000; Joyce & Showers, 2002). Two indicators of student learning outcomes were considered:

i) Cognitive learning outcomes measured in terms of students' performance on the achievement test on the topic '*classification of living thing'*;
ii) Students' attitudes towards biology and the teaching and learning methods before and after implementation of the new approaches by their teachers.

The impact of the PD programme on student learning outcomes was evaluated by using the achievement test, (Appendix 11) which was administered to 153 experimental and 139 control school Form II students, the students' attitude questionnaire (Appendix C3) which was administered to 115 experimental school students only, and the biology teachers' reflective interview (Appendix C5).

7.6.1 Evaluation of students' cognitive learning outcomes

An achievement test was used to measure student learning and understanding of the topic of '*classification of living things'* to form II students in both experimental and control schools. According to Cohen *et al.*, (2007) and Gronlund & Linn (1990) achievement tests measure the attained performance in a given content area. The achievement test was constructed by the researcher by using a table of specification (Gronlund & Linn 1990; (Linn & Miller, 2005) in order to ensure content validity (Gronlund & Linn 1990). The test comprised of 25 multiple choice questions, i.e. the best-answer type (Linn & Miller, 2005). The test questions were piloted with 20 Form II students for further validation and to establish their practicality. This was useful in correcting the problems associated with unclear questions and determination of the actual time for students to accomplish the test. Table 7.19 presents the design of the achievement test.

Table 7.19: The construction of the achievement test by using a table of specification

Subtopics Covered	**Assessed Bloom's Cognitive levels**			**Total Test Items**
	Remembering	**Understanding**	**Application**	
Concept of classification	1	-	-	2
Classification systems	2	2	-	4
Major groups of living things	1	3	-	4
Viruses	-	2	1	2
Monera	1	1	2	4
Protoctista	1	2	1	4
Fungi	1	-	1	2
Bryophyta	-	1	-	1
Filicinophyta/ pteridophyta	-	2	-	2
Total items by weight	**7 (28%)**	**13 (52%)**	**5 (20%)**	**25 (100%**

Findings in Table 7.19 indicate that the test items measured three levels in the Bloom's cognitive taxonomy namely; remembering, understanding and application (Anderson & Krathworhl (2001). Remembering measured the ability of students to recall or remember the taught concepts; understanding measured the ability of students to explain the ideas or concepts in the topic of '*classification of living things',* and application measured the ability of students to use the information or procedures learned from the topic in their everyday situations in order to enhance their competence in the understanding of the topic. The selection of the three levels in the Bloom's cognitive taxonomy based on the goals and objectives of the topics included in the test as appeared in the teachers' schemes of work and O-Level biology syllabus (MOEVT, 2005).

Analysis of the test scores for each of the cognitive level was conducted with the help of the statistic software SSPS version 18, where by the descriptive (mean and standard deviation), and inferential statistics (independent samples *t-test*) were computed to determine whether there was a statistically significant difference in the achievement test scores between experimental and control schools students (Pallant, 2007).

The analysis of the students' achievement test scores involved Bloom's cognitive levels which were thought to provide reasonable results to compare the two groups rather than using the entire scores. Table 7.20 summarises results from the achievement test.

Table 7.20: An independent samples t-test results for the achievement test

Test items and cognitive levels	**Experimental schools N = 153**		**Control schools N = 139**		***P****	****Effect size (*eta squared)***
	Mean	Std. D	Mean	Std. D		
Remembering (7 items)	3.8	1.13	3.0	1.45	.001	.09
Understanding (13 items)	7.8	1.96	4.9	2.80	.000	.26
Application (5 items)	2.4	1.07	1.8	1.19	.009	.05

Note: *is significant at $p < 0.05$ (2-tailed) **effect size:
.01 = small effect size; .06 = medium effect size; .14 = large effect size (Cohen, 1998).

Results in Table 7.20 indicate a statistically significant difference in the mean scores between the two groups for the measured Bloom cognitive levels, (i.e. $p < 0.05$). The effect size (i.e. *eta-squared for the t-test*) statistic (Cohen, 1988) was calculated in order to find the magnitude of the differences between the mean scores for each of the cognitive level. The effect size for understanding level was large (. 26) which indicates an increased level of understanding of the topic of '*classification of living things'* by students in the experimental schools than students in the control schools who were taught mainly by the traditional lecture-style method.

7.6.2 Evaluation of students' attitudes towards biology

Students' attitude questionnaire (Appendix C3) was administered before the adoption of the new approaches in schools 1 and 2 towards the end of the programme. The overall students' attitudes were obtained by using SPSS software, whereby a non-parametric Wilcoxon Signed Rank Test (*z-test*) was used to compute the difference between the pre-test and post-test students' attitudes toward biology and the teaching and learning methods. Table 7.21 presents results from the students' attitude questionnaire.

Table 7.21: Wilcoxon Signed Ranked Test results of students' pre and post-attitudes towards biology

Attitude test measurements	**N**	**Median** *(Md)*	***Z -value***	***P**** **value**	**Effect size (*r*)**
Students' Pre-attitudes	115	50	-5.927	.000	.39
Students' Post-Attitudes	115	54			

Note: *is significant at p < .001 (2-tailed); effect size (r): .1= small effect; .3 = medium effect; .5= large effect (Cohen, 1998).

The Wilcoxon Signed Rank Test in Table 7.21 revealed a statistically significant increase in students' attitudes toward biology and the teaching and learning methods following implementation of the new approaches in schools 1 and 2, $z = -5.93$, $p < .001$, with a medium effect size ($r = .39$). The median score on the students' attitudes scale increased from pre-test attitudes (*Md* = 50) to post-test attitudes (*Md* = 54).

Additionally, an analysis was made in order to categorise students' attitudes related to biology as one of the subjects they are studying and attitudes related to students' experiences with the teaching and learning biology by using the new approaches. Table 7.22 summarises the descriptive statistics of students' attitudes towards biology in Modes and percentages.

Table 7.22: The modes and percentages of students' attitudes towards biology N = 115

Attitude statements	**Time intervals**	**Mode**	**Percentages**
i) Biology is very interesting to me	Pre-test	4	42
	Post-test	5	70
ii) Biology is fascinating and fun	Pre-test	4	30
	Post-test	5	50
iii) I am always under terrible anxiety in biology class	Pre-test	4	64
	Post-test	2	30
iv) I have good feelings towards biology	Pre-test	3	32
	Post-test	4	59
v) Biology is the subject I dislike the most	Pre-test	3	67
	Post-test	1	60
vi) I feel more relaxed in a biology class than in any other class	Pre-test	3	44
	Post-test	4	48
vii) Biology makes me feel secure and at the same time stimulating	Pre-test	3	41
	Post-test	4	55

Note: 5 = strongly agree; 1 = strongly disagree

Findings in Table 7.22 indicate the differences between the pre-test and post-test students' attitudes towards biology in terms of the Modes and percentages in favour of the post-test students' attitudes. These findings suggested that experimental school students had started developing good feelings towards biology.

The second category in the analysis was students' attitudes about teaching and learning biology by using the new approaches. Table 7.23 illustrates the Modes and percentages of students' attitudes toward teaching and learning biology through the new approaches.

Table 7.23 The modes and percentages of students' attitudes towards teaching and learning biology through the new approaches (N = 115)

Attitude statements	**Time intervals**	**Mode**	**Percentages**
i) I am very interested in doing practical work in biology	Pre-test	4	38
	Post-test	5	72
ii) It makes me nervous discussing and asking questions our biology teacher	Pre-test	4	60
	Post-test	2	50
iii) I enjoyed doing biology lesson activities	Pre-test	2	65
	Post-test	4	73
iv) It makes me nervous doing biology experiments	Pre-test	4	43
	Post-test	2	50
v) I feel at ease working with biology group activities	Pre-test	2	77
	Post-test	4	57
vi) Doing group work with my classmates makes me uncomfortable and annoyed	Pre-test	3	50
	Post-test	1	67
vii) I enjoyed doing with hands than listening to biology teachers' explanations	Pre-test	3	32
	Post-test	5	57

Note: 5 = strongly agree; 1 = strongly disagree

Findings in Table 7.23 indicate that all the post-test students' attitudes Mode values, and percentages for each of the measured attitude behaviours were higher than the pre-test students' attitudes for positive statements (e.g. Statements No. *i*, *ii*, and *vii*). These results suggested that students perceived the adoption of the new approaches by their teachers positively.

7.6.3 Teachers' perceptions about the changes of students' attitudes

Responses in the teachers' reflective interview (Appendix C5) indicate that students' involvement in the lesson activities had inspired most of them to like the lesson. The following quote was provided by teacher T7 from School 2.

> *My students were happy with these approaches; they were interested to participate in the classroom activities such as asking questions, discussions, carrying out investigations and reporting their observations.*

Likewise, teacher (T2) explained how students were enthusiastic and proud of their involvement in the lesson activities by saying that:

> *My students enjoyed learning through the new approaches because their involvement in the lesson activities made them more confident in explaining the lesson concepts and ideas, or commenting other students' presentations and sometimes the teacher's explanations*.

Similarly, teacher T5 explains:

> *Most of the students in my class liked the methods I used especially when provided with enough materials and resources for carrying out experiments and observations …you can see how they asked questions in the classroom, or challenged the presented findings of observations or investigations.*

Findings of classroom observations and field notes also show that the introduction of the new approaches enhanced student involvement in the learning process with positive outcomes of seeing students actively participating in the construction of their own knowledge rather than being passive listeners as demonstrated by students during pre-intervention classroom observations (Appendix C4a). At the end of such an interactive session, both the teacher and the students gained a sense of achievement and contentment.

7.6.4 Summary of the impact of the new approaches on student learning outcomes

The impact of the PD programme on student learning outcomes was evaluated by considering two indicators; the cognitive learning outcomes and affective learning outcomes. Findings of cognitive learning outcomes indicate a statistically significant difference in the achievement test mean scores (i.e. $p < 0.05$) for the measured Bloom cognitive levels between experimental and control school students. These results suggest that the adoption of the new approaches by experimental school teachers contributed to an increase in students' understanding of the topic of '*classification of living things'* compared to the outcomes of the traditional methods used in the control schools.

There was a significant increase in students' attitudes toward biology and methods of teaching and learning following the implementation of the new approaches in the experimental schools (i.e. $p < .001$). Similar findings were addressed from the teachers' interview and classroom observations which indicate that adoption of the new approaches has promoted the student lesson interests and active involvement in the construction of their own knowledge and skills about the lesson through group discussions, brainstorming, experimentation, and interaction with teaching and learning resources and with their teachers

7.7 The summary and reflection of the chapter

The implementation of the PD workshop and the activity-based approach supported by the 5Es instructional sequence aimed to investigate the effectiveness of the PD programme in the improvement of teachers' instructional approaches and student learning and understanding of biology. Both qualitative and quantitative data collection instruments and analysis were used. Guskey's (2000) five levels of evaluation of teachers' PD (table 7.1) guided data analysis at different stages of implementation and evaluation. The chapter comprises four main sections; the preliminary procedures prior to implementation of the PD programme implementation of the PD workshop, implementation of the new approaches in schools, and impact of the new approaches to teachers and students.

Findings of students' pre-test attitude questionnaire show that 67% of 115 students indicated undecided about whether they liked or not liked biology as a subject (Table 7.3 statement No. v). The majority of students indicated that they were not familiar with practical activities (Table 7.3 statements No. x - xiii).

Findings of pre-intervention classroom observations show that the observed lessons did not match with the proposed 5Es instructional sequence but had a more traditional lesson format with introduction, presentation, and concluding stages. With this approach the lessons were dominated by teachers' explanations of the lesson facts and skills, while students remained passive recipients with the main activity of copying notes from their teachers (Appendix C4a).

Findings of the workshop evaluation questionnaire show that teachers viewed the PD workshop relevant to their teaching practices and were satisfied with the fact that the PD workshop met their expectations (Mode = 4). Teachers' understanding of the new approaches was enhanced due to their active involvement in the workshop activities such as discussions, demonstration, practice and feedback. In particular, teachers indicated that their confidence was improved, this encouraged them to try-out the new approaches in their schools after studying the curriculum materials and participating in the micro-teaching sessions.

The implementation of the new approaches in the school 1and 2 was supported by the school-based coaching sessions with individual teachers on a one-to-one-basis. Findings of the school follow-up questionnaire indicate that teachers' confidence in the adoption of the new approaches was enhanced through participation and reflections from the technical coaching and peer collaboration practices.

The extent of school and peer support was fairly similar in both schools 1 and 2. Findings of the school support questionnaire and teachers' focus group discussions reveal that the school leadership encourages teachers working with the new approaches and their implementation efforts were honoured by their colleagues despite the fact that the schools did not have schedules that allowed teachers to collaboratively share their professional skills.

Generally both teachers and students involved in the programme had positive experiences with the new approaches. Findings of the Level of Use interview indicate that all seven teachers used the new approaches with varying quality and degrees of effectiveness. The majority of teachers were in Level of Use 4 (i.e. 3 teachers in level 4A – *Routine*, and 2 teachers in level - 4B *Refinement*), one teacher in Level of Use 3- *Mechanical*, and one teacher in level 5- *Integration*.

Findings of classroom observations indicate that teachers' profile practice scores were satisfactory in all stages of the lesson. The descriptive analyses of teachers' instructional practices revealed that the improvements in teachers' classroom practices were the result of their involvement in the PD experience. These findings further revealed that the adoption of the new approaches by teachers in schools 1 and 2 stimulated active learning environments for students. It also fosters cooperative learning among students as well as development of students' lesson interests.

Findings of the teachers' reflective interview show that their opinions about the adoption of the new approaches were positive. The new approaches enhanced their pedagogical knowledge as well as practical skills. For example, using short activities to introduce a lesson and identification of students' prior ideas and conceptions, and using them to plan lesson activities which engaged students in the construction of their own knowledge as well as creating student interest were regarded by teachers' as major achievements. In this study these activities were implemented with the help of the 5Es instructional sequence which played a vital role in supporting students' sequential learning that bridge prior experiences to the new concepts and enhanced conceptual understanding.

Findings of the student evaluation questionnaires and focus group discussion show that 85% (123) of the students experienced the activity-based lessons positively. Students appreciated the opportunity to participate in the understanding of their lessons through: discussion, observations, field study, experimentation, and brainstorming. Similarly, 70% (102) of the students indicated that the new approaches led to increased confidence in doing practical work and increased communication skills among them and with their teachers.
Results of the achievement test show that students who studied the topic '*classification of living things'* through the new approaches had gained a higher understanding of the topic than students who studied the same topic by regular traditional lecture-style methods. Findings of post-test students' attitude questionnaires indicate a positive change of students' attitudes toward learning biology through activity-based approaches. These findings were supported by the teachers' reflective interview and classroom observations.

Chapter 8

Discussion and conclusions

8.1 Introduction and summary of the study

This chapter presents a discussion of the findings and conclusions of the study. Section 8.2 discusses the main findings of the study. Section 8.3 presents the conclusions and implications of the study. Section 8.4 describes the contribution of the study to theory and practice. Section 8.5 presents limitations of the study. Section 8.6 outlines recommendations for improvement of science teaching and learning in Tanzania and future work. Section 8.7 presents a final reflection on the study.

Teaching and learning of science in Tanzanian secondary schools has been viewed as ineffective and not matching the advancements in the scientific development and complexities as advocated by science education reformers (Mushashu, 2000; Tillya, 2004). A number of studies have consistently reported that the dominant method of teaching and learning of science is using the lecture-style approach (Bathlomew, 2008; Chonjo & Welford, 2001; Mafumiko, 2006; Osaki, 2007). A report by the Secondary Education Development Programme (SEDP) confirmed an acute shortage of qualified teachers in secondary schools who can provide quality education (MOEVT, 2010). In-service programmes are considered necessary not only to support teachers in acquiring new instructional approaches, but also to improve the basic quality of teachers since many schools are staffed by unqualified and under qualified teachers (Kitta, 2004; Mafumiko, 2006). Even those with formal qualifications commonly have problems in their teaching due to inadequate preparation during their pre-service education in teacher training colleges, and limited access to regular in-service-training (Kitta, 2004). Furthermore, most Diploma Teacher Colleges continue enrolling students with a weak background in the subjects they teach which contributes to poor student achievement (Babyegeya, 2006; Meena, 2009). This situation is different from practices in developed countries like the

United Kingdom whereby the colleges enrol students with a strong background in the subjects they teach, together with a good linguistic and verbal ability which can exert a more significant impact on student learning outcomes (Maringe, 2005). Therefore, what is regarded as effective pedagogical practices in more developed countries may be new, or not practiced by teachers in developing countries such as Tanzania.

Research findings from cognitive science and science education on learning reiterate the thought that students construct knowledge through active participation in the learning process (Ahn & Class, 2011; Bransford, Brown & Cocking, 1999; Olsen, 2001; Rudolph, 2005). It is within this context that this study was initiated.

The study was guided by three research questions:

1) What are the characteristics of an effective professional development programme that adequately supports learning and teaching of biology in Tanzania?
2) How can a professional development programme be practically designed and implemented to enhance Tanzanian biology teachers' pedagogical knowledge and skills?
3) What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?

The theoretical part of the study focused on a constructivist approach to learning, and the knowledge base for designing curriculum materials and teachers' professional development (PD). The overall research and design activities were structured within a Design-Based Research framework (Wang & Hannafin, 2005; McKenney & Reeves, 2012). This approach was adopted in order to guide implementation of research activities (Section 5.3.1) which involved both quantitative and qualitative data collection methods. The design and research activities of the study were iterative in nature and conducted in three main stages (Section 5.3.3):

i) Preliminary or front-end analysis;
ii) Design/prototyping of the teachers' support materials and PD programme;
iii) Evaluation of implementation of the PD programme.

8.2 Discussion of the main findings of the study

The discussion in this section focuses on the key findings and how they have provided answers for each research question. These findings are discussed in relation to published literature in the field.

8.2.1 Characteristics of the PD programme

This section discusses the first research question: *What are the characteristics of an effective professional development programme that adequately supports learning and teaching of biology in Tanzania?*

The context analysis and review of the literature were instrumental in the design of the PD programme of the study. The programme incorporated components such as: a PD workshop, curriculum materials, school follow-up coaching, and a supportive school environment (Section 4.6.2). These components supported teachers' learning and implementation of the intended improvements (i.e. activity-based approach and the 5Es instructional sequence) in Tanzanian secondary schools. The main characteristics of the PD of the study are described below.

8.2.1.1 Content focus

Borko and Putnam (1996), Cohen and Hill (2001), and Kennedy (1998), emphasised that professional learning is most likely to improve student learning outcomes if it increases teachers' understanding of the subject content they teach, how students learn that content, and how to represent and convey that content in meaningful ways. In this study the PD experience integrated the curriculum materials which provided the content in the form of activity-based biology lessons (Appendix A2), and the teaching procedures (structural specifications) with the specific intention to provide teachers with the pedagogical support for the lesson content, planning, execution, and assessment of student learning (Section 6.2.2). Findings of the study (Sections 7.5.2.1 and 7.5.4) indicate that teachers appreciated the content of the curriculum materials, (e.g. the 5Es instructional sequence) because it provided them with step-by-step procedures to follow when planning and executing activity-based lessons. The 5Es instructional sequence (*excitement, exploration, explanation*, *elaboration and evaluation*) required teachers to start their instructions by using exciting activities which elicits and challenges students' prior experiences and created lesson interests before teachers moved to the *exploration* stage, which allowed students to test their ideas and hypotheses through hands-on activities for conceptual change.

8.2.1.2 Active participation of teachers

Effective PD provides opportunities for active learning and draws teachers into an analysis of their current practice in relation to professional standards for good practice (Birman *et al.,* 2000; Garet *et al.,* 2001; Ingvarson, Meiers, & Beavis, 2005). In this study the activities in the two day workshop (Table 7.5) provided teachers with opportunities to:

- Participate in discussion and reflection on their teaching methods and how these were related to student learning;
- Observe the teaching of the activity-based lessons;
- Practice lesson planning and teaching guided by the 5Es instructional sequence in the micro-teaching set-up;
- Participate in reflections to examine their new practices.

Teachers' participation in these activities increased their understanding of the new knowledge and skills about instructional methods which enhanced the development of local instructional theories to support the adoption of the innovation (new approaches) as part of their teaching practice (Section 7.3.1.3).

8.2.1.3 Activities coherent with the context

The content of the PD, i.e. curriculum materials (Appendix A2) was developed to support teaching and learning of biology by using the existing biology curriculum. The activity-based lessons fitted with the school and teacher's timetable and were carried out within the normal lesson time. Similarly, the 5Es instructional sequence was integrated into the existing teachers' lesson planning format. This made the intervention compatible with the schedules of the schools and teachers. According to Garet *et al.,* (2001) locating PD within teachers' day-to-day practices helps them to link ideas from the workshop to their teaching. In this research such activities had a positive influence on changing teachers' instructional practices and enhancing their pedagogical knowledge and skills.

8.2.1.4 Sustainability of activities

Professional development that is spread over a reasonable time, (i.e. at least 75-100 hours) is more likely to contain the kind of learning opportunities necessary for teachers to put new knowledge and skills into practice (Desimone *et al.,* 2002). In this study the implementation of new approaches in schools took four months (a school term). This duration was important because it provided teachers with opportunities for in-depth discussion and reflection on the implementation of the new approaches in their classrooms. Likewise, the integration of the peer/collegiate coaching component in the teachers' PD (Section 7.4.2) was meant for teachers to continually support each other as they worked with the new approaches

8.2.1.5 Collective participation

According to Cordingley *et al.,* (2005a) collaborative activities lead to greater teacher confidence, improved self-efficacy (with teachers feeling that they are able to make a difference to students' learning), an openness to new ideas, and changing practice, and greater enthusiasm for collaborative working including an opportunity for reassurance when teachers are faced with problems and issues of concern.

The PD programme in this study fostered collaboration with different stakeholders such as experts, teachers, and students. This collaboration provided opportunities for discussion about the design, content, delivery, and challenges during the development stages and implementation of the new approaches in schools (Sections 6.3 and 6.6). Collaboration at these stages enhanced the researcher's knowledge and skills in designing the PD programme and materials, and on specific strategies to support teachers' learning during the PD programme and implementation of the new approaches in schools. Findings of the study show that the technical coaching and peer collaboration which were promoted by the PD programme enhanced teachers' pedagogical content knowledge and skills (Sections 7.4.4 and 7.5.1.2). Teachers in the biology departments collaboratively discussed their experiences and challenges/problems faced during implementation of the new approaches in their classrooms and reflected on possible solutions (Section 7.5.1.2).

8.2.1.6 Follow-up support

Arrangements were in place which ensured pedagogical support and feedback to teachers as they enacted the new approaches in their respective classrooms. Follow-up support was achieved in various ways:

First, teachers were provided with technical coaching in their initial stages of implementation in order to support the integration of the new approaches in teachers' routines (Huberman & Miles, 1984; Showers & Joyce, 1996). This took the form of classroom observation and feedback offered to individual teachers in a non-judgmental manner (Glickman, 1990).

Second, teachers participated in the peer coaching for the purpose of improving the individual practices by refining the adopted teaching and learning approaches, increasing their professional dialogue, and reflecting on their teaching. Findings of the study show that peer collaboration enhanced individual teacher's confidence in using the new teaching and learning approaches (Section 7.5.1.2).

Third, the schools where implementation of the intervention took place provided a favourable environment for teachers to implement the new teaching and learning approaches in their classrooms. This included the provision of materials, time, resources and recognition of teachers who participated in the PD by school leadership and colleagues (Sections 7.5.1.1 and 7.5.1.3). Commenting on the relevance of school support Guskey (2000: 149) asserts that:

> Many improvement efforts in education fail simply because they are unclear, or misleading about the kind of organisational support required to change… sometimes, organisations impose structural or procedural barriers to the implementation of new ideas or practices that prevent even modest levels of success.

Findings of the study indicate teachers' positive perceptions of the extent of school support in their efforts toward implementation of the new approaches. The schools' administration encouraged teachers' participation in the PD activities, and recognised their efforts to improve students' learning (Section 7.5.1.3). Joyce and Showers (2002) and Supovitz and Turner (2000) posit that having administrators' support is essential for the adoption of the new teaching practices and continued use, i.e. where leadership support and commitment is strong it is possible to implement and sustain a change over time (Meiers & Ingvarson, 2005).

On the other hand, teachers indicated in the questionnaire (Appendix C9) that the implementation of the new approaches was somewhat affected by the shortage of materials and resources (Section 7.5.1.1). Similarly, Penuel *et al.,* (2007) found that the school schedules, budgets for equipment and materials, and time for planning, and reflection are constraints that influence whether the learning gained in PD is applied to classroom teaching.

Six of the teachers asserted that their school administrations do not have schedules that allowed them to collaboratively plan and discuss their classroom practices (Table 7.13). Olson *et al.,* (1991: 23) found that interactions between teachers seem to help teachers develop a "body of technical knowledge about what teaching practices are likely to be effective". Likewise, Huberman and Miles (1984) and Smith *et al.,* (2003) held that the greater the communication between teachers, the more likely teachers were to adopt the new practice. Teaching practice is unlikely to change as a result of exposure to training, unless that training also brings with it some kind of external normative structure, a network of social relationships that personalise the structure and support interaction around the problem of practice (Elmore, 1996).

8.2.2 Design and implementation of the PD programme

The design of the PD programme was achieved through a prototyping approach and formative evaluation (Section 6.3). The activities at this stage were guided by the second research question: *How can a professional development programme be practically designed and implemented to enhance Tanzanian biology teachers' pedagogical knowledge and skills?*

Findings of the study show that valuable insights which contributed to the validity and practicality of the curriculum materials and the PD programme (Figure 6.1 and 6.2) were realised because of the iterative activities conducted during the prototyping stage. This had inputs from different people, i.e. experts, teachers, student teachers, and students.

The literature asserts that the use of external expertise in the design of teachers' PD could be a source of not only technical expertise, but as an agent of change (Cordingley *et al.,* 2003). In this study findings from experts' appraisal, provided suggestions for improvement of both the curriculum materials and the PD workshop in terms of their content and practicality in the Tanzanian context (Sections 6.3.1.1and 6.4.1).

Apart from the external expertise, advice was sought from the target users, i.e. teachers and students in order to ensure that the materials and the PD workshop outcomes could be implemented in schools. Findings of the study show that teachers played the following roles in the prototyping stage:

i) Review of the curriculum materials and providing suggestions on the content and organisation (Section 6.3.1.2); and

ii) Trialling of the curriculum materials and the PD workshop (Sections 6.3.2 and 6.4.2) and providing their experiences and criticality.

This information was used to improve the curriculum materials and the PD workshop as a part of the iterative process.

Teachers' involvement in the development of curriculum materials has proven to be favourable for both teachers and the resulting materials (Ottevanger, 2001). Teachers often help "keep it real" by being able to voice interests and concerns that are likely to be shared by others, and determining what is (or is not) feasible, in the target setting (McKenney & Reeves, 2012: 129). According to Hargreaves (1990), Rousseau (2004), and Wikeley (2005), the success of the implementation of a new curriculum at school level depends among other factors on the active involvement of teachers in the curriculum design process, their feeling of ownership, and further preparation with these teachers.

Teachers' participation in the design and trialling of the materials stimulated their awareness and exploration of the alternative instructional approaches (e.g. activity-based approaches) that can be used to improve students' understanding of their lessons. Their involvement not only contributed to the improvements of the curriculum materials and the PD workshop but also in re-designing their own practice (Section 6.3.2). Hawley and Valli (1999) held that when teachers help design their own learning they are likely to feel a greater sense of involvement in the PD experience. Teachers are more likely to use what they learn when the PD development is focused on solving problems in their particular context. Results from the prototyping approach included the improved intervention which was conceived and assembled, i.e. with successive prototypes of the desired intervention (Figure 4.3).

8.2.3 The impact of the PD on teachers' pedagogy and student learning

This section provides information that answers the third research question: *What impact does this professional development programme have on teachers' pedagogy and students' learning of biology?*

The PD workshop was designed to help teachers develop in-depth understanding of the new approaches which were made explicit in the curriculum materials (Appendix A2). The central feature of these materials was the 5Es instructional sequence which supported teachers in planning and teaching activity-based lessons in the workshop setting and later in their respective schools. The evaluation of implementation of the PD programme and its impact on teachers' pedagogy and student learning outcomes was based on Guskey's (2000) five levels of evaluating PD: teachers' reactions, teachers' learning, school support and change, teachers' use of new knowledge and skills, and student learning outcomes (Section 4.7).

8.2.3.1 The impact of the PD workshop on teachers' reactions and learning

Based on the results presented in chapter seven (Sections 7.3.1.2 and 7.3.1.3) it can be concluded that teachers in both schools 1 and 2 reacted positively towards the components and activities of the PD workshop. The workshop satisfied teachers' expectations and it was relevant to their teaching practice. Teachers declared that their involvement in the workshop activities such as discussing and reflecting their prior teaching approaches with colleagues, learning and practising the activity-based lessons, and receiving feedback about their practices contributed to their understanding of the new approaches (Section 7.3.1.2). Such findings might be expected for several reasons which included the fact that the PD workshop for this study denotes a departure from teachers' previous experiences of short and one-session PD activities in Tanzania. It involved teachers with purposeful and intensive PD activities, both in the workshop setting (Table 7.5) and school-based follow-ups in order to advance teachers' knowledge and skills about effective instructional approaches. The activities of the workshop were based on the effective in-service model of

Joyce and Showers (1998; 2002), that has strong empirical support in the literature for skills acquisition and improvement of student performance (Hawley & Valli, 1999; Loucks-Horsley *et al*., 2003).

Teachers indicated that the content of the curriculum materials, i.e. the activity-based lessons and the step-by-step instructional sequence (i.e. 5Es), were helpful in the adoption of the new approaches (Section 7.3.1.3). This confirms the findings of van Den Berg (1996) and Stronkhorst (2001) that when curriculum materials are systematically integrated into a PD workshop they can provide teachers with a successful first time experience that has a fair chance of being used in the classroom. Similarly, Borko and Putnam (1996) held that, teachers' use of curriculum materials in the classroom with their students may help to situate teachers' learning.

Teachers' acknowledgement and demonstrations of learning from the workshop activities (Table 7.8 and Section 7.3.1.3) are considered indicators of effectiveness of the PD experience. However, measuring this learning and coming up with a definitive finding is known to be extremely difficult (Clarke & Hollingsworth, 2002; Meiers & Ingvarson, 2005). The difficulty results from the context where the teachers' learning took place, which was not limited to the PD workshop only but also, the development of the curriculum materials, and the school follow-up coaching sessions. This approach is supported by Borko (2004) that teachers' learning takes place within the multiple contexts of practice including PD, their classrooms, and communities.

For this reason, the decision was made to explore the indicators of teachers' learning by triangulating teachers' self-reported statements (from the open-ended questionnaires) with a demonstration of their learning in the micro-teaching sessions, and from classroom observations. Results from the micro-teaching sessions and classroom observations demonstrated the extent of teachers' understanding of the new approaches (Section 7.3.1.5 and Table 7.10). Similarly, teachers' lesson preparation, i.e. lesson plans and organisation of students' lesson activities indicated that they had followed the 5Es instructional sequence, for example, the two teachers who were involved in the micro-teaching sessions started their lessons by explicitly eliciting students' prior ideas and conceptions by using short activities which created student lesson attention and interests (Section 7.5.3.1). Based on students' prior experiences, teachers engaged students in hands-on activities to test their ideas and hypotheses. Therefore, it can be concluded that there was a concurrence of findings between teachers' perceived knowledge and skills (indicated in their lesson plans), the learning demonstrated by the teachers in the workshop setting and actual classroom observations.

These findings concur with what has been suggested by Garet *et al.,* (2001) that, PD experiences aimed at deepening teachers' content knowledge, pedagogical content knowledge, and integrating them into the daily life of the school are related to teachers' perceptions of enhanced knowledge and skills. More specifically, these initial indicators of teachers' learning are consistent with Joyce and Showers (2002), who showed that a systematic combination of the five training components (i.e. theory exploration, practice, demonstration, feedback, and coaching) leads to effective learning about an intended change and its transfer into classroom practices. In the current study, teachers learned how the 5Es instructional sequence can support effective planning and teaching of the activity-based lessons.

8.2.3.2 Teachers' Levels of Use of the new knowledge and skills

Findings of the post- intervention classroom observations (Appendix C4d) which were triangulated with teachers' reflective interviews, student evaluation questionnaires, and focus group discussions indicate that all seven teachers had used the new approaches to different extents and with varying quality (Table 7.16 and Section 7.5.3.2). These findings support the analysis of the post-intervention teachers' instructional practices which revealed that teachers had substituted active and activity-based approaches guided by the 5Es instructional sequence (Appendix C4d) for the traditional instructional methods demonstrated during pre-intervention classroom observations (Section 7.2.2 and Appendix C4a).

Although there are strong indications that the intervention has resulted in changes in practice, it should be acknowledged that there may be alternative explanations for the observed instructional behaviours. For example, a closer analysis of the findings of classroom observations showed that practice differed between the teachers during the implementation of the new approaches in their respective classrooms. Results of the Level of Use interview indicate that teachers in both schools 1 and 2 were performing at three of the six levels (Section 7.5.2.1), i.e. *mechanical, routine and refinement and integration* with five of seven teachers at level four, i.e. three teachers at *routine* (level 4A), and two teachers at *refinement* (level 4B). According to Guskey (2002) the Levels of Use of the new knowledge and skills are directly related to the depth of participants' own knowledge and skill level. Therefore, individuals at higher and more complex Levels of Use typically have a more comprehensive understanding of the change or innovation.

These results are also consistent with the PD literature on how teachers change as a result of PD activity. Change takes time and can be a complex and highly personal process (Clarke & Hollingsworth, 2002; Fullan, 2001; Guskey, 2002; Hall & Hord, 2001). According to Borko (2004) some teachers change more than others through participation in the PD.

In this study this was apparent from the different individual concerns at the start of school-based follow-up coaching where teachers showed unfamiliarity with, or were not clear about the new approaches. Similarly, findings of post-intervention classroom observations show that teacher T3 had lower profile practice scores than the other teachers (Section 7.5.2.1 and Table 7.16).

The literature supports these findings by indicating that teachers change in different ways as a result of participating in PD, and that multiple factors influence the type and amount of change teachers' experience (Clarke & Hollingsworth, 2002; Smith, *et al.,* 2003). Apart from school support, PD programmes, and working conditions, teachers' change as a result of PD (as is the case in this study) may be attributed to what Smith, *et al.,* (2003) called 'individual' factors. These factors included teachers' concern about their instructional practices, teachers' self-efficacy, teachers' cognitive styles or ways of knowing and teachers' formal education and years of experience.

For example, findings of the context analysis (Section 2.6.2) show that initial formal teacher education did not provide teachers with sufficient knowledge and skills about teaching and learning of their respective subjects. Similarly, findings (Section 7.5.1.1) show that three teachers had never attended any PD experience and were therefore provided with remedial support during the school-based coaching. These background factors including the nature of the topics taught by the individual teacher's (Appendix C4d) might have affected individual teacher's uptake of the new approaches (although these were not investigated as they were beyond the scope of this study). This is because over time, in the context of their classroom work, teachers construct "personal practical knowledge", i.e. an integrated set of knowledge, conceptions, beliefs, and values which greatly influence their practice and how they respond to educational change (van Driel *et al*., 2001: 141).

Similarly, Clarke-Hollingsworth's (2002) model of teacher professional growth suggests that teachers' change as a result of PD occurs through four distinct domains, these are:

i) The personal domains – teachers' knowledge, beliefs and attitudes;
ii) The domain of practice – professional experimentations;
iii) The domain of consequences – improved student outcomes;
iv) External domain – sources of information, stimulus or support.

Based on this model the specific domain will be determined by the change 'type', i.e. where experimentation with a new teaching strategy would reside in the domain of practice, the new knowledge or beliefs would be located in the personal domain. For Clarke and Hollingsworth (2002), 'reflection' and 'enactment' are the mediating processes by which change in one domain leads to change in another.

Findings of the study (Section 7.5.1.2) show that teachers' participation in the peer meetings and collaborative activities i.e. co-lesson planning, classroom observation and preparation of the teaching and learning materials increased their professional dialogue and reflection on practices which contribute to the teacher's professional growth.

8.2.3.3 Impact of teachers' adoption of the new approaches on student learning outcomes

The study used an achievement test, students' attitude questionnaire, teachers' reflective interviews, and students' focus group interviews to investigate student learning and understanding of biology in the aspects of cognitive and affective outcomes. The use of different instruments is supported by Meiers and Ingvarson (2005) who found that it is difficult to identify aspects of the PD programme that might have contributed to the improvement of student learning outcomes unless several measures are used. They argued that the use of evidence from different measures (qualitative and quantitative) over time, could reasonably link student outcomes to the PD experience.

Results of the achievement test show that the students in the experimental schools' scored more highly than their counterparts on the topic of '*classification of living things'*, i.e. there was a statistically significant difference in the mean scores between the two groups (Table 7.20). While there could be other factors that contributed to this results such as students social background, initial levels of attainment and intrinsic motivation (which are beyond the scope of the present study) the experimental school teachers' adoption of the new approaches seem to have positively influenced students' understanding of this topic compared to teachers in the control schools who used the traditional lecture-like methods.

This is supported by findings of teachers' reflective interviews, student evaluation questionnaires and students' focus group discussions (Sections 7.5.4 and 7.5.5) which show that the instructional practices demonstrated by teachers in schools 1 and 2 were different from their previous practices, (i.e. lecture-like methods) and students were involved in the lesson activities.

Findings of students' attitude questionnaire show that students started developing a positive attitude towards biology as a subject as well as the new approaches adopted by their teachers. The analysis of students' pre-test and post-test attitudes (N = 115) through

Wilcoxon Signed Rank Test (Table 7.20) showed a statistically significant increase in students' attitudes towards biology which might be attributed to the impact of the adoption of the new approaches by their teachers. The qualitative data from teachers' reflective interviews and classroom observations also provided evidence of changes in student learning outcomes (Section 7.6.3). For example, explaining how students were enthusiastic and proud of their involvement in the lesson activities, teacher T5 held:

> *Most of the students in my class liked the methods I used….especially when carrying out experiments and observations …you can see how they asked questions or challenged their fellow students' presentation or investigations.*

Findings of students' focus groups discussions about their biology teachers' adoption of the activity-based approaches were positive (Section 7.5.5.1). They expressed that their teachers were open to questions, and supportive, during biology lessons, which gave them confidence to express their ideas more freely than in their regular classes (Section 7.5.5.1). Given such positive perceptions, it is evident that teachers' adoption of the activity-based approach enhanced students' motivation and interest in the learning of biology. This finding is consistent with the views of Bradley (2000) and Thompson and Soyibo (2002) that the use of practical activities has the potential to promote an active classroom learning environment, and that students' participation in these activities leads not only to a greater understanding but also to the greater interest in their lessons.

8.3 Conclusions and implications of the study

The study was initiated to support biology teachers integrate an activity-based approach and the 5Es instructional sequence into their lesson preparation and teaching, as one way towards improving students' involvement in the understanding of their lessons. The literature affirms that, exposing teachers to new knowledge and skills that are directly related to their day-to-day operation in their classrooms can provide opportunities to broaden their awareness of the possibilities for change, and fosters a sense that alternatives are possible (Fullan & Miles, 1992; Van Den Akker, 1998). The findings of the study have shown that the research-informed PD programme which combines a PD workshop, new curriculum materials, demonstration, practice and reflection, and follow-up coaching, has the potential to help teachers' learning and implementation of activity-based biology lessons in their classrooms.

In this study the PD programme, including development of curriculum materials was purposefully designed to alleviate the current constraints on the effective teaching and learning of science, specifically in biology. Chapter two of the study (context analysis) indicated that the dominant teaching method in science classrooms was a lecture-style which did not help students to access science as a field of fascinating phenomena, ideas, and discoveries, as perceived by scientists (Stadler, 2010). Therefore, the PD programme in this study provided biology teachers with an avenue for learning and practising effective teaching methods, i.e. activity-based teaching approaches.

The study proposed the 5Es instructional sequence to provide pedagogical support to teachers in lesson content, planning, execution, and assessment when implementing the constructivist activity based approaches. The remarkable feature in this framework, and mostly significant to Tanzanian teachers, and the science teaching and learning process is *'excitement'* (Section 6.2). Teachers' adoption of the *excitement* stage and subsequent stages in the 5Es instructional sequence contributed to increasing specific instructional strategies to the teachers' repertoires (Section 7.5.3.2). These strategies are considered meaningful to a teacher's classroom instructions since they move away from overly didactic practices as witnessed in the pre-intervention classroom observations (Section 7.2.2 and Appendix C4a), and gradually prepared teachers for developing capacity towards activity-based and student-centred teaching and learning approaches.

Evidence from post-intervention classroom observations (Appendix C4d), teachers' lesson plans, and the researcher's field notes (Section 7.5.3.2) indicate that the 5Es instructional sequence was supportive to teachers during the implementation of activity-based lessons. Teachers' adoption of the *excitement* stage contributed to the changes in the biology teaching and learning from their regular practices (Appendix C4a). It was revealed that when teachers started their classroom instructions by exciting students (i.e. by using short stimulating lesson activities), this not only helped to elicit students' prior ideas and conceptions, but also attracted students' attention to the lesson, and generated curiosity (Section 6.2 and Appendix C4d). Such instructional practices may help to sustain student interest in the lesson and ultimately bridge the existing gap between the teacher-centred instructional methods and student-centred and activity-based instructional methods.

The post-intervention teachers' classroom instructional practices (Appendix C4d) showed improvement from their pre-intervention classroom practices (Section 7.2.2 and Appendix C4a) in terms of:

i) Lesson planning and teaching that accommodated integration of the activity-based approaches supported by the 5Es instructional sequence;
ii) Teachers' use of the short lesson activities such as brainstorming, demonstration, observation and discussions at the starting points of their classroom instructions in order to stimulate student awareness and curiosity;
iii) Teachers' assessment of students prior experiences (via practical activities) and their use to introduce the subsequent lesson activities to enable students to acquire meaningful understanding;
iv) Teachers' use of teaching and learning materials and resources to organise students' hands-on activities that provided them with opportunities for active involvement in the development of conceptual understanding;
v) Teachers' adoption of facilitative roles, i.e. to facilitate students learning through leading discussions, asking open questions, guiding experimentations and observations, and enabling active participation of learners and engagement with ideas;
vi) Students took active roles in the learning process, i.e. through interaction with their teachers, materials and their peers.

Furthermore, the convergence of data from different sources, i.e. Level of Use interview, classroom observation checklists, teachers' reflective interviews, students' evaluation questionnaires and students' focus group discussions indicates that the observed difference in the teachers’ classroom practices (i.e. pre-intervention and post-intervention) was attributed to teachers’ involvement in the PD experience and adoption of the new approaches.

It remains to be seen whether this difference in classroom practices which had positively influenced student learning outcomes both cognitively and affectively is transient or sustainable. Borko and Putnam (1996), Guskey (2000), and Meiers and Ingvarson (2005) held that teachers must be allowed adequate time for relevant impact to take place, in order to capture the chain of impact linking changes from teaching practice brought about by PD, to changes in student learning outcomes. Furthermore, the literature suggests that a a longitudinal view of change is necessary if the impact of PD is to be judged by its impact on student learning outcomes (Meiers & Ingvarson, 2005).

The improved understanding of students in the topic of *‘classification of living things’* and the positive attitudes demonstrated by students in both schools 1 and 2 is a good sign of possible success for the future, as long as efforts are made to properly implement and maintain the innovation.

8.4 Contribution to educational theory and practice

The focus of the study was the improvement of science teaching and learning in Tanzanian secondary schools. The study designed a PD programme to enhance biology teachers’ classroom instructional practices which in turn, could help students in the learning and understanding of their lessons. Hence, the study contributed to the practice and theoretical understanding of the impact of the PD programme on teachers’ instructional practices and students' learning.

Teachers' understanding of the innovation (activity-based approach and the 5Es instructional sequence) was augmented by the design guidelines for the curriculum materials and PD programme. The design guidelines and specifications of the curriculum materials (Sections 6.2 and 6.2.2) provided teachers with the knowledge and procedures towards the intended improvements in their instructional approaches, and furthermore, they are consistent with the current Tanzanian biology curriculum.

The study adapted the 5Es instructional model Bybee (1997) as a framework to support teachers' interpretation of the constructivist activity-based approaches in their instructional practices. The aim was to support teachers with the new knowledge and skills which helped them build their instruction on what students already know and to support them through interaction with materials, peers, and their teachers in order to acquire meaningful learning. According to Timperley *et al.*, (2008) using approaches that integrate theory and practice is more effective than merely teaching theoretical constructs to teachers without helping them to translate those constructs into practice. By doing so, this study has contributed to biology teachers' pedagogical knowledge and skills which has improved teaching and learning of the participants in this study.

It was stated earlier (Sections 6.2 and 8.3) that the study used *excitement* instead of *engagement* (illustrated in Bybee's 5Es model) in order to fulfil the focus of the PD programme and the context in which changes to practice were to be used. The reason behind this adoption was due to the fact that the situation in the science teaching and learning in Tanzanian classrooms required more than the engagement of students in the lesson activities. The study capitalises on the *excitement* stage whereby students' motivation and enjoyment of learning were thought to be a prerequisite for engagement in the learning process for meaningful and sustainable learning to happen. According to Lumby (2011) there is a positive connection between achievements and enjoyment, or a successful social experience within an educational context.

Apart from looking for students' prior experience (addressed in the Bybee's *engagement* stage) this study went further, by suggesting that the use of short lesson activities such as observation, experimentation, and brainstorming at the beginning of the lesson (e.g. Appendix C4d, lessons 1, 2, 4, 5, 6 and 7) would stimulate interest and get them thinking about the concepts at hand, which in turn, could encourage students' involvement in understanding of the lesson concepts. The *excitement* stage provided opportunities for

teachers to identify students' prior knowledge including misconceptions at the beginning of their lessons (e.g. Appendix C4d, lessons 1 and 7), which according to Trigwell & Prosser (1996a) could be useful for students *exploration* activities as well as re-constructing their knowledge to produce a new world view, or conception.
In this study the outcomes of the *excitement* activities were important in the Tanzanian context where they helped teachers to plan subsequent teaching activities (for other lesson stages, i.e. *exploration*, *explanation*, *elaboration* and *evaluation*) which in turn, helped students to link the new concepts to what they already know and hence, facilitated conceptual understanding as described in the following sections.

During the *exploration* stage students had opportunities to explore questions and implement preliminary investigations based on their prior experiences. In this study, all seven teachers guided students in small groups to achieve tasks that they had not yet mastered. This was achieved by asking questions, giving prompts, and providing support during experimentation and observations (e.g. Appendix C4d, lesson 1, 4, 6, and 7). These activities helped students build a base of common experiences and through discussion and dialogue facilitated conceptual understanding (Asoko, 2002; Gabel, 2003; Treagust & Duit, 2009; Vygotsky, 1978).

The *explanation* stage provided students with opportunities to verbalise findings from their investigations and shared these with other students in the classroom. During this stage, all seven teachers took the opportunity to directly introduce the concepts, process or skills so that students utilised their prior understanding of the concepts and helped them changed any incorrect knowledge and skills (e.g. Appendix C4d, lessons 1 and 7).

Students were given the opportunity to advance their newly structured knowledge into deeper and broader understanding during *elaboration* stage in order to extend their conceptual understanding and skills. This was achieved in different ways for example, teachers T1 and T3 used question and answer techniques (Appendix C4d, lessons 1 and 3); teachers T4, T5 and T7 provided their students with alternative practical activities

(Appendix C4d, lessons 4, 5 and 7) which enhanced the application of the learned concepts and skills to new contexts including the world around them.

The *evaluation* stage was where students' comprehension and abilities were assessed and thereby teachers were able to monitor how their students had progressed in the understanding of the concepts or skills. In this study six of the teachers used different techniques such as asking open questions that allowed students to demonstrate the specific knowledge and skills acquired during the lesson (e.g. Appendix C4, lessons 1, 2 and 4); encouraging students to provide explanations of the specific concepts and skills asked by their classmates in order to share their experiences and reflect on the learned concepts (e.g. Appendix C4d, lessons 5 and 7) and, observation and assessment of students' practical activities, i.e. experimentation (e.g. Appendix C4d, lesson 6).

Hodson (2000) and Osborne & Dillon (2008) suggest that this kind of a lesson presentation will provide students with opportunities for cumulative development of understanding of scientific concepts and interests. It would appear that 5Es instructional sequence provided the sequential teaching and learning needed to bridge students' prior knowledge and their acquisition of new concepts and skills.

Furthermore, findings of the study (Section 7.5.3.2) demonstrated that the 5Es instructional sequence provided teachers and students with step-by-step procedures to practice the principles of effective science teaching and learning in classroom settings which reflects constructivist teaching and learning approaches. The activity-based approaches embedded in the 5Es instructional sequence catered to the changing roles of the teachers from mere transmitters to facilitators of knowledge. Students were actively engaged in the lessons and this supported their learning without the requirement to memorise the facts.

The study also contributed to improved practice through the design and implementation of the PD programme which supported teachers' enactment of the activity-based approach supported by the 5Es instructional sequence. The important role of curriculum materials as a component of successful PD experience has re-confirmed findings from other studies conducted in Sub-Saharan African countries (i.e. Mafumiko, 2006; Ottevanger, 2001; Teclai, 2006; Tillya, 2003).

Embedding curriculum materials in the teachers' PD enhanced teachers' understanding of the proposed innovation (Section 7.3.1.3). Furthermore, the PD experience provided teachers with opportunities to interact with curriculum materials, e.g. by providing a forum in the micro-teaching set-up for clarification of the theory, demonstration, and practice of the intended improvements. For example, findings of the study show that teachers' profile practice scores in the *excitement* stage obtained during micro-teaching sessions of the PD workshop (Table 7.10) were higher than the previous try-out stage without the PD workshop (Table 6.6).

Other components of the PD programme which made it effective for teachers' learning and implementation in schools included shared development of curriculum materials, school-based coaching, school and collegiate support. Teachers' participation in these activities strengthened feelings of ownership of the intervention, and this contributed to the success of the teachers' PD.

The study generated five design guidelines, which describe how an innovative intervention can lead to improvement of the current instructional practices in Tanzanian secondary school context. The guidelines (shown below) are grounded in a theoretical body of knowledge with regard to effective PD experience:

i) The PD experience should be built and nurtured on the principles of effective, adult learning, students' learning, and the change process that pertains to implementing the activity-based approach supported by the 5Es instructional sequence. The components in the Joyce and Showers (2002) training model (fig 4.2) will provide a constructivist environment for teachers to learn and practice the new knowledge and skills;

ii) The PD workshop should focus on developing awareness and augmenting teachers' pedagogical knowledge and skills, fostering the transformation of this knowledge and skills into practice and providing teachers with opportunities to reflect on their learning and the practice;

iii) The curriculum materials that have undergone a cyclical and iterative design and formative evaluation should be embedded in the PD process. These materials will support teachers' learning and practice in the activity-based lessons at the workshop site and later in their respective schools;

iv) The school-based follow-up coaching and curriculum materials should give teachers the necessary guidance and support to implement activity-based lessons. The coaching activities will focus on assisting teachers in transferring the workshop learning into actual classroom practices. These activities will be flexible enough to accommodate individual teachers' concerns and will consider issues of a non-judgmental manner (Section 7.4.1.1);

v) There will be a mechanism in place to systematically assess the quality of the overall PD process. Evaluation of the PD process will involve gathering and analysing evidence concerning: teachers' reactions, teachers' learning, school and collegiate support, teachers' use of new knowledge and skills, and student learning outcomes (Guskey, 2000).

According to Van Den Akker *et al.*, (2006), guidelines generated from the design and research activities should not be regarded as 'recipes' for success, but to help others select and apply the most appropriate substantive and procedural knowledge of specific design and development tasks in their own settings.

8.4.1 Methodological contribution

This research has provided insights on how innovative intervention can be designed and enacted to support teachers' learning and practice. The study was carried out within the framework of Design-Based Research (DBR). This approach was chosen because it allowed the realisation of small-scale examples of interventions and the generation of methodological guidelines for the design and evaluation of such interventions (Van Den

Akker *et al.,* 2006). In this study the DBR approach provided flexibility in developing the PD programme stage-by-stage within the problem context:

- The preliminary analysis which included problem identification, diagnosis and initial identification of the design requirements (Chapters 2, 3 and 4);
- The design and empirical testing which took place through a prototyping approach (Chapter 6);
- An evaluation of the implementation of the new approaches in schools (Chapter 7).

These stages are summarised in Chapter 1, Figure 1.1.

The DBR was considered useful and appropriate in the Tanzanian context because of the opportunity for designing an intervention that had local relevance. Furthermore, it provided an opportunity for a better understanding of local implementation conditions and the difficulties teachers might experience in the implementation process, which are important for future improvement of the intervention. The study employed both qualitative and quantitative methods to allow the researcher to develop in-depth analysis and interpretation of the findings (e.g. Chapter 7) which contributed to their validity and credibility. However, the DBR does bring with it methodological problems, and dilemmas as discussed below.

8.4.1.1 The researcher's multiple roles

One of the benefits of the DBR was to stimulate the researcher to learn and perform a number of new roles. In the development of curriculum materials and teachers' PD programme the researcher also acted as the designer, facilitator, and evaluator. Combining the four roles has been rewarding, and at times, challenging for keeping an objective distance from the subject and data gathered. The researcher benefitted from fine tuning the skills related to designing the curriculum materials and teachers' PD, and a broadened understanding of their implementation. Through DBR it was possible to collaborate with experts' and users' during the development stages in order to make the research open to professional scrutiny and critique by other people and thus was instrumental in developing and improving the intervention. In this aspect, there may be increased chances of interpretation bias, i.e. the designer may have neglected the teachers' perspectives and students' comments, which could have further improved the quality of prototypes. To address this, several checks and balances were built into the research process:

- The study employed triangulation of methods, data sources, and repetition of analyses across the cycles of enactment in order to connect processes of enactment to outcomes of interest. Triangulation worked on the premise that the weaknesses in each single data source, method, evaluator, theory, data type , and analysis technique, will be compensated by counterbalancing the strength of another (Miles & Huberman, 1994: Patton, 1990);
- Data collection for research questions 2 and 3, were guided by theoretical frameworks (Table 6.4 and 7.2) based on an extensive analysis of relevant state-of-the-art knowledge, and the design and research activities;
- The design and research procedures were documented and made transparent as much as possible in order to provide critical evidence throughout the research activities for claims about why outcomes occurred (Yin, 1994).

On the other hand, teachers and students may have reacted differently in favour of the researcher, i.e. being the designer of the intervention and observer of how teachers and students were implementing the new approaches in their classrooms could have positively influenced teachers' classroom performance due to the Hawthorne effect (Krathworhl, 1998; Patton, 2002). In this study the Hawthorne effect was reduced by using an assistant researcher in the field implementation stage, and encouraging an atmosphere whereby teachers were continually invited to exercise their discretion and openly/freely express their opinions.

8.5 Limitations of the study

One of the methodological concerns of the research conducted in the naturalistic setting is the generalisation of findings (Walker, 1992). That is, the extent to which the findings are transferable from the situation being studied to others (Lincoln & Guba, 1985). The findings of this study may be generalised to other settings, but in order to increase the 'adaptability' of the findings in the new settings, guidance on how to apply those findings is also required (Wang & Hannafin, 2005: 12). For example, what has been provided (p 216-217).

One other challenge experienced with a DBR approach is determining the most relevant indicators of quality, success, and the impact of interventions. For this challenge the findings of the study demonstrated that Guskey's (2000) model of evaluating PD offers the framework of determining critical indicators of the impact of PD along its five levels (Table 7.1). This framework appears to work in the context of this study and builds on research findings which support the research methods used.

The use of the control school teachers in this study was thought to strengthen the evidence of teachers' improvement of classroom instructional practices, i.e. to what extent the classroom practices demonstrated by the seven teachers from schools 1 and 2 differed from teachers' practices in the other schools at present time. However, this comparison was not possible because the classroom observation checklist (Appendix C4) was not a feasible tool to measure the classroom practices of control school teachers' classroom practices (see Section 7.2.2).

It should be noted that executing the new approaches in schools was a challenging experience for the researcher and the participants due to the fact that the implementation process took place in a socially complex environment with a number of multiple variables. For example, time was an obstacle for teachers' in-depth planning and organisation of students' lesson activities. This is because the participating teachers were teaching other subjects apart from biology and most of them had heavy teaching loads due to the shortage of science teachers in their schools (Table 7.4). Likewise, having many students in the classroom, often over 50, (e.g. School 2) and a shortage of laboratory equipment was challenging to effectively implement the activity-based approaches for teachers and students and these factors might have contributed to individual teacher's differences in the amount and quality of instructional practices demonstrated during post-intervention classroom observations (Appendix C4d and Table 7.16).

Furthermore, teachers who had not attended any PD prior to this study (Section 7.3.1.1) required remedial support during the school-based coaching in order to manage the pedagogical and management-related challenges in their classrooms.

Findings of the study (Sections 7.5.2.1, 7.5.3.1 and 7.5.3.2) show that all seven teachers implemented the proposed innovation in their respective classrooms, but differed in the amount and quality of their instructional practices. Apart from the abovementioned challenges these differences could be associated with the nature of the topics taught by the teachers (Appendix C4d) and the extent to which the teachers had adopted the different stages of the 5Es instructional sequence which guided their instructional practices. This kind of association was beyond the scope of the present study and could be the basis for the further study in order to develop this research.

8.6 Recommendations for improvement of science teaching and learning in Tanzanian secondary schools

This study was conducted at a time in Tanzania when there was a national concern about high levels of failure in science subjects based on final national examination results (Section 2.5.1). Therefore, conducting this research was one of attempts to investigate solutions that may contribute to the improvement of science teaching and learning in Tanzanian O-Level secondary schools. Findings from this study are therefore relevant to the Tanzanian context, specifically for improving biology education in O-Level secondary schools. The study therefore puts forward the following recommendations:

i) The study recommends that science teachers, teacher educators, and curriculum developers in Tanzania should emphasise effective lesson planning to ensure positive effects on student learning to happen. It will be difficult for teachers to adopt any effective science teaching and learning approach if no measures are taken to change the existing traditional lesson planning and teaching styles, which does not encourage the elicitation of students' prior knowledge for teachers to use to support and engage them so that they become motivated to learn. This will help to improve students' conceptual understanding by helping to eliminate misconceptions and thus encourage students' achievement in biology. Apart from teachers' PD (which is rare in Tanzania), effective lesson planning and teaching should be emphasised in the science teaching method courses offered to secondary school teachers;

ii) It is important that Tanzanian science teachers' in-service providers such as the Ministry of Education and Vocational Training, and Regional and Districts Educational officers, are aware of the features that constitute effective PD. Elements such as active participation of teachers, activities which are sustained overtime, school-based PD, collaboration among the PD providers, teachers, and students, and follow-up support are important when designing a PD programme for teachers (Joyce & Showers, 2002; Garet *et al.,* 2001);

iii) The PD of science teachers should be based on their identified needs which are linked to current curriculum and teachers' classroom practices. Findings of the study suggested that a clear understanding of context, realistic understanding of needs of teachers, and students, and appropriate theoretical literature should inform the design and implementation of effective PD of science teaching.

iv) Teachers' support remains critical for successive implementation of innovation (Joyce & Showers, 2002, Putnam & Borko, 2000). Based on the perceived benefits from teachers' involvement in the peer coaching activities during implementation of the new approaches in schools 1 and 2 (Sections 7.4.2 and 7.5.1.2), the study recommends that teachers' PD providers in Tanzania invest in this strategy as one of the on-site avenues for supporting teachers' learning and updating their instructional practices. This strategy could accommodate most of the teachers in schools. School administrations can initiate peer/collegiate coaching among teachers in one department or across departments, and arrange school settings which will provide teachers with opportunities to engage in dialogue that will encourage reconstructing their pedagogical practices to improve student learning.

According to Showers and Joyce (1996) and Wenger (1998) these activities may promote a culture of collaboration and professionalism among teachers. Similarly, studies indicate that peer coaching in schools and across schools is a powerful aid for teachers' learning Jones and Webb (2006) and it may lead to sustained change in teachers' practice and ways of working with students (Cordingley *et al*., 2005a).

v) It is important for PD designers and developers of science PD in Tanzania to consider the potential of embedding the development of curriculum materials in the teachers' PD experience as this could facilitate teachers' learning and classroom enactment. Finding (Section 2.6.4) show that teachers' lack both lesson content knowledge and pedagogical knowledge and skills as a result of poor initial teacher preparation. Therefore, it is necessary to provide teachers with opportunities to be involved in developing or designing specific lesson materials according to their context in order to facilitate the implementation of the proposed innovations.

8.6.1 Recommendation for the future work

The findings of the research have provided evidence of the initial impact of the PD programme on teachers' pedagogy and student learning outcomes. These findings also complement those of Guskey (2000) and Meiers and Ingvarson (2005) who suggest that it is difficult to determine the specific aspects of PD programmes that contribute to student learning outcomes. Therefore, further research would be useful to examine the wider impact of this programme with a range of assessment measures in cognitive, affective, and psychomotor domains including the long-term impact of teachers' classroom practices and on student learning outcomes.

The findings of the study (Section 7.5.2.1 and Table 7.16) show that all seven teachers used the intervention in their respective classrooms to different extents and with varying quality for the taught topics (Appendix C4d). Further research may be needed to investigate the effectiveness of the 5Es instructional sequence in the teaching and learning on other topics of biology.

8.7 Final reflections on the study

The findings of the study demonstrate in line with other authors (e.g. Birman *et al.*, 2000; Garet *et al.*, 2001; Joyce & Showers, 2002; Kennedy, 1999; Loucks-Horsley *et al.*, 2003), that it is the characteristics of the design and approaches adopted within the PD programme that matter for effective teacher learning and improvement of student learning outcomes.

Reflection on teachers' and students' classroom practices in this study showed that the 5Es instructional sequence can be an effective framework to support Tanzanian biology teachers' transition from traditional lecture-style methods to student-centred and activity-based methods, which maximise student learning through active participation and construction of the knowledge. Therefore, it is hoped that this approach is adopted more widely in Tanzanian secondary schools, so that future students may benefit from these new pedagogies, experience success, and thus be encouraged to continue their studies of science.

References:

Abell, S. K. & Lederman, N.G. (eds.) (2007). *Handbook of Research on Science Education*. Mahwah, N.J: Lawrence Earlbaum.

Abrams, E. (1998). Talking and doing science: important elements in a teaching for understanding approach. In: J. J. Mintezes, J. H. Wandersee & J. D. Novack. (eds.) *Teaching science for understanding: a human constructivist view*. San Diego, CE: Academic Press.

Ackland, R. (1991). A review of the peer coaching literature. *The Journal of Staff Development*, 12 (1), 22–27.

Ahn, R & Class, M. (2011). Student-centred pedagogy: co-construction of knowledge through student generated mid-term test. *International Journal of teaching and Learning in Higher Education*, 23 (2), 269-281.

Akar, E. (2005). *Effectiveness of the 5E learning cycle model on students' understanding of acid-base concepts*. Master Thesis, Turkey: Middle East Technical University.

Anderson, L. W. & Krathwohl D. R .(eds.) (2001). *A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Anderson, R. D. (2002). Reforming science teaching: what research says about inquiry. *Journal of Science Teacher Education*, 13 (1), 1-12.

Armbruster, B. B. & Osborne, J. (2002). *The research building blocks for teaching children to read (K-3).* Centre for Improvement of Early Reading Achievement: University of Michigan.

Asoko, H. (2002). Developing conceptual understanding in primary science. *Cambridge Journal of Education*, 32 (2), 153-164

Ates, S. (2005). The effectiveness of the learning-cycle method on teaching DC circuits to prospective male and female science teachers. *Research in Science and Technologica Education*, 23 (2), 213-227.

Aubusson, P., Watson, K. & Brown, G. (1998). *Enhancing lower secondary science*. Penrith: University Western Sydney.

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*, New York: Grune & Stratton, Inc.

Ausubel, D. P. (1968). *Educational psychology: a cognitive view*. New York: Holt, Rinehart and Winston.

Babyegeya, E. (2006). Teacher education in Tanzania: development and prospects, *Journal of Issues and Practice in Education*, 1 (2), 32-46.

Bailey, K. D. (1992). *Methods of social research*. 2nd ed. New York: Free Press.

Baker, R. G. (2001). Classroom coaching: an emergent method of professional development.In: R. Speiser, C. Maher, & C. Walter. (eds.) *Proceedings of the Twenty-Third Annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education.* (2), 751-760.

Ball, D. L. & Cohen, D. K. (1999). Developing practice, developing practitioners: towards a practice-based theory of professional education. In: L. Darling-Hammond & G. Sykes. (eds.) *Teaching as the Learning Profession.* San Francisco: Jossey-Bass.

Ball, D. L. & Cohen, D. K. (1996). Reform by the book: what is-or might be the role of curriculum materials in teachers learning and instructional reform? *Educational Researcher*, 25 (9), 6-14.

Basista, B. & Hill, H. C. (2000). Instructional policy and classroom performance: the mathematics reform in California, *Teacher College Record*, 102 (2), 294-309.

Barab, S. & Leuhmann, A. (2003). Building sustainable science curriculum: acknowledging and accommodating local adaptation. *Science Education*, 87 (4), 454-467.

Barab, S. & Squire, K. (2004). Design based research: putting a stake in the ground. *The Journal of the Learning sciences,* 12 (1), 1-14.

Bates, A.W. (2000). *Managing technological change*. San Francisco: Jossey-Bass.

Bathlomew, L. (2008). *Implementation of problem solving in science education in Tanzania. A study of Advanced Level physics teaching in selected secondary school*s. Master Thesis. Dar es Salaam: University of Dar es Salaam.

Becker, J. M. (1996). *Peer coaching for improvement of teaching and learning*. www.teachersnetwork.org/TNPI/research/growth/becker.htm Accessed: 12 April, 2011.

Bell, B. (2004). On the theoretical breadth of design based research in education. *Educational Psychologist*, 39 (4), 243-253.

Bilgin, I. (2006). The effects of hands-on activities incorporating a cooperative learning approach on eighth grade students' science process skills and attitudes toward science. *Journal of Baltic Science Education,* 1 (9), 27-37.

Biological Sciences Curriculum Study (BSCS). (2006). *Science: an inquiry approach*. Dubuque, IA: Kendall/Hunt Publishing Company.

Bergin, D. A. (1999). Influence on classroom interest. *Educational Psychologist*, 34 (2), 87-98.

Birman, B. F., Desimone, L., Porter, A. C. & Garet, M. S. (2000). Designing the professional development that works. *Educational leadership*, 57 (8) 28-33.

Blaikie, N. (2000). *Designing social research*. Cambridge: Policy.

Borg, W.R. & Gall, M.D. (1983). *Educational research: an introduction* 4th ed. New York: Longman.

Borko, H. (2004). Professional development and teachers learning: mapping terrain. *Educational Researcher*, 33 (8), 3-15.

Borko, H. & Putnam, R.T. (1996). Learning to teach. In D. Berliner & R. Calfee. (eds.) *Handbook of Educational Psychology*. New York: Macmillan.

Bradley, J. D. (1999). Science education at the RADMASTE Centre: the role of University in development. In: S. Ware (ed.) *Science and environment education: views from developing countries*. Washington, DC: The World Bank.

Bransford, J., Brown, A., & Cocking, R. (1999). *How people learn: brain, mind, experience,and school.*Washington, DC: National Academies Press.

Bredderman, T. (1985). Laboratory programmes for elementary school science: a meta-analysis of effects of learning. *Science Education*, 69 (4), 577-591.

Brewer, M. (2000). Research design and issues of validity. In: S. Mckenney & T. Reeves, (2012). *Conducting educational design research*.London: Routledge.

Brooks, J. G. & Brooks, M. G. (1993). *In search of understanding: the case for constructivist classrooms.* Alexandria, VA: Association of Supervision and Curriculum Development.

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

Brown, J. S., Collins, A. & Duguid, (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18 (1), 32-42.

Brownstein, B. (2001). Collaboration: the education of the learning in the future. *Education*, 122 (2), 240-247.

Bryman, A. (2001). *Social research Methods*. New York: Oxford University Press.

Bryman, A. (2008). *Social research methods*. 3rd ed. New York: Oxford University Press.

Buretta, B. (2003). The status of education in Tanzania: *Paper presented at TEA/TEAA Conference*. Arusha: Tanzania.

Bybee, R. W. (1997). *Achieving science literacy: from purpose to practices*. United Kingdom: Heinemann.

Bybee, R. W. (2004). *Learning science and science of learning*: USA: National Science Teachers Association (NSTA) Press.

Bybee, W., Taylor, J., Gardner, A., Van Scotter, P., Powell, J., Westbrook, A. & Landes, N. (2006). *The BSCS 5E Instructional model: origins, effectiveness and applications*. Colorado: Hunt Publishing Company.

Cakir, M. (2008). Constructivist approaches to learning in science and their implications for science pedagogy: a literature review. *International Journal of Environmental and Science Education*, 3 (4), 193-206.

Calderon, T. G., Gabbin, A.L. & Green B. P. (1996). Summary of promoting and evaluating effective teaching. *Journal of Accounting Education*, 14 (3), 367-383.

Canella, G. S. & Reiff, J.C. (1994). Individual constructivist teacher education: teachers as empowered learner. *Teacher Education Quarterly*, 21 (3), 27-38.

Carlton, K. (2000). Teaching about heat and temperature. *Physics Education*, 35 (2), 101-105.

Carr, M., Barker, M., Bell, B., Biddulph, F., Jones, A., Kirkwood, V. & Symington, D. (1994). The constructivist paradigm and some implication for science content and pedagogy. In: P. Fensham, R. Gustone & R. White. (eds.) *The content of science*. London: Falmer.

Carr, W. & Kemmis, S. (1986). *Becoming critical: education, knowledge, and action research*. London: Routledge Falmer.

Chonjo, P., Osaki, K., Possi, M. & Mrutu P. (1996). I*mproving science education in secondary schools: a situational analysis of selected government secondary schools in Tanzania Main land*. Tanzania: Dar es Salaam.

Chonjo, P. & Welford, G. (2001). Reasons for the poor performance of students in A-Level science examinations in Tanzania. *Papers in Education and Development,* (21), 39-51.

Cimer, A. (2007). Effective teaching in science: A review of literature. *Journal of Turkish Science Education*, 4 (1), 21-44.

Clarke, D.J. & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. *Teaching and Teacher Education*, 18 (8), 947-967.

Cochran-Smith, M. & Lytle, S. (2001). Beyond certainty: taking an inquiry stance on practice. In: A. Lieberman & L. Miller. (eds.) *teachers' caught in the action: professional development that matter.* New York: Teachers College Press.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R. & Schuable, L. (2003). Design experiment in education research. *Educational researcher*, 32, (1), 9-13.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. 6th ed. New York: Routledge.

Cohen, D. & Hill, H. (2000). Instructional Policy and classroom performance: the mathematics reform in California. *Teacher College Record*, 102, (2), 294-343.

Cohen, D. & Hill, H. (2001). *Learning policy: when state education reform works*. New Haven, CT: Yale University Press.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences* 2nd ed. New Jersey: Lawrence Erlbaum.

Collins, A., Joseph, D. & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. *Journal of the Learning Sciences*, 13 (1), 15-42.

Collins, A. (1992). Toward a design science of education. In: E. Scanlon & T. O'Shea. (eds.) *New directions in educational technology*. New York: Springer-Verlag.

Collopy. R. (2003). Curriculum materials as a professional development tool. How mathematics textbooks affected two teachers learning? *The Elementary School Journal*, 103, 227-311.

Cook, T. D. & Campbell, D. T. (1979). *Quasi-experimentation: design and analysis issues for field settings.* Boston: Houghton Mifflin.

Cordingley P., Bell M., Rundell B. & Evans, D. (2003). The impact of collaborative CPD on classroom teaching and learning. *Research Evidence in Education* London: EPPI-Centre, Social Science Research Unit, Institute of Education.

Cordingley, P., Rundell, B., Temperley, J., & MvGregor, J. (2005a). *The impact of collaborative CPD on classroom teaching and learning: what does teachers' impact data tell us about collaborative CPD?* London: EPPI-Centre.

Coulson. D. (2002). *BSCS science: an inquiry approach-2002 evaluation findings*. Arnold, MC: PS International.

Creswell, J.W. & Planoclark. V. (2007). *Designing and conducting mixed methods research.* London: Sage.

Creswell, J.W. (2008). *Educational research: planning, conducting and evaluating quantitative and qualitative research*. 3rd ed. Upper Saddle River, New Jersey: Pearson Prentice Hall.

Creswell, J.W. (2009). *Research design: qualitative, quantitative, and mixed methods approaches.* 3rd ed. London: Sage.

Curriculum Cooperation. (1994). *Science - a curriculum profile for Australian schools.* Carlton, Victoria: Curriculum Cooperation.

Darling-Hammond, L. & Bransford, J. (eds.) (2005). *Preparing teachers for a changing world: what teachers should learn and be able to do*. New York: Jossey-Bass.

Davis, A. E. & Krajcik, S.J. (2005). Designing educative curriculum materials to promote teachers learning. *Educational researcher*, 34, (3), 3-14.

Deal, T. E. & Peterson, K. D. (1994). *The leadership paradox: balancing logic and artistry in schools*. San Francisco: Jossey-Bass.

Deboer, G. E. (2002). Student-centred teaching in a standards-based world: finding a sensible balance. *Science and Education*, 11 (4), 405-417.

Demert, W. & Towner, J. (2003). *A review of research literature on the influence of culturally base education on the academic performance as native American students.* Poland: Northwest Regional Education Lab.

Denzin, N. & Lincoln, Y. (2000). The discipline and practice of qualitative research. In: N. Denzin & Y. Lincoln. (eds.) *Handbook of Qualitative Research*. California: Sage
.
Design-Based Research Collective. (2003). Design-based research: an emerging paradigm for educational inquiry. *Educational Researcher*, 32 (1), 5-8.

Desimone, L. M. (2009). Improving impact: studies of teachers' professional development towards better conceptualizations and measures. *Educational researcher*, 38 (3), 181-199. http.//edr.sagepub.com/cgi/content/full/38/3/181. Accessed: 4 October, 2011.

Desimone, L., Garet, M., Birman, B., Porter, A. & Yoon, K. (2002). Improving Teachers In-service professional development in mathematics and science: the role of postsecondary institutions. *Educational Policy*, 17 (5), 613-649.

Dillon, J. & Manning, A. (2010). Science teachers, science teaching: issues and challenges, In: J. Osborne & J. Dillon. (eds.) *Good practice in science teaching: what research has to say.* England: Open University Press.

diSessa, A. & Cobb, P. (2004). Ontological innovation and the role of theory in design experiments. *Journal of the Learning Sciences*, 13 (1), 77-103.

Donovan, M., Bransford, J. & Pellagrino, W. (eds.) (1999). *How people learn: bridging research and practice.*Washington, DC: National Academy Press.

Driver, R., Leach, J., Millar, R. & Scott, P. (1996) *Young People's Images of Science*. Buckingham: Open University Press.

Driver, R., Asoko, H., Leach, J., Mortimer, E. & Scott, P. (1994). Constructing scientific knowledge in classroom. *Educational Researcher,* 23 (7), 5-12.

Driver, R., Squires, A., Rushworth, P. & Wood-Robinson, V. (1994). *Making sense of secondary Science.* New York: Routledge.

Driver, R. (1989). Changing conceptions. In: P. Adey. (ed.) *Adolescent development and school science*. London: Falmer.

Driver, R. & Oldham, V. (1986). A constructivist approach to curriculum development in science. *Studies in Science education*, 13 (1), 105-122.

Duffy, T. & Jonassen, D. (1992). *Constructivism and technology of instruction: a conversation*. Hillsdale NJ: Lawrence Erlbaum Associates.

Ebrahim, A, (2004). The effects of traditional Learning and a learning cycle inquiry learning strategy on students' science achievement and attitudes towards elementary science. Kuwait: *Dissertation abstracts International*, 65 (4), 1232.

Edelson, D. C. (2002). Design research: what we learn when we engage in design. *The Journal of the Learning Sciences,* 11 (1), 105-121.

Elliott, J. (1991). *Action research for educational change*. Milton Keynes England: Open University Press.

Elmore, R., Peterson, P., & McCarthey, S. (1996). *Restructuring in the classroom: teaching, learning, & school organization.* San Fransisco: Jossey-Bass.

Ergin, I. (2012). Constructivist approach based on 5E model and usability instructional physics. *Latin-American Journal of Physics Education*, 6 (1), 14-20.

Ertmer, P. & Newby, T. (1993). Behaviourism, cognitivism, constructivism: comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, 6 (4), 50-72.

Fabiano, E. (1998). Resourcing science and technology education. In: P. Naidoo & M. Savage. (eds.) *African science and technology education into the new millennium: Practices, policy, and priorities.* Johannesburg: Juta.

Ferguson R. L. (2007). Constructivism as a research lens, In G. M. Bodner, and M. Orgill, (eds.) *Theoretical Frameworks for Research in chemistry Education.* Upper Saddle River, NJ: Prentice Hall.

Fishman, B. & Krajcik, J. (2003). What does it mean to create sustainable curriculum innovations? A commentary. *Science Education*, 87 (4), 564-573.

Fishman, B., Marx, R. W., Blumenfeld, P., Krajcik, J. & Soloway, E. (2004). Creating a framework for research on systemic technology innovations. *Journal of Learning Science*, 13 (1), 43-76.

Flick, L. B. (1993). The meaning of Hands-on Science: *Journal of Science Teacher Education*, 4 (1), 1-8.

Flick, U. (1998). *An introduction to qualitative research.* Thousand Oaks: Sage.

Fosnot, C. (1996). *Constructivism: theory, perspectives, and practice*, New York: Teachers College Press.

Fraenkel, J. R. &Wallen, N.E. (2008). *How to design and evaluate research in education.* 7th ed. New York: McGrraw-Hill.

Freedman, M. P. (1997). Relationships among laboratory instruction, attitude toward science, and achievement in scientific knowledge. *Journal of Research in Science Teaching*, 26 (2), 121-131.

Fullan, M. (2001). *Leading a culture of a change*. San Francisco: Jossey-Bass.

Fullan, M. & Miles, M. (1992). Getting reform right: what works and what doesn't, *Phi Delta Kappan*, 73 (10), 745-752.

Fullan, M. G. (1991). *The New Meaning of Educational Change*. London: Cassell Educational Limited.

Gabel, D. (2003). Enhancing the conceptual understanding of science. *Educational Horizons,* 81 (2), 70-76.

Gagne, R. M. (1985). *The conditions of learning*. 4th ed. New York: Holt, Rinehart.

Gardner, P. &Gauld, C. (1990). Labwork and students' attitudes. In: E. Hegarty-Hazel. (ed.) *The student laboratory and the science curriculum*. London: Routledge.

Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon. K. 2001. What makes professional development effective? Results from a National sample of teachers. *Journal of American Educational Research*, 38 (4), 915-945.

Gess-Newsome, J. & Lederman, G. (eds.) (1999). *Examining pedagogical content knowledge*. The Netherlands: Kluwer Academic.

Glatthorn, A. (1995). Teacher development, In: L. Anderson. (ed.) *International Encyclopaedia of Teaching and Teacher Education.* 2nd ed. London: Pergamon.

Glenn, R. E. (2001). What teachers need to be. *The Education Digest*, 67 (1), 19-21.

Glickman, C. D. (1990). Understanding instructional supervision: In: S. J. Zepeda. *Instructional supervision, applying tools and concepts*. New York: Eye on Education, Inc.

Goodlad, J. I., Klein, M. F., Tye, K. A. (1979). The domain of curriculum and their study. In: J. I. Goodlad; M. F, Klein & K. A. Tye. (eds.) *Curriculum inquiry: the study of curriculum practice.* New York: McGraw-Hill.

Goodrum, D., Hackling, M. & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools*. Canberra: Department of Education and Training and Youth Affairs.

Government of the United Republic of Tanzania (GURT) (2001a). *Teacher Education Master Plan –TEMP*. Dar es Salaam: GURT.

Government of the United Republic of Tanzania (GURT) (2001b). *Education Sector Development Programme –ESDP*. Dar es Salaam: GURT.

Gravemeijer, K. (1998). Development research as a research method. In: J. Kilpatrick & A. Steripinska. (eds.) *Mathermatics education as a research domain: A search for identity*. Dordrecht: Kluwer Academic.

Gravemeijer, K. & Cobb. P. (2006). Outline of a method for design research in mathematics education, In: J. van den Akker, K. Gravemeijer, S. McKenney & N. Nieveen. (eds.) *Educational design research*. London: Routledge.

Gray, D. E. (2004). *Doing research in the real world*. London: Sage.

Gray, D. E. (2009). *Doing research in the real world*. 2nd ed. London: Sage.

Green, G. B. & Salkind, N. J. (2008). *Using SPSS for windows and macintosh: analysing and understanding data*. 5th ed. New York: Pearson.

Greene, J. C. (2007). *Mixed methods in social inquiry*. United States of America: Jossey-Bass.

Gronlund, N. E. & Linn, R. L. (1990). *Measurements and evaluation in teaching*. 6th ed. New York: Macmillan.

Gropper, G. l. (1987). A lesson based a behavioural approach to instructional design. In: C. M. Reigeluth. (ed.) *Instructional theories in action*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Grossman, P. (1990). The making of teachers: *Teachers knowledge and teacher education.* New York: Teachers College Press.

Guba, E. G. & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In: N. K. Denzin & Y. S. Lincoln. (eds.) *Handbook of Qualitative Research*. London: Sage.

Guba, E. G. & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newsbury Park, Califonia: Sage.

Guskey, T. R. (2005). Taking a second look at accountability. *Journal of Staff Development*, 26 (1), 10-18.

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan*, 84 (10), 748-750.

Guskey, T. R. (2002). Professional development and teachers change. *Teachers and Teaching: Theory and Practice*, 8 (3), 381-391.

Guskey, T. R. & Spark, D. (2002). Linking professional development to student improvements in student learning. *Paper presented at the annual meeting of the American Educational Research Association*. New Orleans, LA.

Guskey, T. R. (2000). *Evaluating professional development*. London: Sage.

Guskey, T. R. (1986). Staff development and the process of teacher change. *Educational Researcher*, 15 (5), 5-12.

Gustafson, K. L. & Branch, R. M. 1997. Revisioning models of instructional development. *Educational Technology, Research and Development*, 45 (3), 73-89.

Hackling, M. & Prain, V. (2005). *Primary connections stage 2 research reports*. Canberra: Australian Academy of Science and Department of Education and Training.

Hall, G. E. & Hord, S. M. (2001). *Implementing change: patterns, principles, and potholes.* Boston: Allyn and Bacon.

Hand, B., Prain, V., Lawrence, C. & Yore, L.D. (1999). A writing in science framework designed to enhance science literacy. *International Journal of Science Education,* 21 (10), 1021-1035.

Hanley, S. (1994). *On constructivism*. www.inform.umd.edu/ UMS+State/UMD-Projects/MCTP/Essays/Constructivism.
Accessed: 26 February, 2010.

Hargreaves, D. H. (1994). The new professionalism: the synthesis of professional and institutional development. *Teaching and Teacher Education*, 10 (4), 423-438.

Harlen, W. (1999). *Effective teaching of science: a review of research*. Edinburgh: Scottish Council for Research in Education.

Harwell-Kee, K. (1999). Coaching. *Journal of Staff Development*, 20 (3) 28-29.

Haury, D. & Rillero, P. (1994). *Perspectives of hands-on- science teaching*: Columbus: Clearinghouse for Science, Mathematics and Environmental Education.

Hawley, W. & Valli, L. (1999). The essentials of effective professional development: a new consensus, In: L. Darling-Hammond and G. Sykes. (eds.) *Teaching as the learning profession*. San Fransisco: Jossey-Bass.

Henson, K. T. & Eller. (1999). *Educational psychology for effective teaching*. Belmont, CA: Wadsworth.

Hewson, M. G & Hewson P. W. (1998). An appropriate conception of teaching science: a view from studies of science learning, *Science Education*, 72 (5), 597-614.

Hipkins, R., Bolstad, R., Barker, M., Bell, B., Coll, R., Cooper, B., Forret, M., France, B., Haigh, M., Harlow, A. & Taylor, I. (2002). *Curriculum Learning and effective pedagogy: a literature review in science education*. Wellington: Ministry of Education.

Hoadley, C. M. (2004). Methodological alignment in design-based research. *Educational Psychologist*, 39 (4), 203-212.

Hoban, G. F. (2002). *Teacher learning for educational change*. Buckingham: Open University Press.

Hodson, D. & Hodson, J. (1998). From constructivism to social constructivism: a Vygotskian perspective on teaching and learning science. *School Science Review*, 79 (289), 33-41.

Hodson, T. A. (2000). Simulations for teaching basic life processes. *Journal of Biological Education*, 55 (6), 670-686.

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

Hongoke, C. (1997). *Educational innovation in developing countries*: *the case for unified science in Tanzania*. PhD Thesis. United Kingdom: University of Manchester.

Huberman, M. & Miles, M. (1984). *Innovation up close: how school improvement works.* New York: Plenum Press.

Ingersoll, R. & Kralik, J.M. (2004). The impact of mentoring on teacher retention: what the research says? *Research Review*. http://www.ecs.org/clearinghouse/50/36/5036.htm Accessed: 24 October, 2011.

Ingvarson, L. (2005). *Getting professional development right.* Symposium, Australian Council for Educational Research. http://www.acer.edu.au/workshops/documrnts/ingvarson.pdf Accessed: 14 October, 2011.

Ingvarson, L. (1998). Professional development a pursuit of professional standards: the standard-based professional development system. *Teaching and Teacher Education*, 14, (1), 127-140.

Ingvarson, L., Meiers, M. & Beavis, A. (2005). Factors affecting the impact of professional development progress on teachers' knowledge, practice student outcomes and efficacy. *Educational Policy Analysis Archives*, 13 (10), http://epaa.asu.edu/epaa/v13n10 Accessed: 14 October, 2011.

Jamieson, S. (2004). Likert scales: how to (ab)use them. *Medical Education*, 38 (12), 1217–1218.

Jeanpierre, B., Oberhauser, K. & Freeman, C. (2005). Characteristics of professional development that effect changes in secondary science teacher’s classroom practices: *Journal of Research in Science Teaching*, 42 (6), 668-690.

Johnson, B. & Christensen, L. (2004). *Educational research: qualitative and quantitative, and mixed approaches.* 2nd ed. Boston, MA: Allyn and Bacon.

Jonassen, D. H. (1990). Thinking technology: toward a constructivist view of instructional design. *Educational Technology, 30* (9), 32-34.

Jones, J. & Webb, M. (2006). Assessment for learning (AfL) across the school: a case study in whole school capacity building. *Paper presented at the British Educational Research Association Annual Conference*, University of Warwick.

Joyce, B. & Showers, B. (1998). *Student achievement through staff development*. 2nd ed. United States of America: Longman Inc.

Joyce, B. & Showers, B. (2002). *Student achievement through staff development*. 3rd ed. United States of America: Longman Inc.

Joyce, B., Weil, M. & Calhoun, E. (2000a). *Models of teaching*. Boston: Allyn and Bacon.

Joyce, B., Calhoun, E. & Hopkins, D. (2000b). *Models for learning: tools for teaching.* Buckingham: Open University Press.

Kelly, A. (2004). Design research in education: yes, but is it a methodological? *Journal of the Learning Sciences,* 13 (1), 115-128.

Kelly, P. & McDiarmid, G. W. (2002). Decentralisation of professional development: teachers' decisions and dilemmas. *Journal of In-service Education*, 28 (3), 409 – 425.

Kennedy, A. (2005). Models of continuing professional development CPD: a framework for analysis. *Journal of In-service Education*, 31, (2), 235-250.

Kennedy, M. (1999). Form and substance in mathematics and science professional development: *NISE Brief*, 3 (2).

Kitta, S. (2004). *Enhancing mathematics teachers' pedagogical content knowledge and skills*. PhD Thesis. University of Twente, Netherlands: Print PatnersIpskamp.

Kitwood, T. (1997). *Values in adolescent life: toward a critical description*: PhD Thesis. School of Research in Education, University of Bradford.

Knamiller, G., Osaki, K. & Kuonga, H. (1995). Tanzania teachers' understanding of the science embedded in traditional technologies. *Science and Technological Education*, 13 (2), 67-76.

Krathworhl, D. M. (1998). *Method of educational and social science research: an integrated approach.* 2nd ed. New York: Longman

Kurplus, R. & Thier, H. D. (1967). *A new look at elementary school science*. Chicago: Rand-McNally.

Kvale, S. (1994). Ten standard objections to qualitative research interviews: *Journal of Phenomenological Psychology*, 25 (1), 147-173.

Kyle, W. C., Bonnstetter, R. J. & Gadsten, T. (1988). An implementation study: An analysis of elementary students' and teachers' attitudes toward science in process-approach vs.traditional science classes. *Journal of Research in Science Teaching*, 25 (2), 103-120.

Lave, J. & Wenger, E. (1991). *Situated learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lawrenz, F., Wood, B. N., Krichoff, A., Kim, N. K. & Einsenkraft, A. (2009). Variables affecting physics achievement. *Journal of Research in Science Teaching*, 49 (5), 961-976.

Leach, J. & Scott, P. (1995). The demands of learning science concepts: issues of theory and practice, *School Science Review*, 76 (277), 47-56.

Leeuw, V. (2003). *Upgrading of science and mathematics teachers for an educational leadership role in Tanzania*. Master Thesis. Enschede: University of Twente.

Liang, L. L. & Gabel, D. (2005). Effectiveness of a constructivist approach to science instruction for prospective elementary teachers. *International Journal of Science Education*, 27 (10), 1143-1162.

Lieberman, A. & Pointer Mace, D. H. (2008). Teacher learning: the key to educational reform. *Journal of Teachers Education*, 59 (3), 226-234.

Lincoln, Y. S. & Guba, E.G. (1985). *Naturalistic Inquiry*. Newbury Park, CA: Sage.

Linn, M., Davies, E., & Bell, P. (2004). *Internet environments for science education*. London: Lawrence Erlbaum Associates.

Linn, R. L. & Miller, D. M. (2005). *Measurement and assessment in teaching*. 9th ed. United States of America: Pearson Education Inc.

Little, J. W. (1999). Organising schools for teachers learning. In: Darling-Hammond & G. Sykes. (eds.) *Teaching as the learning profession*: *Handbook of Policy and Practice*. San Francisco, CA: Jossey-Bass.

Little, J. W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*, 15 (2), 129-151.

Littledyke, M. (1998). Teaching for constructive learning. In: M. Littledyke & L. Huxford. (eds.) *Teaching the primary curriculum for constructive learning*. London: David Fulton Publishers Ltd.

Llewellyn, D. (2005). *Teaching high school science through inquiry:a case study approach.* Thousand Oaks, CA:Corwin press.

Lloyd, G. (1999). Two teachers' conceptions of a reform-oriented curriculum. Implications for mathematics teachers' development. *Journal of Mathematics Teachers Education*, 2 (2), 187-206.

Lofland, J. & Lofland, L. (1984). *Analysing social settings.* Belmont, CA: Wadsworth Publishing Company Inc.

Lord, T. (1997). A comparison between traditional and constructivist teaching in college biology. *Innovative Higher Education*, 21 (3), 197-216.

Lorsbach, A. W. & Tobin, K. (1993). Constructivism as a referent for science teaching. *NARSTNews*, 34 (3), 9-11.

Lorsbach, A.W. (2006). The learning cycle for as a tool for planning science instruction. http://www.coe.ilstu.edu/scienceed/lorsbach/257/rcy.htm Accessed: 4 July, 2011.

Loucks-Horsley, S., Hewson, P. W., Love, N. & Stiles, K. (1998). *Designing professional development for teachers of science and mathematics.* Thousand Oaks, CA: Corwin.

Loucks-Horsley, S., Love, N. K., Stiles, E., Mundry, S. & Hewson. P. W. (2003). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin.

Loucks-Horsley, S., Stiles, K. & Hewson, P. W. (1996). *Principles of effective professional development for mathematics and science education: A synthesis of standard, NISE brief*. University of Wisconsin, Madison: National Institute for Science Education.

Lumby, J. (2011). Enjoyment and learning: policy and secondary school learners' experience in England. *British Educational Research Journal*, 37 (2), 247-264.

Lumpe, A. T. & Oliver, J. S. (1991). Dimensions of hands-on science: *The American Biology Teacher*, 53 (6), 345-348.

Mafumiko, F. (2006). *Microscale experimentation as a catalysts for improving the chemistry curriculum in Tanzania*. PhD Thesis. University of Twente: Print Patners Ipskamp.

Mafumiko, F. (1998). *The role of practical work in chemistry education in Tanzania: exploration of current practices and potential alternatives*. Master Thesis. Enschede: University of Twente.

Marek, E. A., Eubanks, C.,Gallaher, T.H. (1990). Teachers' understanding and use of the learning cycle. *Journal of Research in Science Teaching*, 27 (9), 821-834.

Maringe, F. (2005). Approaches in science teacher preparation: a comparative study of England and Zimbabwe. *Education-Line*, 1-21. http://www.leeds.ac.uk/educol/documents/153570.htm. Accessed: 12 November, 2011.

Matthews, M. R. (1997). Introductory Comments on Philosophy and Constructivism in Science Education. *Science Education*, 6 (2), 5-14.

Matthews, M. (2002). Constructivism and science education: a further appraisal. *Journal of Science Education and Technology*, 11 (2), 121-134.

Maxwell, J. A. (1996). *Qualitative research design: an interactive approach*. 2nd ed. Thousand Oaks, CA: Sage.

Mayer, R. (2004). Should there be a three-strike rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59 (1), 14-19.

McCormack, A., Gore, J. & Thomas, K. (2006). Early career: teachers' professional learning. *Asian-Pacific Journal of Teachers Education*, 34, 95-113. EBSCO hot ERIC database (EJ 72902) Accessed: 24 August, 2010

McTaggart, R. (1991). *Action research: a short modern history*. Greenlong, Vic: Deakin University.

McGervey, J. D. (1995). Hands-on physics for less than a dollar per hand. *Physics Teacher*, 33 (4), 238-241.

McKenney, S. (2001). Computer-*based support for science education material developers in Africa: exploring potentials*. PhD Thesis. University of Twente, Enschede: Print Partners Ipskamp.

McKenney, S. & Reeves, T.C. (2012). *Conducting educational design research*. London: Routledge.

McNeill, K. & Krajcik, J. (2007). Scientific Explanations: Characterizing and evaluating the effects of teachers' instructional practices on students' learning. *Journal of Research in Science Teaching*, 45 (1), 53-78.

McQueen, R. & Knussen, C. (1999). *Research methods in Psychology: a practical introduction*. Europe: Prentice Hall.

McRae, D. (2003). Student learning: the starting point for starting teachers learning. *Paper presented at the Curriculum Corporation Conference*, Perth: Australia.

McRae, D., Ainsworth, G., Groves, R., Rowland, M. & Zbar, V. (2001). *Professional development 2000 Australia*. Canberra: Australian Department of Education, Training and Youth affairs.

Meena , W. E. (2009). *Curriculum innovation in teacher education: exploring conceptions among Tanzanian teacher educators.* PhD Thesis. Finland: Ȧbo Akademi University Press.

Meiers, M. & Ingvarson, L. (2005). *Investigating the links between professional development and student learning outcome.* Canberra: Australian Council for Educational Research.

Meinhard, R. (1992). *Concepts/Process-based science in the elementary schools*: Salem, OR: Oregon Department of Education.

Mertens, M. D. (1998). *Research methods in education and psychology: integrating diversity with qualitative and quantitative approaches:* Thousand Oaks: Sage.

Meyer, L. (1988). Research on implementation: what seems to work. In: S. J. Samuels & P. D. Pearson. (eds.) *Changing school reading programs* Newark, DE: International Reading Association.

Miles, M. B. & Huberman, A. M. (1994). *Qualitative data analysis: an expanded source book,* London: Sage Publications.

Millar, R. & Osborne, J. (eds.) (1998). *Beyond 2000:Science education for the future.* London: King's College.

Millar, R. (1991). *The role of processes in science education:* Philadelphia: Open University Press.

Millar, R. (2002). Thinking about practical work. In: S. Amos & R. Boohan (eds.) *Aspects of teaching secondary science: perspectives on practice,* London: Routledge Falmer.

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

Ministry of Education and Culture (MOEC). (1995)). *Education and Training Policy* (ETP). Dar es Salaam: MOEC.

Ministry of Education and Culture -MOEC. (2001). Teacher Education Master Plan (TEMP). Dar es Salaam: MOEC.

Ministry of Education and Culture-MOEC. (2002). *Secondary Education Development Plan (SEDP*). Dar es Salaam:MOEC.

Ministry of Education and Culture-MOEC. (2002). *Education II project*. Dar es Salaam : MOEC.

Ministry of Education and Culture-MOEC. (2005). *Biology syllabus for secondary schools: Form I- IV*. Dar es Salaam: Tanzania Institute of Education.

Ministry of Education and Vocational Training- MOEVT. (2010). *Secondary Education Development Plan (SEDP)*. Dar es Salaam: MOEVT.

Mintzes, J. J., Wandersee, J. H. & Novak, J. D. (1998). *Teaching science for understanding: a human constructivist view*. San Diego, CA: Academic Press.

Moore, A. (2000). *Teaching* and *learning pedagogy: curriculum and culture.* London: Routledge Falmer.

Moore, R. (2004). *Education and society: issues and explanations in the sociology of education.* Cambridge: Polity.

Morgan, D. (1996). *Planning focus groups*: Thousand Oaks. CA: Sage.

Morrison, G. R., Ross, S. M., Kemp, J. E (2001). *Designing effective instruction.* 3rd ed. New Jersey: John Wiley & Sons, Inc.

Muijs, D. & Lindsay, G. (2000). *Evaluating continuing professional development: testing Guskey's model in UK*. www.coe.fav.ed.conference/papers/Muijis%20an%20Lindsay.pdf Accessed: 24 August, 2011.

Muijs, D. (2011). *Doing quantitative research in education with SPSS.* 2nd ed. London: Sage.

Mushashu, B. (2000). The questions of quality in public secondary schools: what is to be done? In: J. Galabawa, F. Senkoro & A. Lwaitama. (eds.) *Quality of education in Tanzania: issues and experiences.* Dar es Salaam: University of Dar es Salaam.

Mushashu, B. (1997). Quality of education in public secondary schools: Major problems and solutions. *Paper presented at the conference on quality of education in Tanzania*. Arusha: Tanzania.

National Research Council (NRC) (2000). *Inquiry and the National science education standards: a guide for teachers and learning.* Washington, DC: National Academy Press.

National Staff Development Council (2001). *Standards for staff development*. http;//www.nsdc.org/educato rindex.htm Accessed: 13 October, 2011.

National Science Teachers Association (NSTA) (2009). *The Biology teachers' handbook.* USA: NSTA Press.

Neuman, W. L. (1999). *Social research methods: qualitative and quantitative,* Boston: Allyn and Bacon.

Neuman, W. L. (2000). *Basics of social research: qualitative and quantitative.* Boston: Allyn and Bacon.

Nieveen, N. (1999). Prototyping to reach Product Quality: In: J. van den Akker, R. M. Branch, K. Gustafson, N. Nieveen, & T. Plomp. (eds.) *Design approaches and tools in education and training.* London: Kluwer Academic Publishers.

Norman, D. (1982). *Learning and Memory*: New York: W.H. Freeman.

Northern Examination and Assessment Board (NEAB). (1998). *Science for public understanding (syllabus*). Harrogatte, United Kingdom: NEAB.

Novak, J. D. (1998). Learning*, creating and using knowledge: concept maps as facilitative tools in schools and corporations*. Mahwah, NJ: Lawrence Erlbaum.

Olsen, R.V. (2001). Learning about students’ knowledge and thinking in science through large-scale quantitative studies. *European Journal of Psychology*, 16 (3) 403-420.

Olson, T., Butler, J., & Olson, N. (1991). *Designing meaningful professional development: a planning tool (Field test version)*. Portland, OR: Northwest Regional Educational laboratory.

Oppenheim, A.N. (1996). *Questionnaire design, interviewing and attitude Measurement.* London: Printer Publishers Ltd.

Osaki, K. M. (1999). Science Education in Secondary Schools (SESS): *Internal project evaluation commissioned by GTZ.* Dar es Salaam: Ministry of Education and Culture.

Osaki, K. M., Ottevanger, W., Uiso, C. & Van den Akker, J.(eds.) (2002). *Science education research and teacher development in Tanzania*.Amsterdam: Vrije Universiteit Printers.

Osaki, K. M. (2007). Science and mathematics teacher preparation in Tanzania. Lessons from teacher improvement projects in Tanzania. *NUE Journal of International Cooperation*, 2, 51-64.

Osborne, J. & Freyberg, P. (1985). *Learning in science: the implications of children's science*. London: Heinemann.

Osborne, J. & Wittrock, M. (1983). Learning sciences: a generative process, *Science Education*, 67 (4), 489-508.

Osborne, J. (1996). Beyond constructivism: *Science Education* 80 (1), 53-82.

Osborne, J. (1997). Practical alternatives, *School Science Review*, 78 (285), 61-66.

Osborne, J. & Dillon, J. (2008). Science education in Europe: critical reflections. *A Report to the Nuffield Foundations*. King's College: London.

Osborne, J. & Dillon, J. (eds.) (2010). *Good practice in science teaching: what research has to say*. 2nd ed. United Kingdom: Open University Press.

Ottevanger, W. (2001). *Teacher support materials as a catalyst for science curriculum implementation in Namibia*. PhD Thesis. Enschede: University of Twente, Enschede. Print PartnersIpskamp.

Pallant, J. (2007). *SPSS Survival manual: a step-by-step guide to data analysis using SPSS version 17.* 3rd ed. England: Open University Press.

Pallant, J. (2010). *SPSS Survival manual: a step-by-step guide to data analysis using SPSS program.* 4th ed. England: Open University Press.

Parkinson, J. (2004). *Improving secondary science teaching*. London: Routledge Falmer.

Patton, M. (1990). *Qualitative evaluation and research methods.* 2nd ed. Beverly Hills, CA: Sage.

Patton, M. (2002). *Qualitative research and evaluation methods*. 3rded. London: Sage.

Penuel, W., Fishman, B., Yamaguchi, R. & Gallagher, L. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal*, 44 (4), 921-958.

Piaget, J. (1975). *The development of thought*: New York: Viking.

Porter, A. C., Desimone, L. M., Garet, M. S., Yoon, K. S., & Birman, B. F. (2000). *Does professional development change teachers practice? Results from a three year study.* Washington, DC: USA Department of Education.

Posner, G. J., Strike, K. A., Hewson, P. W. & Gertzog, W. A. (1982). Accommodation of a scientific conception: toward a theory of conceptual change, *Science Education*, 66 (2), 211-227.

Putnam, R. & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teachers learning? *Educational Researcher*, 29 (1), 4-15.

Prawat, R. S. (2000a). Dewey meets the 'Mozart of Psychology' in Moscow: The untold story. *American Educational Research Journal*, 37 (3), 663-696.

Pritchard, A. (2010). *Ways of learning: learning theories and learning styles in the classroom.* 2nd ed. London: Routledge.

Ramsey, J. (1993). Developing conceptual storylines with the learning cycle. *Journal of Elementary Science Education*, 5 (2), 1-20.

Reeves, T. C., Herrington, J. & Oliver, R. (2005). Design research: a socially responsible approach to instructional technology research in higher education. *Journal of Computing in Higher Education*, 16 (2) 97-116.

Reeves, T. C. (2000). Socially responsible educational technology research. *Educational Technology*, 40 (6), 19-28.

Remillard, J. T. (2000). Can curriculum materials support teachers learning? Two fourth-grade teachers' use of new mathematics text. *Elementary School Journal*, 100 (4), 331-350.

Richardson, V. (1997). Constructivist teaching and teacher education: theory and practice. In: V. Richardson. (ed.) *Constructivist teacher education: building new understandings*. Washington, DC: Routledge Falmer.

Richey, R. C & Klein, J. D. (2007). *Design and development research: methods, strategies, and issues*. Mahwah, NJ: Lawrence Erlbaum.

Richey, R. C., Klein, J. D. & Nelson, W. (2004). Developmental research: studies of instructional design and development. In D. Jonassen. (ed.) *Handbook of Research for Educational and Communication Technology.* 2nd ed. Mahwah, NJ: Lawrence Erlbaum.

Richey, R. C. & Nelson, W. (1996). Developmental research: In: D. Jonassen. (ed) *Handbook of Research for Educational Communications and Technology*. New York: Simon & Schuster.

Ritchie, S. M. (1998). The teacher's role in the transformation of students' understanding. *Research in Science Education*, 28 (2), 169–185.

Robson, C. (2002). *Real world research: a resource for social scientists and practitioners-researchers*. 2nd ed. United Kingdom: Blackwell.

Rogers, P. (2007). Teachers' professional learning in mathematics: an example of a change process. In: J. Watson & K. Beswick. (eds.) *Proceedings of the 30th Annual Conference of Mathematics Education Research Group of Australasia* (2) 631-640. http;//www.merga.net.au.documents/R P 582007.pdf Accessed22 April, 2012

Rosenshine, B. (1997). Advances in research on instruction. In: J.W. Lloyd, E.J. Kameenui & D. Chard. (eds.) *Issues in Educating Students with Disabilities*. Mahway, NJ: Lawrence Erlbaum.

Ross, P. H., Freeman, H. E. & Lipsey, M. W. (1999). *Evaluation: a systematic approach*. 6th ed. London: Sage.

Rousseau, C. K. (2004). Shared beliefs, conflict, and a retreat from reform: the story of a professional community of high school mathematics teachers. *Teaching and Teacher Education*, 20 (8), 83-796.

Rowe, K. R. (2003). The importance of teachers' quality as a key determinant of student' experiences and outcomes of schooling. *Paper presented to the research conference*: *Building teacher quality, what does research tells us*? Melbourne: Australian Council for Educational Research.

Rudestan, K. E. & Newton, R. R. (2001). *Surviving your dissertation: a comprehensive guide to content and process.* 2nd ed. Newbury Park, CA: Sage.

Rudolph, J. L. (2005). Inquiry, instrumentalism and the public understanding of science. *Science Education*, 89 (5), 803-821.

Russels, J. & Hollander, S. (1975). A biology attitude scale. *The American Biology Teacher*, 37 (5), 270-273.

Sarantakos, S. (2005). *Social education research*. 3rd ed. New York: Palgrave.

Saunders, M., Lewis, P. & Thornhill, A. (2000). *Research methods for business sensitive pedagogy*. London: University of Western Ontario.

Saunders, M. & Vulliamy, G. (1983). The implementation of the curricular reform: Tanzania and Papua New Guinea. *Comparative Education Review*, 27 (3), 351-373.

Saunders, W. L. (1992). The constructivist perspective: implication and teaching strategies for science. *School Science and Mathematics*, 92 (3), 136-141.

Schizya, F. (1997). Teaching and learning mathematics in Tanzania secondary schools. *A paper presented in the Symposium in Mathematics Modelling Workshop on mathematics education,* Arusha: Tanzania.

Schollum, B. & Osborne, J (1985). Relating the new to the familiar, In: J. Osborne & P. Freyberg. (eds.) *Learning in science: the implication of children's science*. Portsmouth, NH: Heinemann.

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

Schnell, T. J. (1996). Teaching and learning in classroom contexts. In: D. C. Berliner & R. Calfee. (eds.) *Handbook of Educational Psychology*. New York: Macmillan.

Schunk, D. H. (1991). *Learning theories: an educational perspective*. New York: Macmillan.

Schwarz, C., Gunckel, K., Smith, E., Covitt, B., Bae, M., Enfield, M. & Tsurusaki, B. (2008). Helping elementary pre-service teachers learn to use science curriculum materials for effective science teaching. *Science Education, 92* (2), 345-377.

Scott, P., Asoko, H., Driver, R. & Emberton, J. (1994). Working from children's ideas: planning and teaching a chemistry Topic from a constructivist perspective. In: P. Fensham, R. Gunstone & R. White. (eds.) *The content of science: a constructivist approach to its teaching and learning*. London: Falmer.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental design for generalized causal inference*. Boston: Houghton-Mifflin.

Showers, B. & Joyce, B. (1996). The evolution of peer coaching. *Educational Leadership, 53* (6), 12–16.

Shymansky, J. L., Yore, L. D. & Anderson, J. O. (2000). *A study of changes in students' science attitudes, awareness and achievement across three years as a function of the level of implementation of interactive-constructivist teaching strategies promote in a local systemic reform effort*. Arlington, VA: National Science Foundation.

Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher,* 15 (3) 4-14.

Shulman, L. S. (1987). Knowledge and teaching: foundations of the new reform. *Harvard Education Review,* 57 (1), 1-22.

Singleton, R.A. & Straits, B.C. (2005). *Approaches to social research*. 4th ed. New York: Oxford University Press.

Skamp, K. (ed.) (1998). *Teaching primary science constructively,* Sydney: Harcourt.

Smaling, A. (2003). Inductive, analogical, and communicative generalization. *International Journal of Qualitative Methods, 2* (1), 1-31.

Smith, M. R. (1981). *Learning to learn: applied theory for adults*. Chicago: Follet.

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

Smith, C., Hofer, J., Gillespie, M., Solom, M., & Rowe, K. (2003). *How teachers change: a study of professional development in adult education.* Boston: National Centre for the Study of Adult Learning and Literacy.

Sommer, B. & Sommer, R. (1997). A *practical guide to behavioural research, tools and techniques*. 4th ed. New York: Oxford University Press.

Stadler, M. (2010). Working towards European models of sustainable CPD for science teachers using international research and exchanging national experiences. *Paper presented at the International Seminar, Professional Reflections.* York: National Science Learning Centre.

Stein, M. K., Smith, M . S. & Silver, E. A. (1999). The development of professional developers: learning to assist teachers in new settings in new ways. *Harvard Educational Review,* 69 (3), 237-269.

Staver, J. R. & Small, L. (1990). Towards a clearer representation of the crisis in science education. *Journal of Research in Science Teaching*, 27 (1), 79-89.

Stohr-Hunt. P. M. (1996). An analysis of hands-on experience and science achievement. *Journal of Research in Science Teaching,* 33 (1), 101-109.

Stoll, C., de Feiter, L. & Van den Akker, J. (eds.) (1996). Improving science and mathematics teaching in southern Africa: effectiveness of interventions. *Proceedings of a Regional Conference, December 11–14, Windhoek, Namibia.* Amsterdam: VU University Press.

Strauss, A. & Corbin, J. (1998). *Basics of qualitative research*: *techniques and procedures for developing grounded theory*. 2nd ed. London: Sage Publications

Strike, K. A. & Posner, G. J. (1992). A revisionist theory of conceptual change, In: R. A Duschl & R. J Hamilton. (eds.) *Philosophy of science, cognitive science and educational theory and practice.* New York: State University of New York Press

Stronkhorst, R. (2001). *Improving science education in Swaziland: the role of in-service education*. PhD thesis. Enschede: University of Twente.

Sund, R. &Trowbridge, L. (1973). *Teaching science by inquiry in secondary School*: USA: Bell & Howell.

Supovitz, J. & Turner, H. (2000). The effects of professional development on science teaching: practices and classroom culture. *Journal Science Teachin*g, 37 (9), 963-980.

Swanage, M., Lane, N. 1999. *Primary investigations*. www.science.org.au/pi/intro.htm Accessed 12 August, 2011.

Tashakkori, A. & Teddlie, C. (eds.) (2003a). *Handbook of mixed methods in social and behavioural research*. Thousand Oaks, CA: Sage.

Teclai, T.A. (2006). *The potential of a professional development scenario for supporting biology teachers in Eritrea.* PhD thesis. University of Twente, Enchede: Print Patners Ipskamp.

Tessmer, M. (1993). *Planning and conducting formative evaluations: improving the quality of education and training.* London: Kogan Page.

Thompson, C. L. (2003). *Improving student performance through professional development for teachers*. NC: Educational Research Council.

Thompson, J. & Soyibo, K. (2002). Effects of lecture, teacher demonstrations, discussion and practical work on 10^{th} graders' attitude to chemistry and understanding of electrolysis. *Research in Science and Technological Education,* 20 (1), 25-37.

Tillya, F. N. (2003). *Teacher support for the use of MBL in activity-based Physics teaching in Tanzania.* PhD Thesis. University of Twente, Netherlands: Print Partners Ipskamp.

Timperley, H., Phillips, G. & Wiseman, J. (2003). The sustainability of professional development in literacy: part 1, changing and sustaining teachers' expectations through professional development in literacy. *Report to the Ministry of Education, New Zealand.* www.minedu.govt.nz, Accessed: 10 March, 2012.

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics*, 90 (5), 403-418.

Tobin, K. (1993). *The practice of constructivism in science education*. USA: Lawrence, Erlbaum.

Tobin, K. & Tippins, D. (1993). Constructivism as a referent for teaching. In: K. Tobin. (ed.) *The practice of constructivism in science education.* Hillsdale, NJ: Lawrence Erlbaum.

Treagust, D.F & Duit, R. (2009). Multiple perspectives of conceptual change in science and the challenges ahead. *Journal of Science and Mathematics Education in Southeast Asia,* 32 (2), 89-104.

Trigwell, K. & Prosser, M. (1996a). Congruence between intention and strategy in science teachers' approach to teaching. *Higher Education,* 32 (1), 77-87.

Trowbridge, L.W., Bybee, R. W. & Powell, J. C. (2004). *Teaching secondary science: strategies for developing scientific literacy.* USA: Pearson Prentice Hall.

Tytler, R. (2002). Teaching for understanding in science: students' conceptions of research and changing views of learning. *Australian Science Teachers Journal,* 4 (3), 14-23.

Tytler, R. (2003). A window for purpose: developing a framework for describing effective science teaching and learning. *Research in Science Education*, 33 (6), 273- 298.

Turpin, T. J. (2000). A study of the effects of an integrated, activity-based science curriculum on students' achievement, science process skills, and science attitudes. *Dissertation Abstracts International*, 61 (11), 4329A (UMI No. AAT 9993727).

Ünal, S. (2008). Changing students' misconceptions of floating and sinking using hands-on activities. *Journal of Baltic Science Education*, 7 (3) 134-146.

United Republic of Tanzania (URT). (2009). *A performance audit report on school inspection programme for secondary schools in Tanzania*. Tanzania: Dar es Salaam.

United Republic of Tanzania (URT). (1996). *Education and Training Policy*. Dar es Salaam: Ministry of Education and Culture.

Van Den Akker, J., Gravemeijer, K., Mckenney, S., & Nieveen, N. (eds.) (2006). *Educational design research*. London: Routledge.

Van den Akker, J. (2002). The added value of development research for educational development in developing world. In: K. Osaki, W. Ottevanger, C. Uiso, & J. Van den Akker. (eds.) *Science education research and teacher development in Tanzania*. Amsterdam: Vrije Universiteit.

Van den Akker, J. (1999). Principles and methods of development research. In: Van den Akker, J. Branch, R. M Gustafson, K, Nieveen, N. & T. Plomp. (eds.) *Design approaches and tools in education and training.* London: Kluwer Academic.

Van den Akker, J. (1998). The science curriculum: between ideals and outcomes. In: B. Fraser & K.Tobin. (eds.) *International Handbook of Science Education*. Dordrecht: Kluwer Academic.

Van den Akker, J. & Voogt, J. (1994). The use of innovation and practice profiles in the evaluation of curriculum implementation. *Studies in Educational Evaluation,* 20 (1), 503-512.

Van den Berg, E. (1996). *Effects of in-service education on implementation of elementary science,* Enschede: University of Twente.

Van Driel, J., Beijaard, D. & Verloop, N., (2001). Professional development and reform in science education: the role of teachers' practical knowledge. *Journal of Research in Science Education.* 38 (2), 137-158.

Van Manen, M. (1990). *Researching lived experience: human science for an action sensitive pedagogy*. London: University of Western Ontario.

Von Glasersfeld, E. (1996). Introduction: aspects of constructivism. In: C. T. Fosnot. (ed.) *Constructivism: theory, perspectives, and practice*. New York, NY: Teachers College Press.

Vosniadou, S. (1997). On the development of understanding of abstract ideas. In: K. Harnqvist & A. Burgen. (eds.) *Growing up with science*. London: Jessica Kingsley.

Vygotsky, L. (1978). *Mind in society: the development of higher psychological processes.* MA: Harvard University Press.

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

Weber, R. P. (1990). *Basic content analysis*. Newsbury Park, CA: Sage.

Wellington, J. (1998). *Practical work in school science: which way now?* London: Routledge.

Wenger, E. (1998) *Communities of practice: learning, meaning, and identity*. Cambridge: Cambridge University Press.

White, B. Y. & Frederiksen, J. R. (1998). Inquiry, modelling, and metacognition: making science accessible to all students. *Cognition and Instruction*, 16 (1), 3-118.

Wikeley, F. (2005). Evaluating effective school improvement. *School Effectiveness and School Improvement*, 16 (4), 387-406.

Williams, M. (2000). Interpretations and generalization. *Sociology. 34* (2), 209- 224.

Wilson, C. D., Taylor, J. A., Kowalski, S. M. & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching*, *47* (3), 276-301.

Windschitl, M. (2002). Framing constructivism as the negotiation of dilemmas: an analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research, 72* (2), 131-175.

Wittock, M. (1994). Generative science teaching, In: P. Fensham, R. Gunstone & R. White. (eds.) *The content of science*. London: Falmer.

World Bank. (2009). Tanzania: country brief. http://hdl.handle.net/10986/2629 Accessed: 12 March, 2011.

Woolnough, B. (1991). *Practical science: the role and reality of practical work in science*. Great Britain: Open University Press.

Wormstead, S., Becker, M. & Congalton, R. (2002). Tools for successful student teacher-scientist partnerships: *Journal of Science Education and Technology*, 11 (3), 277-287.

Yin, R. (1994). *Case study research: design and methods*, Beverly Hills, CA: Sage .

Zeegers, Y. (1995). Supporting teachers to implement the National curriculum: a New Zealand perspective. *Australian Science Teachers Journal*, 4 (4), 45-48.

Zemke, R. & Zemke, S. (1988). Things we know for sure about adult learning. *Training*, 57 (1), 1-22.

Appendices

It has been stated earlier in the methodology chapter (Chapter 5) that the study used different data collection instruments at different stages, while other instruments were used more than once. It is most likely that the instruments named '**C**' were extensively used during the third stage of the study.

Appendix A1: Experts' Appraisal guiding questions

Dear Prof /Dr ______________________________________

You are requested to look through the attached prototypes that have been developed with an aim of improving biology teaching and learning methods in Tanzanian Secondary schools**.**

Your opinions and suggestions are highly valuable for improvement of the validity and the initial practicality of the prototypes. Specifically, this appraisal seeks answers, and explanation of the following questions:

1) Are the prototypes useful for the intended users to implement the developed intervention?
2) Can the prototypes improve the users' professional knowledge?
3) Can the components and the 5Es instructional sequence in the curriculum materials provide an easy way for teachers to implement the activity-based teaching and learning approaches?
4) Can the components and activities of the professional development programme enhance biology teachers' learning and practising implementation of the activity-based lessons?
5) Will the activity-based approach and the 5Es instructional sequence useful in improving biology teaching and learning in Tanzanian schools?
6) How can the materials and components of the professional development programme be further improved?

Thanks very much for participating in this study

Appendix A2: Curriculum Materials

Introduction to the biology curriculum materials

The curriculum materials include five lessons developed through integration of the activity-based approach supported by the 5Es instructional sequence (see the Table below) with teacher's roles and student activities. The aim is to improve the current lesson preparation and implementation which inculcates teacher-centred teaching methods and rote learning, and focusing on supporting biology teachers on effective classroom instructional practices including exciting activities which involve students prior to the engagement in the whole sequence of lesson development.

Specifically, the materials will provide teachers with:

i) Appropriate instructional techniques relevant for representation of scientific phenomena;
ii) Skills in anticipating, understanding, and dealing with students' ideas about science;
iii) Driving questions for teachers to develop lesson plans as well as to use with their students;
iv) Approaches to help students to collect, compile, and understand data and observations;
v) Ideas on recognising the importance of (sometimes) having students design their own investigations;
vi) Recommendations for how teachers can support students making explanations based on the evidence;
vii) Suggestions on how teachers can promote students' lesson interest through practical activities and art-facts;
viii) Methods for developing factual and conceptual knowledge of science content, including concepts likely to be misunderstood by students.

The curriculum materials comprise of five activity-based lessons, which were developed from the topics that appear in the current version of Tanzanian Ordinary Level biology syllabus (2005), the topics are:

i) Classification of living things (2 lessons);
ii) Cell structure and functions;
iii) Transport of materials in living things; and
iv) Balance of nature.

Lesson presentation (structural specification)

The curriculum materials bear some additional information about lesson description and the specific teachers' roles and students' activities adapted from the 5Es Instructional model. These components are:

i) ***Lesson preparation:***

- **A brief lesson description of what the lesson looks like**: This aims at providing the general overview of the lesson including specific activities and instructional strategies.

- **Lesson objectives**: Indicate learning outcomes expected to be achieved by students by the end of the lesson
- **Materials and resources:** These are teaching and learning aids required for the lesson activities and in the facilitation process. Possible alternative materials and resources are encouraged depending on the context and availability.
- **References**: These are the suggested possible textbooks and reference books that a teacher may refer to, to enrich his/her subject content knowledge and may guide students' assignments.
- **Lesson timing**: This part indicates the possible timing for each stage of a lesson and activities.

ii) ***Lesson development activities:*** This part is guided by the '5Es' with the description of teachers' roles and students' activities in a logical manner, i.e. *Excitement, Exploration, Explanation, Elaboration* and *Evaluation* as summarised in the following table.

The 5Es instructional sequence

Stages	Summary of teachers' roles and student activities
Excitement	The teacher to use short activities that generate students' curiosity, create interest, raises questions, and elicits responses that uncover what the students know or think about the concept/topic.The activities should make connections between the past and present learning experiences, expose prior conceptions, and organise students' thinking toward the learning outcomes of the current activities. The instructional objectives should be provided by the end of this stage.
Exploration	Exploration experiences provide students with a common base of activities (with minimum supervision from the teacher) within which current concepts, misconception, processes, and skills are identified and conceptual change is facilitated. Students may complete the activities (laboratory, or outdoor) that help them to use prior knowledge to generate new ideas, explore questions (inquiry), and possibilities, design, and conduct preliminary investigations.
Explanation	The explanation phase focuses students' attention on particular aspects of their excitement and exploration experiences and provides opportunities to demonstrate their conceptual understanding, process skills, or behaviours. It also provides opportunity for teachers to directly introduce/facilitate a concept, process, or skill. An explanation from the teacher may guide students toward a deeper understanding which is a critical part of this stage.
Elaboration	Teachers challenge and extend students' conceptual understanding and skills. Through new experiences, the students develop deeper and broader understanding, more information, and adequate skills. Students apply their understanding of the concept by conducting additional activities.
Evaluation	Evaluation occurs throughout the lesson. It provides an opportunity for students to demonstrate and check their understanding of the concepts. The evaluation stage encourages students to assess their understanding and abilities and provide opportunity for teachers to evaluate student progress towards achieving lesson objectives. The joint-students and teacher's reflection of all important concepts, skills, and processes may conclude the lesson.

Source: Adapted from (Bybee *et al.,* 2006).

iii) ***Suggestion of homework ideas***: These are the assignments (in the form of questions or activities) with a purpose of extending and applying the concepts or skills learned from the lesson. Students may accomplish them at home, after the lesson, or part of it may be done in the classroom/laboratory if the teacher finds it relevant. The teacher should monitor the evaluation of this assignment and ensure immediate feedback is given in order for students to realise its contribution to the understanding of the taught concepts.

iv) ***Teachers' notes***: This is the summary of important ideas or concepts a student is required to learn from the lesson (the teacher may decide the best ways to present the class summary notes).

v) ***Remarks***: This part may be used by the teacher to explain what has been learned from the lesson or some important observations, suggestions, and comments from the current lesson which may be valuable for the following lesson

LESSON ONE

Topic: Classification of Living Things

Lesson: **The Concept of classification**

Class: Form One

Lesson Description: This lesson involves outdoor activities (field study) which include collecting and classifying living organisms, followed by the discussion of the criteria used for their classification.

Lesson Objectives: By the end of the lesson each student will be able to:

- Explain the meaning of classification of living things.
- Group living things according to their similarities and differences
- Explain the importance of classifying living things

Lesson materials and resources:

Insect catching nets, plastic bags, containers, bottles, hand lenses, microscopes, microscope slides, preserved living organisms, pictures of various organisms placed on the manila sheet or flip chart, and field-guide papers,

References:

1. Aggarwal, S. (2002). *Biology laboratory manual for class XI*. New Delhi: Vikas Publishing House PVT Ltd.
2. Burton, I.J. (2003). *The Cambridge revision guide: GCE O Level biology*. Singapore: Cambridge University Press.
3. Mackean, D.G. (2000). *Introduction to Biology 3rd Ed*. London: Jon Murray (Publishers) Ltd.
4. Tanzania Institute of Education. (2002). *Biology for secondary schools book one*. Dar es Salaam: Tanzania Institute of Education.
5. Tanzania Institute of Education, (2001). *Teaching methods across the curriculum*. Dar es Salaam, Tanzania Institute of Education.
6. Tanzania Institute of Education (1998), *Biology Practical manual, O'Level Secondary Schools,* Dar es Salaam: Tanzania.

Lesson Time: 80 minutes

Lesson Development Activities

Excitement (15 minutes)

The teacher to organise short activities that will create students' interest and elicits responses that uncover what they know or think about the concept of classification in living organisms e.g. sorting and grouping various pictures of organisms, models, drawings, pens, plant leaves or classifying members of their class (these activities may be conducted in small groups or demonstrated by few students). Thereafter, students may be asked to explain what they think the term *classification* is, from the activities they performed and their prior knowledge, and why it is important to know it. The teacher to summarise students' experiences and mentioned what students are expected to achieve from the lesson.

Students to provide their prior experiences and express their current understanding of classification based on the activities performed in the classroom. They may be guided to ask questions or any clarification from the demonstrated or performed activities

Exploration (30 minutes)

Students in groups of 4-6 will be guided to conduct a field work in the areas previously visited by their teacher. They will collect and observe living things and record their observations in the provided field-guide papers (as shown below).

Name of Organisms	**Habitat**	**External observable Features**	**Categories of observed organisms**

During the field study the teacher should observe and listen to students' interactions and where possible to ask questions (on specific observations) in order to make their observations meaningful.

Students to participate in the field activities and sharing their experiences within the group in order to acquire a common set of experiences, which will help them to compare their experiences and results from observations. Each group to complete the field-guide paper for presentation.

Explanation (15 minutes)

Students to present their findings

The teacher should encourage students to use experiences and data from the *excitement* and *exploration* stages to support explanation of their findings. The teacher may ask students questions in order to reinforce their understanding and explanations with evidence from their observations.

a) Categorise all organisms you have observed in specific groups of living things.

b) How many groups of living things you have encountered?

c) Explain the reasons for assigning living organisms at each group.

d) What can you say about members of each group? Are they similar or not? Explain your answer.

Students to provide answers to the asked questions and clearly connect their explanations to evidence and experiences with the *excitement* and *exploration* stages.

The teacher should facilitate the lesson concepts after students have expressed their experiences and make use of specific examples from students' activities. This will help students to explain the lesson concepts by using scientific language as required by the subject, at the same time to reflect and perhaps revise their ideas to match with what they did and observed.

Elaboration (10 minutes)

The teacher to focus students' attention to the conceptual connections between the new and the former experiences on classification and encourage students to use experiences learned to explain the importance of classification of living things.

Students may be assigned alternative tasks to help them apply or extend what they have acquired from the previous stages to new situations. For example, the teacher may provide each group a flip chart with 14 or more pictures of different organisms, each of them labelled with a letter *i.e. a, b, c*….. then, the students may be asked to classify them in different ways as they wish. For example, by colour, shape, size, number of legs or as plants and animals.

The following question may guide this activity:

a) Explain how to classify the provided organisms

Students to provide answers to the asked question by making the conceptual connections between the new and prior experiences, to use scientific terms and descriptions in order to arrive at reasonable conclusions from evidence and data. They have to communicate their understanding to others in the classroom, i.e. by making presentations and apply the learned concepts and skills in answering of the questions from their teacher.

Evaluation (10 minutes)

The teacher should guide students' as they demonstrate understanding of the learned concepts and performed skills. The teacher should allow sufficient time for students to compare their ideas with those of others in order to help other students to revise their thinking.

The teacher may ask questions for assessment of students' understanding:

a) Briefly explain how this lesson was important to you.

b) What is the importance of classifying living things?

Students to provide answers to the asked questions by demonstrating what they have learned about the concept of classification and how well they can make use of the skills, i.e. by using observations, evidence, and previously accepted explanations.

Students should evaluate their own progress and knowledge by comparing the current understanding of the taught concepts and their field experiences with their prior knowledge.

Suggested homework ideas: Choose one of the following cases and produce its classification pattern; school library, school flower garden, and wild animals (or any other cases depending on the context).

Teacher's remarks: The teacher may explain any observation/comments or suggestions from the lesson which may be valuable for the next lesson.

Teachers' Notes

Biology aims at obtaining knowledge about every organism. But living things are so many and varied that it would be impossible during one's lifetime to study all organisms. When organisms are classified in their natural groups it becomes possible to know biologically many organisms, because what is required is to study the representative organisms of each natural group. The purpose of classification is to organize the vast number of known plants and animals into groups and categories that could be named, remembered and studied easily. Hence, the process of identifying distinctions (differences) among organisms and placing them into groups that reflect their most significant characters and relationships is called biological classification.

One of the methods that can be used to study classification is field study. When this method is used in association with other methods like observation, projects and discussion students and even teachers become excited to learn and understand various concepts in the classification of living things.

Reasons for classifying living things

- Classification makes the study of living things easy;
- It facilitates the identification of organisms;
- It makes a study of different organisms very convenient;
- It helps to identify the differences in structure, functions, development, and evolutionary history of living things;
- It helps to understand the interrelationship among different groups of organisms;
- It is used in various fields of applied biology such as agriculture, public health and environmental biology e.g. classification of pests, vectors and pathogens.

LESSON TWO

Topic: Classification of Living Things

Lesson: Classification Systems.

Class: Form One

Lesson Description: In this lesson students will make observations about the provided living things and classify them based on the observable and morphological features.

Lesson Objectives: By the end of the lesson each student will be able to:

- Explain the meaning of classification systems
- Recognise the various types of classification systems
- Describe the features of each classification system
- Perform practical activities on the classification of living things according to artificial and natural systems.
- Outline the differences between the two classification systems.

Lesson Materials and Resources: variety of the collected and preserved animals and plants (animals such as grasshoppers, house flies, butterflies, small birds, lizards, rats, frogs, fish and bats).

References

1. Aggarwal, S. (2002). *Biology laboratory manual for class XI*. New Delhi: Vikas Publishing House PVT Ltd.
2. Burton, I. J. (2003). *The Cambridge revision guide: GCE O Level biology*. Singapore: Cambridge University Press.
3. Mackean, D.G. (2000). *Introduction to Biology 3rd Ed*. London: Jon Murray (Publishers) Ltd.
4. Tanzania Institute of Education. (2002). *Biology for secondary schools book one*. Dar es Salaam: Tanzania Institute of Education.
5. Tanzania Institute of Education, (2001). *Teaching methods across the curriculum*. Dar es Salaam, Tanzania Institute of Education.
6. Tanzania Institute of Education (1998), *Biology Practical manual, O'Level Secondary Schools,* Dar es Salaam: Tanzania.

Lesson Time: 80 minutes.

Lesson Development Activities

Excitement (15 minutes)

The teacher to create lesson attention by seeking explanations for the following situations;

When you go to the supermarket or to any local market (name it for familiarity) how can you find any substance you are looking for? E.g. vegetables, meat, milk, and fruits.
The teacher to invite a few students to explain what they think are the correct explanations of the mentioned cases, where possible, to ask for more examples from their everyday experiences. The teacher should summarise students' explanations of different cases and clarify the new terminologies in the classification systems i.e. natural and artificial classification systems.

Students to explain their current understanding of the classification systems from everyday experiences and the examples provided in the classroom. Students may ask their teacher more questions or require clarification on the topic. They will note down the scientific terms used in the classification systems which will be relevant for understanding of the lesson activities in the *exploration* stage.

Exploration (30 minutes)

The teacher to guide students in small groups to perform activities which aim at grouping the animals based on the artificial and natural classification systems

Activity (2a) Observation of the collected animals from the previous lesson and the preserved ones in the laboratory (if any).

i) Classify the provided animals into specific groups .
ii) Identify the number of animals in each group
iii) Name and give reasons for assigning them into groups you have obtained?

Following this activity the teacher may guide students to identify the basic features of the artificial and natural systems of classification.

Activity (2b) Students to repeat the same procedures in activity **(2a)** but this time they have to classify the given animals based on the observable morphological features.

Guiding question:

a) Have you obtained the same groups of animals as the case in activity **(2a**)? Suggest reasons for your answer.

Students to familiarise themselves with the animal samples and conduct investigations in groups. They will observe and record their findings as instructed and compare them with that of other students in the class so as to acquire a common set of experiences.

Explanation (15 minutes)

The teacher to encourage students to explain concepts and definitions in their own words and ask questions that may help students express their understanding. For example:

a) Which method of grouping gave you fewer animals in a group?
b) Which method gave you many animals in a group?
c) Can you suggest reasons for your answers?

Students to provide answers to the asked questions and explain concepts and ideas in their own words using prior experiences and evidence acquired from the practical investigations.

The teacher should request for justification from students' explanation and provides sufficient time for students to compare their ideas and experiences in the classroom. Thereafter, the teachers may facilitate the lesson concepts and make use of the students' observations.

Students to listen careful the explanation about the two systems of classification from their teacher, and be able to explain their ideas by using appropriate scientific language and relate them to the experiences from their previous practical observations.

Elaboration (10 minutes)

The teacher to encourage students to apply or extend the concepts and skills in new situations, for example:

a) Explain what you could do when you encountered one or two organisms that did not fit into either of your groups.
b) What do you think are the differences between the two systems of classification?

The teacher should remind students about alternative explanations of classification systems, and the importance of using the existing data and evidence to support their explanation.

Students should make the conceptual connection between the new and previous experiences and to apply the experiences learned into a new situation as required. Students must use evidence and data to support their arguments.

Evaluation (10 minutes)

The teacher to provide sufficient time for students to compare their ideas with those of others, this may help other students to revise their thinking. To ask students questions to test their understanding of the taught concepts. For example:

a) What are the advantages and disadvantages of Artificial and Natural systems of classifications

Students to answer the question by demonstrating what they have learned and how well they can make use of the acquired knowledge and skills. They need to assess their own progress by comparing their current understanding with their prior knowledge. The teacher may guide students to ask or answer questions in order to enhance deeper understanding of concepts.

Suggested homework ideas: Imagine you are one of the biological explorers who have arrived at an area that no one else has ever been before. How would the knowledge of classification systems help you to study the plants in that area?

Teachers Remarks: The teacher may explain any observation/comments or suggestions from the lesson which may be helpful for the next lesson.

Teachers Notes

There are many organisms in the world. Some organisms share some characteristics, while others do not. That is why scientists have classified organisms into various groups. Grouping organisms according to shared characteristics is not a simple task, and scientists often disagree about the best way to classify organisms. Some think that organisms should be grouped according to differences or similarities in the way they look or act. Other scientists argue that classification should base on the characteristics derived from a shared evolution. Conflicting philosophies about classification have resulted in a variety of classification methods, each with their own set of assumptions, techniques, and results. The two types of classification are **natural system of classification and artificial system of classification**

Natural classification is based on two ideas:

• Homologous structures

• Evolutionary relationships

Homologous structures are features of organisms that are **similar in structure** but may look very different from each other and may be used for different purposes. For example; horse's front leg, the human arm and a bat's wing are all **homologous** structures. They have the same number and arrangement of bones and this means that they probably evolved from a single type of structure that was present in a common ancestor millions of years ago. A fly's wing is not homologous with a bat's wing. It may look similar and do the same job but it develops from a completely different origin. The fly's wing has no bones and is not covered by feathers. A bat's wing and a fly's wing are termed **analogous**. A bat and a fly would not be grouped together!

In a **natural classification system**, biologists group together organisms which are structurally similar and share common ancestors. Natural classification produces a branching set of relationships as in the case of how the plants are divided into major subgroups such as mosses, ferns, conifers and flowering plants. Each of these subgroups can be divided further. In this diagram only the two main groups of flowering plants have been shown. Where organisms are divisions of the same subgroup, such as the monocotyledons and dicotyledons, they are more closely related and may share more similar features than with the mosses and ferns.

Artificial classification

With **artificial** classification you can use any grouping you like. You could put all the animals that fly in the same group. This group would then include birds, bats and many insects. You could put all animals that live in water and have streamlined, fish-like bodies in the same group. This group would then include fish and whales.

Artificial classification systems are also used as the basis for **dichotomous keys** that biologists use to identify organisms.

LESSON THREE

Topic: Cell Structure and Function

Lesson: **The Concept of a Cell**

Class: **Form One**

Lesson description: Students will prepare and observe plant and animal cells and use their practical experiences to identify the components of the two cells and their functions.

Lesson objectives: By the end of the lesson each student will be able to:

- Explain the meaning of a cell
- Prepare a wet mount of a plant cell
- Observe plant and animal cells using a light microscope
- Draw and label plant and animal cells
- Explain the function of the different parts of plant and animal cells.

Lesson materials and resources

Light microscopes, microscope slides and cover slips, droppers, forceps, mounting needles, scalpel or a sharp knife, water, iodine solution, a piece of onion bulb and the prepared animal cell slides, manila cards of different colours and marker pens.

References:

1. Aggarwal, S. (2002). *Biology laboratory manual for class XI*. New Delhi: Vikas Publishing House PVT Ltd.
2. Burton, I. J. (2003). *The Cambridge revision guide: GCE O Level biology*. Singapore: Cambridge University Press.
3. Mackean, D.G. (2000). *Introduction to Biology 3rd Ed*. London: Jon Murray (Publishers) Ltd.
4. Tanzania Institute of Education. (2002). *Biology for secondary schools book one*. Dar es Salaam: Tanzania Institute of Education.
5. Tanzania Institute of Education. (2001). *Teaching methods across the curriculum*. Dar es Salaam, Tanzania Institute of Education.
6. Tanzania Institute of Education (1998), *Biology Practical manual, O'Level Secondary Schools,* Dar es Salaam: Tanzania.
7. Ministry of Education and Culture. (2005). *Biology syllabus for Secondary schools Form I-IV*. Dar es Salaam: Tanzania Institute of Education.

Lesson time: 80 minutes

Lesson Development Activities

Excitement (15 minutes)

The teacher to determine students' lesson interest and their current understanding of the concept of cells through brainstorming e.g. by asking four students at a time, to write on the blackboard a statement or anything that shows the meaning of a word 'cell'. The teacher to invite other students in the class to comment on the information provided by their fellows and try to illustrate their alternative conceptions. The teacher to guide students' presentation of their prior experiences about the meaning of a cell, and require students to verify their ideas.

Students will express their current understanding of a cell concept by writing statements or drawing diagrams. They will be guided to present the common ideas from each category of statements, or diagrams, and finally, may ask questions or anything they wish to know about a cell concept. The teacher to conclude by explaining the meaning of a cell as required and preparing students for further lesson activities.

Exploration (25 minutes)

The teacher to introduce students to the lesson activities and get them familiar with the materials and resources. Where necessary, to demonstrate or show them a video on how to prepare and use wet mounts for cell study.

Activity (2a): Preparation of the wet mount from cells of an onion bulb or any other plant material and observation of them under microscope starting with the low power objective followed by high power objective. Students have to draw diagrams of plant cells observed on a sheet of paper.

Activity 2b): To observe animal cells from the prepared slides or from any small animal like a rat by using a microscope, and to draw the diagrams. To guide students to make sense of their experiences through probing and at the same time to ensure sufficient time for students to accomplish lesson activities in their respective groups.

Students in groups of 4-6 to conduct investigations, from which they will prepare, observe, and draw varieties of plant and animal cells. Each group to compare their investigations with those of others in order to acquire a common set of experiences and learn from each other.Students may practice peer marking of the two types of cells.

Explanation (15 minutes)

The teacher to encourage students to use their common experiences and data from the previous lesson stages to support explanations of the concepts they are studying. The teacher may ask for justification or evidence to support the students' explanation.

The following questions may guide students understanding and explanations:

a) What steps have you followed in the preparation of wet mounts?
b) How did you get the structure of a cell you drew?

c) Are there other things you have observed? If yes, what do they look like?

Students to base their answers to the asked questions on the evidence acquired from investigations and prior knowledge. Sometimes, they have to reflect on their explanations and perhaps revise their ideas.
The teacher has to facilitate the basic concepts and procedures of a lesson after students have expressed their experiences in order to familiarise students with the basic scientific terms and descriptions.

Elaboration (15 minutes)

The teacher to direct students' attention to the conceptual connections between the new and the prior lesson experiences and to reinforce students' use of scientific terms and descriptions previously introduced to other contexts.

The teacher may ask questions that will help students to make reasonable conclusions from evidence and data:

a) What do you think are the reasons for preparing the wet mounts of a plant cell?
b) Compare your diagrams with the one in the textbooks and provide the appropriate labeling.
c) Mention the similarities and differences between typical plant and animal cells.

The teacher should guide students to match the parts of the cells written on the prepared pink/yellow cards with the functions written on the white cards.

Students should communicate their understanding to other students in the class through group work presentations. For example, to compare the two cells and to name the correct parts as required, and to match the cards appropriately in order to show their understanding of the different parts of the cells.

Evaluation (10 minutes)

The teacher to assess students' knowledge and skills by looking for evidence indicating students' changes in their thinking or behaviour. The following questions may guide

a) Write down 5 things you have learned from today's lesson.
b) Why do plant and animal cells have different shapes?

Students have to answer the questions by using evidence and previously accepted explanations. They have to evaluate their own progress and knowledge by demonstrating an understanding of acquired concepts and skills (i.e. what they have learned from the lesson). They have to compare their current thinking with that of others and perhaps to revise their ideas.

Suggested homework ideas: Students in a group of four, will make a model of plant and animal cells by using different materials and explain the function of each part of a cell (the teacher may clarify to students this activity if necessary).

Teachers Remarks: The teacher to explain any observations/comments or suggestions from the lesson which may be valuable for the next lesson.

Teacher's notes

Living things are made of **cells**. All cells have parts that perform a certain activity. Cells have an outer covering called **cell membrane** this give cells their shapes, regulate what enters and leaves the cells. One of the important substances is **water.** Other substances pass through the cell membrane in a solution form. The cell membrane also provides protection and support for the cells.

Plant cells have a thick outer covering called **cell wall,** which is **made** of fibres of cellulose that give them shape and strength. The cell wall fits closely just outside the cell membrane

Cytoplasm is the clear jellylike material inside the cell. Many chemical reactions (i.e. metabolic reactions) take place in cytoplasm to keep a cell alive.

Nucleus is the control centre of the cell; it contains a number of chromosomes made of DNA that direct chemical reactions and controls cell division.

The cytoplasm and the nucleus make up the **protoplasm** of a cell.

Plant cells have additional structures such as; large central **vacuole** with a space containing a cell sap which stores extra water and gives extra support to the cell by pressing hard against the cell wall; and **Chloroplasts** which are small bodies lying in the cytoplasm; they are green in colour because they contain a photosynthetic pigment called chlorophyll.

LESSON FOUR

Topic: Transport of materials in living things

Lesson: **Diffusion, Osmosis and Mass flow**

Class: Form Two

Lesson description: Students will identify procedures for conducting experiments to illustrate the processes of diffusion, osmosis and mass flow and apply the knowledge and skills from observations to explain the meaning and the roles they play in living organisms.

Lesson objectives: By the end of the lesson each student will be able to:

- Carry out experiments to demonstrate the processes of diffusion, osmosis and mass flow.
- Explain the meaning of diffusion, osmosis and mass flow.
- Outline the differences between diffusion, osmosis and mass flow.
- Explain the role played by diffusion osmosis and mass flow in the transport of materials in living things.

Lesson materials and resources

Water, potassium permanganate crystals, fresh young pawpaw petioles, round potato scalpel/knife, measuring cylinder, small round bottles, beakers of different sizes, sugar crystals, water plants. Coloured solution (red or blue)

References

1. Aggarwal, S. (2002). *Biology laboratory manual for class XI*. New Delhi: Vikas Publishing House PVT Ltd.

2. Burton, I.J. (2003). *The Cambridge revision guide: GCE O Level biology*. Singapore: Cambridge University Press.

3. Mackean, D.G. (2000). *Introduction to Biology 3rd ed*. London: Jon Murray (Publishers) Ltd.

4. Tanzania Institute of Education. (2002). *Biology for secondary schools book one*. Dar es Salaam: Tanzania Institute of Education.

5. Tanzania Institute of Education, (2001). *Teaching methods across the curriculum*. Dar es Salaam, Tanzania Institute of Education.

6. Tanzania Institute of Education (1998), *Biology Practical manual, O'Level Secondary Schools*, Dar es Salaam: Tanzania.

Lesson time: 80 minutes

Lesson Development Activities

Excitement (15 minutes)
The teacher to determine students' current understanding of the meaning of osmosis, diffusion and mass flow by instructing a few students to demonstrate short activities to generate curiosity and lesson interest, e.g. one student to open a bottle of perfume/air freshener at one corner of the classroom and ask each student in the class who smells it to stand up. Similarly, to use the predict and explain technique to ask questions related to osmosis e.g. explain what will happen when a fresh water fish is kept in the ocean? The teacher should lead the whole class discussion on the two cases and how they are related to the concepts of osmosis and diffusion.

Students should participate in the activities by providing their prior experiences and ask questions about the specific concept they wish to know.

Exploration (30 minutes)
The teacher to guide students to work in groups of 4-6 and get them familiar with the lesson materials and the activities, i.e. 2a- for osmosis, 2b- for diffusion and 2c- for mass flow.

The teacher may encourage student-to-student interactions within each group and use probing to help students make sense of their experience. The following questions may guide;

a) Write procedures for each experiments you have performed
b) Make observations and record any changes occurred/noticed
c) Where necessary illustrates your observations with diagrams.

The teacher has to provide sufficient time for students to accomplish their tasks.

Students to conduct investigations in their respective groups, showing the procedures and recording all their observations in the provided papers as indicated below.

Aim of the experiment	**Procedures**	**Observations**

Students to design their own models of osmosis, diffusion and mass flow using different materials and share the results with other students in the classroom. They may try different ways of arriving at the same conclusion (e.g. by using alternative materials) and compare their experiences and findings with those of other students in the class (limited examples may be used to serve time).

Explanation (15 minutes)

The teacher to guide students to use their experiences and data from the *excitement* and *exploration* stages to develop explanations of the three concepts. The teacher may ask questions to help students express their understanding and explanations with evidence from the lesson activities.

The following questions may guide

Activity 2a)

i) What happened to the level of water in the beaker with potatoes? Or pieces of pawpaw petioles in the two beakers with different solution?
ii) What changes happened to the sugar crystals in the potato hole? Or what changes happened to the pawpaw petioles in the beaker with a salt solution?

Activity 2b)

i) What happened to the water in the measuring cylinder after dropping two particles of potassium permanganate crystals/blue powder?

Activity 2c)

i) Explain what you have observed when a water plant was kept in the red/blue coloured solution.

Students to provide answers to the asked questions based on the evidence acquired during the *exploration* stage. They need to reflect and perhaps revise their ideas to complement what they did and observed and be able to express their ideas using appropriate scientific language as required by the subject.

After students have expressed their experiences the teacher should facilitate the lesson concepts in order to correct any misconceptions or difficulties experienced by students and ensure appropriateness in the use of scientific terms. The teacher has to refer to the specific observations or activities performed by students.

Elaboration (10 minutes)
The teacher to direct students' attention to the conceptual connection between the new and the former experiences and encourage students with the application of the acquired knowledge and skills in everyday life situations. Throughout the lesson the teacher has to reinforce the use of scientific terms and descriptions previously introduced and ask questions that may help students arrive at appropriate conclusions based on evidences and data.

The following questions may guide:

a) How could you explain the changes of volume of water in the beaker with a potato?
b) Can you explain what happened to the sugar crystals in the potato hole?
c) Provide reasons why dried beans swell when they are soaked.
d) Can you explain how the concentration of colour and its distribution patterns happened in the measuring cylinder?
e) Briefly explain the reasons for the changes observed when water plant was kept in the coloured solution. What can you conclude from this observation?

Students to answer the questions by making the conceptual connection between the experiences from the lesson activities and their prior knowledge in order to arrive at reasonable conclusions. Students must use scientific terms, descriptions and communicate their understanding to other students in the classroom.

Evaluation 10 minutes
The teacher to assess students' knowledge and skills by looking for evidence that students have changed their thinking or behaviour. To guide students to assess their own learning and group-process skills in order to identify what they have learned from the lesson (e.g. may be asked to explain the concepts learned in today's lesson). The teacher may ask questions to test their mastery of knowledge and skills e.g. *Explain the differences between the processes of osmosis, diffusion, and mass flow.*

Students to demonstrate their understanding of the concepts studied by identifying things they have learned and answering questions by using observations, evidence, and previously accepted explanations. They may assess their own progress by comparing their current understanding with their prior knowledge about transport of materials in living things.

Suggested homework ideas: Students in groups of four, should design an experiment to illustrate one of the concepts discussed in today's lesson, i.e. osmosis, diffusion and mass flow (using different materials) and explain how the process is relevant to a named living cell.

Teachers Remarks: The teacher may explain any observation/comments or suggestions from the above lesson which may be valuable for the next lesson

Teachers Notes

Living things require food, oxygen and water to carry out their life processes such as growth, respiration reproduction, growth, movement and excretion. These substances have to be absorbed and transported to different parts of the body. As a result of metabolism, waste products such as carbon- dioxide and urea are formed. These waste products must be expelled from the body otherwise they become toxic. Therefore the body needs some transport mechanisms to carry out these functions. These mechanisms are diffusion, osmosis, and mass flow.

The concept of Osmosis and Diffusion and Mass flow in cells

In order for cells to interact with their environment, chemicals, including water, must be able to move across the cell membrane and across the cell. Movement within the cell occurs by a process known as diffusion. Molecules move across the cell membrane by a related process known as osmosis.

Diffusion is the movement of molecules from a region of higher concentration to a region of lower concentration. This happens because of random molecular motion. Molecules move around randomly until there is an even mixture throughout the container in which they are enclosed. The overall effect is that molecules move "down" a concentration gradient from a region of high concentration to a region of low concentration

Diffusion occurs for two reasons:

a) There is a great deal of empty spaces between the molecules of all substances. This space is greater in gases and much less in liquids and least of all in solids.

b) All molecules are in a state of constant random movement so that they collide and intermingle all the time.

Osmosis can be defined as the diffusion of water molecule through a selectively permeable membrane from a weak to a strong solution.

Osmosis is the movement of molecules down a concentration gradient and at the same time across a membrane. Cell membranes do not allow all molecules to cross them. They are said to be "selectively" or "differentially" permeable. Only certain molecules can cross the membrane into or out of a cell. For example, water can cross the membrane while sodium and chlorine ions (dissolved salt) cannot. Therefore, a cell membrane is partially permeable.

Mass flow in plants illustrates the path of water and dissolved minerals from the root to the leaves of the plant. These processes involve water and dissolved minerals uptake from the soil to the root hairs and its passage from the root hairs to vascular tissues of a root, stem and leaves.

One example of a **mass flow transport system in animals** is blood, which not only delivers the necessary nutrients, oxygen and other things to a cell, but also carries white blood cells within it, which combat infection and other harmful invaders. The lymph node system and lymph fluid would also be considered a mass transport system, since they carry the debris drained out of blood and filter it and check it for harmful substances and basically do a cleaning up before returning the fluid back to the heart.

LESSON FIVE

Topic: The Nature of the Environment

Subtopic: Interaction of Organisms in the Environment

Class: Form Two

Lesson Description: This lesson involves students doing field study in the specific areas to study the natural environment, the components, and interactions among organisms.

Lesson objectives: By the end of the lesson each student is expected to be able to:

- Explain the meaning of an environment
- Categorise the components of the environment (biotic and abiotic)
- Identify the types of interaction among living organisms and the non-living organisms

Materials and resources:

Organisms in their natural habitats (biotic and abiotic), polythene bags, plastic bottles with lids, insect nets (various sizes), gloves, thermometers, litmus papers, hand lenses, field notebooks, field guide sheets

References:

1. Aggarwal, S. (2002). *Biology laboratory manual for class XI*. New Delhi: Vikas Publishing House PVT Ltd.
2. Burton, I. J. (2003). *The Cambridge revision guide: GCE O Level biology*. Singapore: Cambridge University Press.
3. Tanzania Institute of Education. (2002). *Biology for secondary schools book two*. Dar es Salaam: Tanzania Institute of Education.
4. Mackean, D.G. (2000). *Introduction to Biology 3rd Ed*. London: Jon Murray (Publishers) Ltd.
5. Tanzania Institute of Education, (2001). *Teaching methods across the curriculum*. Dar es Salaam, Tanzania Institute of Education.
6. Tanzania Institute of Education (1998), *Biology Practical manual, O'Level Secondary Schools,* Dar es Salaam: Tanzania.

Lesson time: 80 minutes

Lesson Development Activities

Excitement (20 minutes)

The teacher to organise short activities which may create students lesson interest e.g. asking students to watch the environment outside the class through the classroom door and windows and try to note down different things as they could, and if possible identify any kind of relationship among them.

The teacher to lead group discussion on the students' current understanding of the meaning and the components of the environment and encourage students to use their experiences to support explanations they provide. The teacher should summarise students' experiences and provide explanations of the key terms used in the ecosystem such as biotic, abiotic, producers, consumers, and decomposers.

Working in the groups of 4-6 students will discuss the meaning and the components of the environment. Each group will present their findings and each student should note down other experiences emerged from their colleagues and their teacher.

Exploration (30 minutes)

The teacher to guide students in the field work by visiting areas such as a pond, forest, a river, areas with old logs, and stones. The teacher should explain about the field activities and use of the field guide paper and notebooks to guide students' observations. Where necessary, the teacher should provide explanation on how to use the equipment and other lesson materials. The teacher has to ensure sufficient time for students to accomplish the tasks and sharing their results as indicated in the field guide papers.

An example of a field guide paper

Habitats	Name of organisms observed	Biotic components	Abiotic components	Observed interactions among organisms

Students in groups will participate in the field work as instructed and and shared their experiences with other students in the groups.

Explanation (10 minutes)

Each group will present their findings followed by the whole class discussion.

The teacher to encourage students about using prior experiences and data from the *excitement* and *exploration* stages to support explanations of the concepts. The following questions may guide the discussion:

a) How many organisms have you collected/observed?
b) Were the organisms living or non- living? Explain briefly.
c) Categorise organisms you have collected based on the places you have observed or obtained them.
d) What type of relationship have you identified among specific organisms observed/collected?
e) How can you explain the meaning of environment from what you have observed/collected?

Students to provide answers to the asked questions by making the conceptual connections between their prior knowledge and field observations in order to arrive at reasonable conclusions by using data and evidence.

The teacher should facilitate the important concepts of the lesson after students have expressed their explanations and make use of their observations. This will help students compare their previous explanations with the appropriate scientific explanations.

Elaboration (10 minutes)

The teacher should further encourage students to apply and extend the concepts and skills in a new situation and remind students of the alternative explanations (i.e. the concepts of environment, biotic and abiotic factors, and interaction of organisms) and use of the existing evidence.

The following question may guide:

a) What can you say about the importance of having different environments as observed?
b) Briefly explain any kind of interaction among organisms you have observed/collected during the field study.
c) Why do you think such kind of interaction existed?
d) What is the importance of the identified interaction to the environment?

Students to provide answers to the asked questions by using appropriate scientific language and base their explanations on the evidence and experiences acquired from the previous stages of the lesson.

Evaluation (10 minutes)
The teacher to assess students' knowledge and skills by looking for evidence indicating that students have changed their thinking or behaviour at the same time to allow students to assess their own learning.The following questions may guide:

a) Explain examples of the feeding relationship among organisms you have observed/collected.

Students should provide answers to the asked question by using the acquired knowledge and skills from field observations and teacher's lesson explanations. They should assess their own progress by comparing the current understanding of the taught concepts with their prior knowledge.

Suggested homework ideas: Students working in a group of six will design a habitat and explain how it is suitable for particular organisms of their interest.

Teachers Remarks: The teacher may explain any observation/comments or suggestions from the above lesson which may be valuable for the next lesson.

Teachers Notes:

Every species are linked, directly or indirectly, with a multitude of others in an ecosystem. Plants provide food, shelter, and nesting sites for other organisms. For their part, many plants depend upon animals e.g. in plant reproduction (bees pollinate flowers, for instance) and for certain nutrients (such as minerals in animal waste products). But the interaction of living organisms does not take place on a passive environmental stage. Ecosystems are shaped by the non-living environment (abiotic) of land and water, solar radiation, rainfall, mineral concentrations, temperature, and topography. The world contains a wide diversity of physical conditions, which creates a wide variety of environments: freshwater and oceanic, forest, desert, grassland, tundra, mountain, and many others. In all these environments, organisms use vital earth resources, each seeking its share in specific ways that are limited by other organisms. In every part of the habitable environment, different organisms vie for food, space, light, heat, water, air, and shelter. The linked and fluctuating interactions of life forms and environment compose a total ecosystem; understanding any one part of it requires knowledge of how that part interacts with the others.

An ecosystem consists of a community of organisms and the *abiotic* factors of the habitat interacting with each other. It is basically a complete and self contained ecological unit. The science of the interaction of organisms in the environment is called ecology. The living part of an environment is called biotic while the non living part is called *abiotic.* The biotic part of the environment can be studied under the following categories;

- Producers: these are the *autotrophs.* They synthesize the food by using light energy. They include green plants, algae, *protists* and phototropic bacteria.
- Consumers: these are *heterotrophs* that obtain energy from producers directly or indirectly. These could be herbivores or carnivores
- Decomposers: these are *saprophytic* like fungi and bacteria which feed on dead and decayed organic matters.

Appendix A3: The Trial professional development workshop components and activities

Workshop sessions	Workshop activities	Duration
Theory exploration	i) *Introduction to the workshop* (aims and objectives) ii) *Completion of teachers' expectation questionnaire*. iii) *Exploring participants' prior conceptions*; participants were given opportunities to discuss in groups of 2 issues related to biology teaching and learning approaches. The discussion was guided by the following questions • How do you teach biology? • How do your students learn biology? • Is there relationship between their learning styles and your teaching approaches? • What do you think are the best approaches of teaching biology? • What constitutes an effective biology lesson based on the approaches you have mentioned? iv) *Presenting the theory*; • A brief discussion and reflection on participants' experiences and responses to the asked questions. • Presentation about the meaning of an activity-based teaching and learning (from teaching and learning theory perspective) and the rationale of using it in developing curriculum materials by using the 5Es instructional sequence. • v) *Reading materials*: • Participants to explore information about teaching science with learners thinking in mind; techniques used to explore children's thinking about aspects of science. • Implementation problems and challenges • The advantages of activity-based teaching and learning approaches.	2.30 hrs
	• To teach one lesson (40 min) from the curriculum materials in order to demonstrate the practicality of the activity-based approach and the 5Es	

Demonstration	instructional sequence with students. • Participants to provide their reflection based on the demonstrated lesson by focusing on the activities in the lesson development stage (represented by 5Es). • Plenary discussion on the demonstrated lesson.	70mins
Practice and Feedback	*Introduction to the curriculum materials* • Teachers to look through the curriculum materials and develop a plan for teaching one lesson. (40 or 80 Minutes). *Micro-teaching* • One of the teachers to conduct a microteaching session with the invited students. • Teachers to provide feedback and reflection on the micro-teaching session.	3.00hrs
Workshop evaluation	• Concluding remarks (about the new approaches) • Teachers to complete evaluation questionnaire	20 Min

Appendix B:

Biology teachers' evaluation questionnaire (Users' appraisal)

The following questions aim at collecting your opinions about the curriculum materials which you have provided. Please write your opinions/comments in the provided space for each question. The information you provide will be regarded as confidential and only be used for this study.

Preliminary information

School ___________________________________

Classes/Forms taught___________________________________

Teaching experience ___________years:

Questions:

1. Briefly indicates your general impression about the curriculum materials by explaining the following.
   i) Relevance of the lesson materials
   ____
   ____
   ii) Lesson content
   ____
   ____
   iii) Design and structure
   ____
   ____
   iv) Lessons presentation/ sequence
   ____
   ____
2. What did you like most from the curriculum materials? Please provide reasons.
   ____
   ____
3. What you dislike about the materials? Please provide reasons.
   ____
   ____
4. What do you suggest to be added to the materials? Please provide reasons.
   ____
   ____

5. What things would you like to be taken out of these materials? Please provide reasons.

____

____

6. What do you think about using this kind of instructional approaches in the lesson preparation and teaching?

____

____

7. What problems do you foresee?

____

____

8. Will you be able to get all the materials and resources for the lessons you have examined? If not, what will you do?

____

____

9. What are your comments/suggestions on the materials?

____

____

Thanks for your time and cooperation

Appendix C1: Teachers' expectation questionnaire

Dear Teacher,

The following questions aim at collecting information about your professional background and expectations towards attending the professional development workshop that focus on how activity-based approach can effectively be used in the teaching and learning of biology. The information that you provide will be highly confidential and used only for the purpose of this research.

General information

Name of your school ____

Gender: Male ☐ Female ☐

Your educational qualification: ☐ Diploma ☐ BEd (Sc) ☐ BSc (Ed) ☐ED (Sc)

Teaching experience in year's: ☐ 1-5 years ☐-10 years ☐1-15 years ☐ 16 + years

Classes/Forms you are currently teaching biology Form 1 ☐ Form 2☐ Form 3 ☐ Form 4☐

Other subjects you are teaching: ☐ Geography ☐ Chemistry ☐ Agriculture

Your teaching load per week ___________periods

Other responsibilities at your school

____

1. Have you ever participated in a workshop(s) related to teaching biology by using activity-based approaches? If *yes* would you please identify the key issues discussed?

   ____

   ____

   ____

2. What do you expect to gain from this workshop?

   ____

   ____

   ____

Thank you for completing the questionnaire

Appendix C2: Workshop evaluation questionnaire

This questionnaire aims at collecting your opinions about this workshop. You are requested to provide your genuine responses about the questions. For the tabulated questions read the statements carefully and put ‘tick’ (√) at the box showing the preferable behaviour of your choice.

Participants’ reactions

1. What is your overall impression of this workshop? Please ‘tick’ the correct box.

The workshop ….	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Was according to my expectations					
Was useful for my professional growth					
Was relevant to my teaching practices					
Enhanced my understanding of teaching methods					
The objectives were met					

2. What is your opinion for the following aspects of the workshop? Tick the correct box

Aspects of the workshop	Very good	Good	Just okay	Poor	Very Poor
Theory exploration					
Demonstration and discussions					
Preparation of Micro-lessons: Lesson plans and teaching and learning materials					
Practice: Microteaching with invited students					
Feedback and reflection					

Please provide any further comments regarding your experience with the workshop components

____

____

3. What were the most effective sessions of this workshop? Please explain your answer.

____

____

4. What were the least effective sessions of this workshop? Please briefly explain your answer.

____

____

5. How do you rate the following aspects of the workshop? Tick the correct box

Workshop content, process and context	**Very good**	**Good**	**Just okay**	**Poor**	**Very poor**
Workshop content The knowledge and skills explored in the workshop are useful for improving my teaching practices					
My time in the workshop was well spent					
Process The workshop activities were well planned and organised					
The activity-based approach and 5Es instructional sequence are immediately useful to my teaching					
Sufficient time was provided for accomplishment of activities					
The presenter was well planned					
Context The resources were sufficient and conducive for learning					
The workshop venue was conducive					
The refreshments and lunch were nicely prepared and served on time					
The transport allowance was fair and motivating					

6. Provide any further comments regarding your experience of the above aspects of the workshop;

____

____

____

Participants' learning from the workshop

7. Please indicate in the following statements the degree you have agreed or disagree.

Workshop activities	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
After participating in this workshop my awareness and understanding of the activity based teaching and learning approaches was enlightened					
The demonstration of the lessons with video show made me consider practicing the activity-based teaching and learning					
After studying the exemplary lessons and practicing the design of these lessons I am convinced that I can put it into practice in my class					
The micro-teaching and feedback sessions raised my awareness of my own teaching behaviour and knowledge about alternatives					
After attending the micro-teaching conducted by a colleague, I had a confidence to use the activity-based approach with my students.					
Following this workshop, I will start teaching my lessons by eliciting students' prior conceptions in order to make my teaching meaningful.					
I will plan and organise my biology lessons differently because of this workshop					

8. What other things do you think you have learned from this workshop?

____

____

____

____

____

9. Do you think you can use the activity-based approaches and 5Es instructional sequence addressed by exemplary curriculum materials in your school? Please explain briefly your answer.

____
____
____
____

Thanks very much for participating in this study

Appendix C3: Students' attitude questionnaire

Dear Students, the following statements aim at determining your attitudes towards biology and the teaching and learning process. Please indicate the extent of agreement for each statement by ticking **(√)** the appropriate box.

Attitudes statements	Strongly disagree	Disagre e	Neutral	Agree	Strongly agree
Biology is very interesting to me					
I am very interested doing activities in biology class					
Biology is fascinating and fun					
I am always under terrible anxiety in biology class					
I have a good feeling toward biology					
Biology is the subject that I dislike the most					
I feel more relaxed in a biology class than in any other class					
It makes me nervous discussing and asking questions for our biology teachers					
I enjoy doing biology lesson activities					
It makes me nervous doing biology lesson experiments					
Biology makes me feel secure, and at the same time is stimulating					
I approach biology with a feeling of hesitation.					
I feel at ease working with biology group activities					
Doing group work with my classmates makes me feel uncomfortable and annoyed.					
I enjoy doing more with my hands than listening to biology teacher's explanations.					

Appendix C4: Curriculum profile-classroom observation checklist

School name ____________________

Date ____________________

Teacher's name ___________________

Lesson title ______________________________________

Class ___________________ Lesson duration ___________

Observer Name ___________________________________

Part: A

Instructions: The following table comprises statements about classroom events (performed by the biology teacher and students) at each stage of lesson development. On the right hand side there are three columns labelled '**Yes**, **Partly**, and **N/A** **Yes-**indicate that the activity was clearly performed and observed, **Partly-** indicate that the activity was partly done; and **N/A-**indicate that the activity was not performed at all by the teacher and students. Put **'X'** to indicate your observations to the appropriate statements at each stage of a lesson.

Curriculum statements about classroom events at each stage of a lesson	**Yes**	**Partly**	**N/A**
Excitement			
1) The teacher introduces a lesson by motivating activities, events, or questioning			
2) The teacher explicitly identifies students ideas and conceptions about the activity			
3) The teacher creates interest in the lesson using various techniques			
4) The teacher encourages students to ask questions to generate their curiosity			
5) The teacher elicits responses that uncover what students think about the lesson			
6) The teacher guides students to make the connection between what they know and the new lesson ideas			
7) Students seem to have a sense of what they are expected to do and start in a focused way			
8) Students show lesson interest by asking questions			

Exploration			
1) The teacher introduces to students the lesson activities/practical work			
2) The teacher encourages students to perform lesson activities in groups with a minimum support			
3) The teacher assigns the appropriate number of students for each group			
3) The teacher assigns various roles to group members.			
5) The teacher observes and listens to students as they interact with their groups.			
6) The teacher probes to re-direct the students' investigations (when necessary)			
7) Students execute lesson activities/practical work to test their prior ideas and experiences.			
8) The teacher makes sure student execute activities and use materials/equipment correctly			
9) The teacher interacts equally with all groups			
10) The teacher assists students when necessary (but not immediately)			
11)Students try alternative ideas and discuss them with others in a group			
12) The teacher provides sufficient time for students to accomplish the assigned activities.			
13) Students record observations and ideas generated when doing activities			
Explanation			
1) The teacher allows students to draw their own conclusion from the performed activities in groups.			
2) The teacher encourages students to explain the lesson concepts and definitions in their own words.			
3) The teacher asks for justification (evidence) and clarification from students.			
4) Students explain the possible solutions or answers to others (peers)			
5) Students question explanations from their colleagues.			
6) The teacher formally provides definitions and explanations for the concepts under study.			
7) Students listen to, and try to comprehend explanations offered by their teacher			
8) The teacher uses students' experiences as the basis for facilitating the new concepts			

Elaboration			
1) The teacher encourages students to apply and extend the concepts in new situations			
2) Students use previous information to ask questions, propose answers, make decisions and design experiments.			
3) The teacher guides students to understand discrepancies in their results			
4) Students record observations and explanations, and check for understanding among peers			
5) The teacher refers students to data and evidence and asks questions			
6) The teacher reminds students of alternative explanations			
7) Students draw reasonable conclusions from the evidence.			
Evaluation			
1) The teacher asks open-ended questions to assess students knowledge and skills			
2) The teacher provides general lesson conclusion/summary			
3) Students ask questions that would encourage future investigations			
4) Students demonstrate understanding of the knowledge and skills			
5) The teacher responds to questions/answers from students thoroughly.			
6) The teacher explains homework ideas/assignment.			

Part B.

General classroom observation follows up questions

1 Please provide the required information as you have observed in the classroom

a) Number of students in the class ______________________

b) Number of small groups of students__________________

c) Average number of students in a group ____________________________________

2 Was time allocated for lesson activities adequately? Please explain your answer

____

____

3 What were the specific activities used for excitement stage?

____

____

4 How does the teacher respond to the students' questions?

i) Positively
ii) Negatively
iii) Partially/surface (where necessary provide explanations)

____

____

5 Please provide a sketch of the sitting arrangement as it appeared during the lesson and if possible explain briefly. (draw in the attached paper).

6 Please briefly explain about the physical environment of the classroom, if it is inside the building what were the resources, materials, and equipment observed. If outside the building what was the context?

____

____

____

____

7 How you can summarise students' involvement and responses to the lesson activities?

____

____

____

Appendix C4a: Pre-intervention classroom observations for individual teachers

Pre-intervention classroom observations were conducted by the researcher before implementation of the new approaches in schools. The aim was to gather information about the teaching and learning of biology in the secondary schools. This activity was carried out during November 2010. A total of seven lessons were observed as outlined below:

1) *The process of photosynthesis* – Form II; teacher T1
2) *Kingdom Plantae* – Form II Teacher T2
3) *Urinary system and its adaptive features* – Form III; teacher T3
4) *Human digestive system* - Form II; teachers T4
5) *Pollination* – Form III; teacher T5
6) *Mitosis and growth* - Form IV; teacher T6
7) *Cell structure and function* – Form I; teacher T7

Note: The colours represent the teachers' instructional practices at the lesson stages such as:

Introduction - orange

Presentation - red

Conclusion - purple

Description of the individual teachers' lesson observations

Teacher 1

The teacher started the lesson by collecting the previous lesson's assignment from students for examination before asking two questions about the previous lesson and one question about the new lesson. The questions were on the *meaning of nutrition*, the *types of nutrition* and the *meaning of photosynthesis*. Students' answers for the second question were superficial which required further attention from the teacher to justify students' prior knowledge. The teacher ignored this aspect and continued asking other students.

Nevertheless, students' responses for the questions asked were not considered when the teacher introduced the lesson about *photosynthesis.*

The teacher explained the process of *photosynthesis* in plants by considering the materials, conditions and products. Students were directed to observe the diagrams in their text books which illustrate experiments to find out whether *chlorophyll* and *light* are necessary factors for the process of *photosynthesis*. Furthermore, the teacher explained the *photosynthesis* equation from students' text books and how the products from this equation could be detected. Students did not comment or ask anything from the teacher's explanation or the experiments they read from their text books. Similarly, the teacher did not encourage students to do so; the whole lesson was dominated by the teacher's explanation. Students were given 10 minutes to copy the lesson notes and diagrams from the blackboard and their textbooks.

The teacher provided a brief summary of the lesson before she asked two questions to test students' mastery of the lesson concepts, e.g. *Where does photosynthesis occur? What are the conditions necessary for photosynthesis to happen?* These questions were short and simple because their answers could be read from the teachers' notes. Even at this time there were no questions from the students. Students were assigned to write the importance of *photosynthesis* as part of their homework assignment which according to the teacher's lesson plan was a part of the following lesson.

Teacher 2

The teacher started her lesson by asking questions on the new topic about the *kingdom Plantae* in order to capture students' prior conceptions, i.e. *What are the features of the members of the plant kingdom?* Students provided answers to this questions which were summarised by the teacher on the blackboard, but the teacher wrote only answers from the students that were correct and ignored the wrong or unrelated answers. While students' answers were kept on the blackboard the teacher started the new lesson through explanation of the *features* and the *divisions of the kingdom Plantae* without any reference to the students' previous experiences. The teacher's lesson explanation took 40 minutes and exclusively based on her lesson notes without any teaching and learning materials such as varieties of plants that could support students in the identification of the main features of the *kingdom Plantae*. Students remained passive listeners sometimes, taking notes from the teacher's explanations.

This lesson was poorly ended, i.e. apart from being teacher led; students had no opportunity to reflect on the lesson concepts. The question asked by the teacher about the distinctive features of the *kingdom Plantae* was answered by a few students which suggested that the majority of students did not follow or understand the lesson. The teacher did not provide homework activity.

Teacher 3

The lesson started by the teacher asking one question from the previous lesson about *excretory organs* in human beings which guided the whole class discussion. Two students provided short answers but could not clearly explain the differences among the mentioned *excretory organs*. The teacher did not appear to care about the depth and diversity of students' answers/explanation; she just moved to the new lesson about the *urinary system*. The teacher's presentation exclusively depended on her lesson notes. On one occasion the teacher showed students a diagram illustrating the human *excretory system* in order to identify the main parts. Students looked uncomfortable with this diagram (i.e. It was difficult to relate the teacher's explanation about *urinary system* and the diagram in order to draw a meaningful understanding of how the different parts of the *urinary system* were adapted to their roles) because this diagram was provided at the end of the teacher's explanation of the lesson facts and was meant for students to copy rather than to learn by engaging with it during the explanation. Students were not given an opportunity to reflect or comment on the teacher's presentation or the diagram. They had to copy the provided notes and diagram before the next teacher's lesson.

The teacher asked two simple questions and because their answers were obvious from the provided notes, this deprived students from making any critical reflection of the taught concepts e.g. *Name the four organs of the urinary system? What is the function of a nephron?*

Teacher 4

The teacher was somewhat weak in subject content knowledge and also not very good in comprehending students' contribution to the lesson. The whole lesson was teacher-driven. The teacher started the lesson by explaining the topic and what students had to learn. She continued explaining about the structure of the *alimentary canal* without explaining its meaning or asked students to do so before she could move to the *digestive process* in the human being. The teacher supported her explanation with a small diagram on the A3 paper which could not easily observed by all students in the class. The class was completely dull with the majority of students making noises because they failed to follow their teacher's presentation as well as the diagram.

The teacher used most of the lesson time to write notes on the blackboard for students to copy at the same time assigning one student to draw the diagram for others to copy. By the end of the lesson students were given a task i.e. *to explain the digestive process in the following parts of human alimentary canal: the mouth, stomach and small intestine*. Students were told to discuss their answers in small groups of 5 with the possibility of presenting their answers during the next lesson.

Teacher 5

The teacher started her lesson by asking questions from the previous lesson on the *reproductive parts of the flower*. Students' answers included naming of the parts and their functions. Students provided haphazard answers which could indicate poor understanding of the learned concepts. The teacher did not ask for clarification and completely ignored the conflicting answers provided by her students. The teacher spent only about 7 minutes in this part before she started the new lesson on *pollination.*

The teacher explained the meaning and types of *pollination*. The teacher's explanation was supported by a diagram of the *hibiscus* flower illustrated on the blackboard. The teacher's explanation of the lesson and the use of the diagram were not sufficient enough to explain the whole concept of *pollination* and the types. Therefore, it was difficult for students to identify and understand the types of *pollination*. The teacher continued with the lesson explanation at the same time writing lesson notes on the blackboard for students to copy in their exercise books. These parts of a lesson consumed ¾ of the lesson time, i.e. 80 minutes where by neither the teacher nor the students asked or commented on anything about the lesson.

The teacher ended her lesson by asking questions based on the provided notes, e.g. *What is pollination? Explain the difference between self-pollination and cross-pollination.* Three students responded to the teacher's questions through reading the answers from their notes (for the first question) but were unable to answer the second question clearly because they couldn't find the direct answers from their notes and their teacher did not encourage students to think about this question or comment on students' answers, she just assigned them a homework task, i.e. *to explain the importance of pollination.*

Teacher 6

The teacher introduced the lesson by asking two questions from the previous lesson about the *meaning* and *factors* affecting the growth in plants and animals. Most students wanted to answer these questions but the teacher allowed only four students who did not provide the correct explanations for the two questions. However, the teacher didn't comment on the students' diverse answers, and she continued with the new lesson about *mitosis in relation to growth.* The teacher was confident in the subject content knowledge based on her explanation of the lesson facts but she completely ignored students' involvement. On one occasion students were told to observe the stages of *mitosis* from the prepared flip charts. But as in the case of previous lessons the students' main activity was to copy notes provided by their teacher. This situation was not conducive for students to ask any question or reflect on the teacher's explanation, they just remained passive listeners and tried to copy everything the teacher said or wrote on the blackboard.

The teacher ended the lesson by asking a few questions which did not encourage students' reflection on the taught concepts, e.g. *mention the stages of mitosis*. Students' answers to these questions were directly read from the teacher's notes while other students were still copying notes from the blackboard. The teacher provided a homework task about reading about the significance of *mitosis in the growth* process but students were not clear about the specific things they needed to focus on for this assignment.

Teachers 7

As for the case of the previous lessons the teacher introduced her lesson through asking questions from the previous lesson about the *cell concept and characteristics*. Only few students were ready to answer the questions. The students lack confidence and their answers were superficial which did not impress their teacher. The teacher highlighted the main concepts in the previous lesson before she could introduce the new lesson about the *types of the cells.* Neither students have opportunities to reflect or comment on the teacher's explanation nor does the teacher encouraged students to do so. The teacher explained about the plant and animal cells while writing and drawing the two types of cells on the blackboard for students to observe and copy in their exercise books. The students remained passive listeners and observers of the teacher's blackboard illustrations. The teacher provided students with 15 minutes to accomplish the writing of the lesson notes thereafter provided a summary of the lesson before she could provide homework assignment which required students to explain the similarities and differences between the plant and animal cells. Students were given one day to accomplish this task and submit for examination.

Appendix C4b: Group A and B micro-teaching profile practice scores
(i.e.100% = all items for each stage were met in full)

Statements about classroom events at different stages of the lessons	GROUP A: Scores				GROUP B: Scores			
	Yes =2	Partly = 1	N/A =0	Total Scores	Yes =2	Partly = 1	N/A = 0	Total Scores
Excitement								
1) The teacher introduces a lesson by an activity or through brainstorming	2	0	0	2	2	0	0	2
2) The teacher explicitly identifies students ideas and conceptions about the activity	2	0	0	2	2	0	0	2
3) The teacher creates interest in the lesson by using various techniques	2	0	0	2	2	0	0	2
4) The teacher encourages students to ask questions to generate their curiosity	0	1	0	1	0	1	0	1
5) The teacher elicits responses that uncover what students think about the lesson	0	1	0	1	2	0	0	2
6) The teacher guides students to make connections between what they know and the new lesson ideas	2	0	0	2	2	0	0	2
7) Students seem to have a sense of what they are expected to do and start in a focused way	0	1	0	1		1	0	1
8) Students show lesson interest by doing practical work and asking questions	0	0	0	0	0	1	0	1
Total scores for Excitement in percentage				**11/16 = 69**				**13/16= 81**
Exploration								
1) The teacher introduces to students the lesson activities/practical work	2	0	0	2	2	0	0	2
2) The teacher encourages students to perform lesson activities in groups with a minimum support	0	1	0	1	2	0	0	2
3) The teacher assigns the appropriate number of students for each group	2	0	0	2	2	0	0	2
4) The teacher assigns various roles to	0	0	0	0	0	1	0	1

group members.								
5) The teacher observes and listens to students as they interact with their groups.	2	0	0	2	2	0	0	2
6) The teacher probes to re-direct the students' investigations (when necessary)	0	1	0	1	0	1	0	1
7) Students execute lesson activities/practical work to test their prior ideas and experiences.	0	1	0	1	2	0	0	2
8) The teacher makes sure student execute activities and use materials/equipment correctly	2	0	0	2	2	0	0	2
9) The teacher interacts equally to all groups	0	2	0	1	2	0	0	2
10) The teacher assists students when necessary (but not immediately)	2	0	0	2	2	0	0	2
11) Students try alternative ideas and discuss them with others in a group	2	0	0	2	2	0	0	2
12) The teacher provides sufficient time for students to accomplish the assigned activities.	2	0	0	2	2	0	0	2
13) Students record observations and ideas generated when doing activities	0	2	0	1		1	0	1
Total scores for Exploration in percentages				**19/26 = 73**				**23/26 = 88**
Explanation								
1) The teacher allows students to draw their own conclusion from the performed activities in groups.	2	0	0	2	2	0	0	2
2) The teacher encourages students to explain the lesson concepts and definitions in their own words.	2	0	0	2	0	1	0	1
3) The teacher asks for justification (evidence) and clarification from students.	0	1	0	1	2	0	0	2
4) Students explain the possible solutions or answers to others (peers)	0	1	0	1	2	0	0	2
5) Students question other explanations from their colleagues.	0	0	0	0		1	0	1
6) The teacher formally provides definitions and explanations for the concepts under study.	2	0	0	2	2	0	0	2
7) Students listen to, and try to comprehend explanations offered by their teacher	0	1	0	1	0	1	0	1
8) The teacher uses students' experiences as the basis for facilitating the new concepts	2	0	0	2	2	0	0	2

Total scores for Explanation in percentage				**11/16= 69**				**13/16 = 81**
Elaboration								
1) The teachers encourage students to apply and extends the concepts in new situations	2	0	0	2	2	0	0	2
2) Students use the previous information, to ask questions, propose answers, make decisions and design experiments.	2	0	0	2	2	0	0	2
3) The teacher guides students to understand discrepancies in their results	0	0	0	0	0	1	0	1
4) Students record observations and explanations, and checks for understanding among peers	0	1	0	1	0	1	0	1
5) The teacher refers students to data and evidence and asks questions	0	1	0	1	2	0	0	2
6) The teacher reminds students of alternative explanations	0	1	0	1	0	1	0	1
7) Students draw reasonable conclusions from the evidence.	0	1	0	1	0	1	0	1
Total scores for Elaboration in percentage				**8/14 = 57**				**10/14= 71**
Evaluation								
1) The teacher asks open-ended questions to assess students knowledge and skills	0	1	0	1	2	0	0	2
2) The teacher provides general lesson conclusion/summary	2	0	0	2	0	1	0	1
3) Students ask questions that would encourage future investigations	0	0	0	0	2	0	0	2
4) Students demonstrate understanding of the knowledge and skills	0	1	0	1	0	1	0	1
5) The teacher responds to questions/answers from students thoroughly.	0	0	0	0	0	1	0	1
6) The teacher explains homework ideas/assignment.	2	0	0	2	2	0	0	2
Total scores for the Evaluation stage				**6/12 = 50**				**9/12 = 75**
Average Total Scores in percentages				**65**				**79**

Appendix C4c: Post-intervention teachers' classroom observation scores
(i.e.100% = all items for each stage were met in full)

Statements about classroom events at each stage of a lesson	**Teachers from school 1 and 2**						
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
Excitement							
1) The teacher introduces a lesson by an activity or through brainstorming	2	2	1	2	2	2	2
2) The teacher explicitly identifies students ideas and conceptions about the activity	2	2	1	2	2	2	2
3) The teacher creates interest in the lesson by using various techniques	2	2	1	1	2	2	2
4) The teacher encourages students to ask questions to generate their curiosity	2	1	0	1	2	1	2
5) The teacher elicits responses that uncover what students think about the lesson	1	1	1	1	1	1	1
6) The teacher guides students to make connections between what they know and the new lesson ideas	1	0	1	1	1	1	1
7) Students seem to have a sense of what they are expected to do and start in a focused way	2	1	1	2	1	1	2
8) Students show lesson interest by doing practical work and asking questions	1	1	0	1	1	1	1
Total Excitement scores in percentage	**75**	**63**	**46**	**69**	**75**	**69**	**75**
1) The teacher introduces to students the lesson activities/practical work	2	2	1	2	2	2	2
2) The teacher encourages students to perform lesson activities in groups with a minimum support	2	2	1	1	2	1	2
3) The teacher assigns the appropriate number of students for each group	2	2	2	2	2	2	2
4) The teacher assigns various roles to group members.	1	1	0	1	1	1	2
5) The teacher observes and listens to students as they interact with their groups.	2	2	1	2	2	2	2
6) The teacher probes to re-direct the students' investigations (when necessary)	1	1	0	1	1	0	1
7) Students execute lesson activities/practical work to test their prior ideas and experiences.	2	2	2	2	2	2	2
8) The teacher makes sure student execute activities and use materials/equipment correctly	2	2	1	2	2	2	2
9) The teacher interacts equally to all groups	2	2	1	2	2	2	2

10) The teacher assists students when necessary (but not immediately)	2	2	1	2	2	2	2
11) Students try alternative ideas and discuss them with others in a group	2	1	1	1	1	2	2
12) The teacher provides sufficient time for students to accomplish the assigned activities.	2	1	1	1	2	2	2
13) Students record observations and ideas generated when doing activities	2	2	2	2	2	2	2
Total Exploration scores in percentages	**92**	**85**	**54**	**81**	**88**	**85**	**96**
1) The teacher allows students to draw their own conclusion from the performed activities in groups.	2	2	1	1	2	2	2
2) The teacher encourages students to explain the lesson concepts and definitions in their own words.	2	2	1	1	2	2	2
3) The teacher asks for justification (evidence) and clarification from students.	2	1	0	2	2	2	2
4) Students explain the possible solutions or answers to others (peers)	2	2	2	1	2	2	2
5) Students question other explanations from their colleagues.	1	1	1	2	1	1	1
6) The teacher formally provides definitions and explanations for the concepts under study.	2	2	2	2	2	1	1
7) Students listen to, and try to comprehend explanations offered by their teacher	2	2	1	1	1	2	1
8) The teacher uses students' experiences as the basis for facilitating the new concepts	2	2	1	1	1	1	2
Total Explanation scores in percentages	**94**	**87**	**56**	**62**	**87**	**81**	**81**
1) The teachers encourage students to apply and extends the concepts in new situations	2	2	2	2	2	2	2
2) Students use the previous information, to ask questions, propose answers, make decisions and design experiments.	2	1	1	2	2	2	2
3) The teacher guides students to understand discrepancies in their results	2	1	1	1	2	2	2
4) Students record observations and explanations, and checks for understanding among peers	1	2	0	1	1	1	1
5) The teacher refers students to data and evidence and asks questions	2	1	1	1	2	1	2
6) The teacher reminds students of alternative explanations	1	1	0	1	2	1	1
7) Students draw reasonable conclusions from the evidence.	1	1	1	1	1	2	1

Total Elaboration scores in percentages	**79**	**64**	**43**	**64**	**75**	**79**	**79**
1) The teacher asks open-ended questions to assess students' knowledge and skills	2	2	1	1	2	2	2
2) The teacher provides general lesson conclusion/summary	2	2	2	2	2	2	2
3) Students ask questions that would encourage future investigations	2	2	1	1	1	0	1
4) Students demonstrate understanding of the knowledge and skills	1	1	0	1	1	1	1
5) The teacher responds to questions/answers from students thoroughly.	2	2	1	2	2	1	2
6) The teacher explains homework ideas/assignment.	2	2	1	2	2	2	2
Total Evaluation scores in percentages	**92**	**92**	**50**	**75**	**83**	**67**	**83**
Average teacher scores in percentages	**86**	**78**	**52**	**70**	**82**	**76**	**83**

Appendix C4d: Description of post-intervention classroom observations for individual teachers

Post-classroom observations were carried out by the researcher in collaboration with the assistant researcher during May 2011. The aim was to examine teachers' changes and improvement in their classroom instructional approaches following the adoption of the new teaching and learning approaches, i.e. the activity-based approach supported by the 5Es instructional sequence. The observed lessons were:

1) *The concept of the environment* –Form II; teacher T1
2) *Drugs and drugs addiction* – Form III; teacher T2
3) *Reproduction in animals* – Form IV; teacher T3
4) *Classification systems* - Form I; teachers T4
5) *Human skeleton* – Form III; teacher T5
6) *The process of Germination* Form IV; teacher T6
7) *Food substances* – Form II; teacher T7

The general description of the individual teachers' classroom practices

Note: The colours represent the instructional practices at each stage in the 5Es instructional sequence.

Excitement – **orange**

Exploration- green

Explanation –red

Elaboration - blue

Evaluation - purple

Teacher T1

The teacher had a plan showing students' activities at the beginning of the lesson. She assigned all students in the class to observe the outside environment through the class windows and doors in order to identify different things as much as they could. Thereafter, the students were organised in groups of six in order to discuss the meaning of an *environment based on their observations.* Students' answers were written on the blackboard for others to reflect and comment before the teacher introduced other lesson activities. Students were guided to performed field work activities in order to test their prior conceptions about the meaning and components of the environment as a result of the previous activity. The teacher provided each group with a field guide paper and required students in groups to find the answers for each component. The teacher was also going around each group in order focus their observations through asking questions and/or answering questions from students and sometimes helping students who could not record their observations. Students were reminded about the time for these activities (i.e. 30 minutes).

After students completed the field work, each group was guided to present their findings. They were further required to use their findings to answer the following questions: *How many organisms have you observed or collected? Explain the specific areas where you have found your organisms. Have you noticed any kind of relationship among your organisms*? If the answer is '*yes', can you provide examples of relationships among your organisms*? *How can you explain the meaning of environment from what you have observed?* Students provided answers to these questions by making the conceptual connections between the knowledge obtained from their observations and prior experiences. The teacher summarised the key facts from students' explanations and facilitated the content knowledge based on students' prior experiences and findings. The teacher referred to students presentation and corrected misconceptions retained in students' explanations such as; '*an environment is the area with living things*' this was a definition presented by two groups. In order to ensure students understood the lesson the teacher guided the whole class discussion by following questions: *What can you say about the importance of having different environments? Explain any kind of interaction you have identified during the field work. What is the importance interaction of organisms to the environment?* This activity teacher encouraged students to apply and extend the concepts learned from the previous lesson stages.

Many students wanted to provide answers for these questions and on two occasions, students provided answers which were not connected to the previous activities. The teacher took this opportunity to remind students to support their answers and explanations with their fieldwork experiences and their presentation which could enhance their understanding. The teacher then provided a summary of the key concepts of the lesson (i.*e. biotic and abiotic factors*) followed by an open-ended question which provided students an opportunity to demonstrate their understanding and conceptual changes e.g. *explain the importance of the feeding relationships among the observed organisms*. The teacher also provided students with a homework activity to further extend what they learned during the lesson, i.e. *identify any habitat and explain how it is suitable for particular organisms of your interest.*

Teacher T2

This lesson started by the teacher providing students (in groups of 6) with posters, brochures, and duplicated diagrams, and pictures about different drug addiction practices of. Students were encouraged to observe and read the provided explanation for each case in order to answer the following questions i*) Explain the meaning of drug addiction,* ii*) Identify the different types of drug addiction, and* iii*) Explain why some people become addicted and others not?* While three groups showed unfamiliarity with the assigned lesson activities, the teacher somehow was less supportive to encourage these students to answer the questions. Two students were given opportunities to comment or ask questions about their fellows' presentation. The teacher summarised some of the students' findings on the blackboard before she explained the lesson objectives and required students to remain in their groups for further lesson activities. The teacher guided students in the small groups to discuss and present their findings about problems associated with drug addiction and their preventive measures. In order to save time the teacher assigned 3 groups to work with problems associated with drug addiction and the other 3 to work with the preventive measures. The teacher supervised students' discussion by asking questions in order to focus their discussion and learning from the activities they were doing. Each group leader organised the answers for presentation.

During presentation the teacher encouraged students to share and contribute their experiences to what was presented by their colleagues. The teacher facilitated the lesson content knowledge by referring to the concepts presented by different groups. While students were trying to conceptualise the factual explanations from their teacher, they had to explain the examples of drug addiction in their society and what they think could be the preventive measures. Three students had opportunities to present their cases which demonstrated the extent of their understanding of the previously lesson concepts. The teacher probes students to ensure that a meaningful understanding took place. This could have helped the student to reflect on the lesson activities in relation to the teacher's explanation of the lesson.

The teacher asked students questions to identify what they learned from the lesson in order to make a self-assessment. Most of students responded positively. They were also assigned a homework activity in groups, i.e. to *demonstrate different roles associated with drug addiction and preventive measures*. Each group had to present this activity at the beginning of the next lesson.

Teacher 3

The teacher did not look well prepared at the beginning of her lesson. She started her lesson by asking her students general questions about the previous lesson (*reproduction in the flowering plants*) which did not focus on stimulating students' curiosity and/or the prior conceptions apart from recalling factual information. The teacher did not probe further with questions about the new lesson instead; she continued explaining about the lesson and ignored students' responses. As the lesson continued students were organised into groups and assigned to discuss the different parts of *human reproductive system* and their functions. The teacher was less supportive to students' group activities and did not provide sufficient time to accomplish their tasks (i.e. 10 minutes). The teacher rushed to explain the lesson facts based on her lesson notes with the support of the two diagrams about *human male and female reproductive systems* and ignored the students' experiences from the group discussion therefore, it was not clear why students were told to discuss in the small groups. The teacher's explanation of the lesson facts consumed most of the lesson time (i.e. 30 minutes). Eight students wanted to ask questions about this lesson but the teacher responded to only three questions from students. At the same time, the teacher asked two general questions which required only short answers from the students and therefore discouraged further discussion and reflection about the taught concepts, *i.e. What are the main parts of the male reproductive system? What are the functions of the female reproductive system?*

Although much of the lesson time was consumed by the teacher's explanation of the lesson facts two students asked their teacher the following questions: *What are the functions of the glands associated with the male reproductive system? How fertilisation does takes place in the fallopian tubes?* The teacher could not provide the answers for these questions because the lesson time was over and instead, she promised to provide their answers during the next lesson.

Teacher 4

The teacher was well organised and started her lesson by small group activities which included grouping of the plant leaves followed by the discussion about their differences and similarities. Students were actively involved in classifying the plants leaves into several groups and were able to provide reasons for their choices. Four students asked questions about their types of the leaves. The teacher encouraged each group to explain the reasons for grouping their plant leaves. After 15 minutes students provided diverse findings which represented their prior conceptions about grouping of living things. This was followed by the teacher's explanation of the new lesson about *classification systems* and required students to remain in their previous groups for further lesson activities. For the second activity students were provided with preserved animal specimens to classify and grouping had to base on: what they eat, where they live, how they move, and their body size. Students were required to write all the features they considered in grouping the provided animals. The teacher supervised students activities by asking guiding questions and helping few groups on how to observe different features by using equipment such as hand lens. Students looked active and interested with grouping of the animal specimens.

Each group was given the opportunity to present their findings and these differed among the groups. Other students were invited to comment on their fellows' presentations especially on the reasons they based to classify their organisms. The teacher finally taught the lesson content knowledge (i.*e. artificial and natural classification systems)* but she didn't always referred to students' experiences from the activities which could help her students to conceptualise the concept of classification systems and acquired meaningful understanding.

As the lesson progressed students were provided with different specimens from the previous ones in order to demonstrate the taught concepts and facilitate understanding through the application of the acquired knowledge and skills. The specimens were: *tilapia fish, butterflies, small snakes, snails, bat, earthworms, birds and frogs*. Students classified each of them based on the knowledge and skills from the previous lesson activities. They were asked to report how many groups they obtained and what criteria they used. All students were able to categorise the specimens but, two groups did it through trial and error, i.e. without providing specific features of the groups which was an indication that the previous lesson stages were not quite clear to these students. The teacher tried to encourage students to use the experiences from the previous lesson activities in order to identify the correct groups for the given specimens and their characteristics. This helped students to identify the features for each group. Following this activity the teacher guided the whole class discussion by asking students to explain what they learned from the lesson and *how the artificial classification system differed from natural classification system*. Students provided explanations for these concepts and at the same time used this opportunity to reflect on their conceptual changes and perform a self-assessment. The teacher finally provided a homework task about how they can group the organisms of their interest from their environment based on the *natural classification system.*

Teacher 5

This teacher was very active in stimulating students in the whole lesson through her easy and friendly way of communicating with students. As the lesson started she invited a few students to explain and demonstrate their knowledge about the human skeleton in order to identify how the different parts can support movement. Students participated actively to draw on the flip charts while others explained about the structure of the human skeleton. Students' explanations and diagrams were kept on the blackboard for further discussion and reflection. As the lesson continued, the teacher guided students in small groups to perform several lesson activities. Each group was provided with a model of the human skeleton and the associated parts (*i.e. bones, cartilages and joints*) together with other models of vertebrae. Students observed and discussed how each part supported movement in the human body. The teacher moved around the groups to guide and help students who faced difficulties in making observations or not knowing the vertebrae. Students' discussion was summarised on the flip charts for presentation. Each group had opportunity to present their findings for other students to compare and provide their comments. The teacher asked students to explain some parts of their presentation with evidence from their observations. This was followed by teacher's facilitation of the lesson content knowledge based on students' presentations in order to ensure connectivity and in-depth understanding of the lesson. Few students took this opportunity to ask their teachers questions. The teachers responded to students' questions in a positive way, giving additional information about the performed lesson activities

The teacher further guided students to explain how the different parts of the skeleton in other animals such as birds or reptiles support their body movements. Students tried to provide explanations which demonstrated the extents of understanding the taught concepts. The teacher probes few students who failed to relate their explanation with the evidence from the previous experiences and with the model of human skeleton. Thereafter, the teacher highlighted the key concepts of her lesson such as; the meaning of skeleton, the components and their adaptation to support movements in the body. One student asked a question *about how a human body performed functions involving bending without tearing or breakage.* The teacher responded by initiating a short discussion guided by this question and reminded students about the models of human skeleton, the *vertebral column*, *vertebrae* associated with it, and how they supported movements of different parts of the body. Most students were active participants in the discussion but the lesson time was over. The teacher provided the homework assignment which required students to draw the diagrams (e.g. the *thoracic*, *lumbar*, and *sacral vertebrae*) and explain how they are adapted to support movements in the body.

Teacher 6

The teacher was quite confident during the lesson which began by inviting three students at a time to explain and illustrate their conception about seed germination. Other students were given opportunities to ask questions and where possible to present alternative illustrations about seed germination. Students' illustrations were summarised on the blackboard for students to refer during the next activities.

For the first activity students were guided to discuss (in group of 6) about conditions necessary for seed germination which they will consider when designing their experiments. Within 20 minutes each group presented their findings summarised on the flip charts. The teacher invited other students to share the information from other groups and encouraged them to comment or ask questions. The teacher facilitated the discussion about the conditions necessary for seed germination in relation to students' presentations which helped most of students to acquire an understanding of the factors necessary for seed germination.

For the second activity students in their respective groups were assigned to design experiments on seed germination by testing the previously identified factors. The teacher provided the guiding questions such as: *write the aim of the experiment, the materials and procedures*, record *the changes happened to each type of the seed until they germinate and finally, draw a well labelled diagram of any two types of germinating seeds.*

As the lesson continued students developed the plan of their experiments with a support of the acquired knowledge and skills from the previous lesson activities. The teacher moved around the groups in order to support students with skills of designing experiments. Most students were eager to know how to design experiments; they were busy in collecting the respective equipment and materials. Students were reminded to set up their experiment carefully and would expect to have the results after 3-4 days.

Teacher 7

This lesson was well planned and the teacher was very cooperative with her students from the start to the end of the lesson. Students were guided to explain with examples, the meaning and types of food substances by using their everyday experiences. Every student in the class was asked to provide his/her experience. The teacher summarised students' experiences on the blackboard for other students to reflect on. This was followed by the explanation of the new lesson about *food substances and their properties*.

The teacher displayed seven groups of food materials in front of the classroom for students in group of 6 to identify their types and functions in the human body. Most students enjoyed doing this activity because they were familiar with the food materials, but they had problems in identifying their properties as well as their function in the body. The teacher provided support to specific groups which asked questions or required further explanation. Students were provided sufficient time to accomplish their activities. After 30 minutes each group was guided to present their findings in terms of the type of food substance, where it is found, the properties, and its function in the body. Other students were encouraged to ask questions or to provide their experiences. None of the groups mentioned all the information required. Two groups had incorrect information about the properties and functions of their food substances, e.g. vitamins and fats/oils. The teacher facilitated this part of the lesson based on the students' findings. She explained clearly by using the problems experienced by her students during observations and discussion in order for students to acquire meaningful understanding.

The teacher further provided her students with alternative activity in order to help them demonstrate their understanding of food substances. This time students observed the pictures showing various food materials on the big wall chart. The teacher asked them to identify their specific groups with at least two reasons. Most students were able to classify the food materials into specific groups of food substances, but few did so through trial and error, i.e. without knowing the reasons. The teacher took this opportunity to remind students about the learned concepts from previous lesson activities in order to ensure that they understood the lesson.

Furthermore, the teacher encouraged her students to ask questions about what they had learned. One of the students asked; *how food substances such as vitamins maintained in the preserved food materials such as vegetables and fruits?* As in the case of teacher T5 this teacher re-directed the question to guide a whole class discussion which encouraged other students to contribute and share their experiences which reflected their level of understanding of the lesson. The teacher summarised the key concepts of the lesson and finally provided a homework activity to be done individually, i.e. *Explain the deficiency of any three food substances in the human body.*

Appendix C5: Biology teachers' reflective interview

The following questions seek your general impression about using the activity-based approach and the the 5Es instructional sequence in the teaching and learning of biology in your classroom.

1. What is your general view about using the activity-based approach and and the 5Es instructional sequence?

2. How were curriculum materials and the professional development workshop supportive for your lesson preparation and teaching?
3. How does your teaching enhanced student participation in your lesson? Were there any difference from the previous/regular biology lessons?

4. Do you think your students liked the approaches you have adopted? Please explain your answer?

5. Were there any specific problems or challenges in using the new approaches with your students or yourself?

Thanks very much for your cooperation

Appendix C6 : Student valuation questionnaire

Dear Student,

The following questions aim at looking your general perception of the activity-based teaching and learning approach used by your teachers during the lesson. Please write your answers in the provided spaces. The information you provide in this questionnaire will only be used to this study and not otherwise.

Preliminary information

Your school name; ____

Your class/Form level; ____

Your Age; _________years Gender; _________________

1. In the following tables indicate with explanations different lesson activities you favoured or unfavoured during the lesson

Table 1: Favoured lesson activities

Favoured lesson activities	Explanations

Table 2: Unfavoured lesson activities

Unfavoured lesson activities	Explanations

2. How did the lesson differ from your regular biology lessons?

____

____

3. Provide examples of the lesson activities you were involved during biology lesson sessions

4. In what ways your involvement in the lesson activities has benefited the process of learning and understanding of biology?

5. What problems or challenges faced when involved in doing lesson activities

6. Write down any other suggestions or comments about your involvement in today's biology lesson

Thanks very much for your cooperation

Appendix C7: Students focus group interview?

The following questions seek information about how students perceived the use of the activity-based teaching and learning approaches in their classroom.

1. Teachers' role as a facilitator

a) Do you think your biology teacher used to prepare herself for biology lessons? If 'yes' in what ways, could you briefly explain? If 'no' why not?
b) What were the lesson activities your biology teachers used to provide in the classroom as he/she started and end the lesson?
c) Does your teacher assist you while doing lesson activities? If 'yes' in what ways? Could you explain how? If 'no' why not?
d) Does your teacher encourage you to ask questions? How?
e) Does your teacher interact with and respond positively to your questions/answers? Please explain your answer.

2. Assessment of students' prior knowledge

a) Does your teacher try to find what you already know about the lesson at hand? If 'yes' can you explain how, if 'no' why not?

3. Lesson activities

a) Of the activities you performed in the biology lessons which ones did you like most? Please provide some reasons.
b) Did you find the activities meaningful in the understanding of the lesson concepts? If 'yes' could you give some examples? If 'no' explain briefly how the lesson activities were meaningful to you?
c) Do you think that everybody in the class understood this lesson? or were there some confusion or problems experienced?
d) To what extent can you say that the methods used in today's lesson differ from your previous biology lessons (before the introduction of activity-based approaches?)
e) Do you have any suggestions or comments or any other thing you would like to say about today's lesson activities which might be useful to you in the understanding of biology?

Thanks for participating

Appendix C8: Biology teachers' Level of Use interview (LoU) scheme

Description of levels of use of innovation

Category	Level of use	Characteristics	Teachers behaviours
Non users	0	Non use	Takes no action with respect to the innovation
	1	Orientation	Seek information about the innovation
	2	Preparation	Prepares for the first opportunity to use
Users	3	Mechanical	Focuses on day-to-day use, which tends to be disjointed, and superficial with little insights.
	4	Routine (4A)	Establishes an appropriate pattern of use with little preparations.
		Refinement 4B)	Varies use within the context to improve the impact on students.
	5	Integration	Makes deliberate efforts to coordinate with others in using the innovation.
	6	Renewal	Seeks more effective alternatives to the established use of the innovation

Dear Teachers,

The following questions are intended to gauge the effect of the new approaches you have adopted concerning the integration of activity-based teaching and learning and the 5Es instructional sequence into your lesson planning and teaching

A. Level of Use that define non-users

i. Are you using the activity-based teaching and learning approach in your lessons? If the answer is 'No' then the follow-up questions are

(a) Are you looking information about involving students in the lesson activities?

- No (*level 0 nonuser*) or
- Yes (*level 1 orientation*)

(b) Do you intend to use activity-based approaches for your lessons sometimes in the coming days?

- Yes and he/she specifies when to do so (*level 2. Preparation*)

B. Levels of Use that define users

If the answer is 'Yes' for (**i**) then the follow-up questions are:

(a) What kinds of activities are you engaging your students or what are you doing regarding your use of the activity-based approaches for your lessons?

- *Indicates that he/she is actively engaged with the activity-based approaches and is making adaptations in order to master the use of activity-based lessons in his/her classroom,*
- *There is a day-to-day focus on planning and general inefficiency in how to engage students in the lesson activities,*
- *He/she is endeavouring to make the necessary change in terms of adapting the activity-based approaches, managing time and other logistics.*

Decisions: he/she can be categorized to be in *Level of Use 3, mechanical*. Teachers at this level they may need assistance and support to iron out their daily classroom enactment, provision of curriculum materials, and instructional presentation.

- *Indicates that he/she thinks has established a regular way or pattern of integrating activity-based approaches in his/her lessons and does not need to make any effort to change or do adaptations;*
- *Indicates his/her use of activity-based lessons is stabilised and right now he/she think or see no reasons to make changes regarding his/her use of activity-based lessons;*
- *Indicates he/she is doing impact assessment and making changes to improve it.*

Decisions: he/she deserves applause for achieving a *Routine (levels 4A &4B)*

ii. Are you coordinating your use of the activity-based approaches with other users, including others in different departments? If the answer is 'Yes' and if he/she;

- *Indicates making adaptations for the benefits of students and this action was done together with one or more fellow teachers;*
- *Points out some collaborative activities in the school where they carry out adaptation in their use of the activity-based teaching and learning approaches that deemed to benefit students.*

Decisions: he/she can be considered to be in *Level of Use 5, integration* (impact-oriented). The possible assistance that could be considered is creating realistically conducive conditions where fellow teachers who wish to collaborate could do so.

Follow up question for (ii)

(a) Are you planning or exploring how to make major modifications or replace students' activity-based lessons? If the answer is 'Yes', and if he/she;

- *Indicates exploring some means to modify or replace in major ways or all together with the use of the activity-based approaches in a way that it would benefit students.*

Decisions: he/she can be labelled as in the *Level of Use 6, Renewal*. The teacher deserves kudos for achieving that and he/she may be asked to reflect and share experiences with other teachers in that respect.

If the answer is 'No' for (a): then he/she is in *Level of Use 5 (Integration).*

Appendix C9: School support questionnaire

Dear Teacher,

This questionnaire focuses on the extent of support provided to you by the school during the implementation of activity-based teaching and learning approaches in your classroom. It attempts to measure the degree to which the school's support facilitation, materials, resource, and recognition of those participants involved in the programme. Please indicate the extent to which you agree or disagree with the following statements by ticking **(√)** the appropriate box.

General information

Name of your school ____

Gender: ☐ Male ☐ Female

Your educational qualification: ☐ Diploma ☐ BEd (Sc) ☐ BSc (Ed) ☐ Med (Sc)

Teaching experience in year's: ☐ 1-5 years ☐ 6-10 years ☐ 11-15 years ☐ 16+ years

Classes/Forms you are currently teaching biology ☐ Form 1 ☐ Form 2 ☐ Form 3 ☐ Form 4

Other subjects you are teaching: ☐ Geography ☐ Chemistry ☐ Agriculture

Your teaching load per week ___________periods

Other responsibilities at your school

____

School support statements	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The physical conditions of the school (laboratory, supplies, classrooms, school compound) enhanced my implementation efforts					
The necessary facilities of the school are made available to me at the appropriate time					
I had a quiet place to plan and discuss the important issues about my work					
I had sufficient time to prepare students' activities					
I had ample time to reflect on activity-based approaches and make appropriate adoptions.					
The school encourages implementation of new strategies aimed at improving students learning					
The school administration is open to suggestions for improving instructional approaches					
Fellow teachers share my enthusiasm for experimenting with new methods for teaching					
We frequently engage in conversations about ways to improve our teaching approaches					
Fellow teachers often ask about your improvements with students					
I had opportunities to visit the classroom of fellow teachers and observe their teaching					
The headmaster is the active and enthusiastic leader					
The headmaster encourages teachers to participate in workshops intended for their professional growth.					
The school administration has schedules that allow you to collaboratively plan and discuss with fellow teachers					
The head of the school recognises and honours the teacher’s success with students’ achievement.					
You are encouraged to plan lessons collaboratively with your fellow department teachers.					

Thank you for your cooperation

Appendix C10: Biology teachers' focus group interview

This instrument aims to add more detail to the responses you provided in the school support questionnaire. Please provide additional information to the following questions. I would like to assure you that all the information you provide will be treated strictly confidentially and used for this research only.

1. How was your school administration supportive in providing the necessary materials and resources needed for the implementation of this programme?

2. Did you get enough time to prepare your lessons and reflect on them?
   Please explain briefly your answer.

3. Does the school encourage you to experiment with new teaching methods? Please explain briefly your answer.

4. In what ways does the school administration have schedules that allow you to collaboratively plan your lessons and discuss with fellow teachers?

5. How could you describe your school administration in terms of support in the efforts to improve students' learning and achievements?

Thank you for participating

Appendix C11: Achievement test

School name: ______________________________________
Student name: ____________________________________
Student class/stream: ____________________________
Examination Time: 40 Minutes: Date: May 2011.

<u>Test Instructions</u>
This test comprises of the 25 Multiple Choice test items. Read ALL questions carefully and draw a circle ◯ on an alphabetical letter indicating your *Best* answer for each question.

1. Classification of living organisms is largely based on the
   A Morphology
   B Anatomy
   C Differences
   D Similarities

2. Which one of the following represents the highest rank of classification in the taxonomy?
   A Phylum
   B Species
   C Kingdom
   D Genus

3. The system of allocating the scientific names to different organisms is called
   A Binomial nomenclature
   B Nomenclature
   C Taxonomy
   D Classification

4. Which one of the following represents the correct scientific names of human beings?
   A Homo Sapiens
   B Homo sapiens
   C Home sapiens
   D Home Sapiens

5. Which one of the following classification terminologies best shows the true relationships of living things?
   A Binomial Classification
   B Artificial classification
   C Natural Classification
   D Modern Classification

6. The wings of grasshoppers and those of birds are said to be
   A Analogous
   B Homologous
   C Similar
   D Inanimate

7. Which pair of the classification ranking system best represents the two parts of scientific names of an organism?
   A Genus and class
   B Kingdom and phylum
   C Genus and species
   D Family and species

8. Which one of the following organisms has both living and non-living characteristics?
   A Bacterium
   B Amoeba
   C Fungus
   D Virus

9. A biologist discovered a new cell in a culture which had a distinct cell wall but did not have a definite nucleus. This cell is likely to be a
   A Virus
   B Bacterium
   C Protozoa
   D Plant

10. The following groups of organisms are unicellular except
   A Paramecium
   B Amoeba
   C Spirogyra
   D Plasmodium

11. Which one of the following organisms has both plant and animal characteristics?
   A Virus
   B Euglena
   C Amoeba
   D Spirogyra

12. Which one of the following organisms belongs to the division bryophyta
   A Liverwort
   B Mushroom
   C Ferns
   D Algae

13. To which kingdom of living organisms does the division filicinophytha belongs?
    A Protoctista
    B Plantae
    C Monera
    D Fungi

14. Which one of the following groups of diseases is caused by bacteria?
    A Malaria, Pneumonia, Cholera
    B Pneumonia, Elephantiasis, Cholera
    C Tuberculosis, Gonorrhoea, Cholera
    D Gonorrhoea, Small pox, Pneumonia

15. Bread will not become mouldy as rapidly if placed in a refrigerator because
    A Cooling reduces the growth of mould
    B Darkness reduces the growth of mould
    C Cooling prevent the bread from drying out so rapidly
    D Mould requires both heat and light for best growth.

16. Glycogen is a starch-like compound specifically stored in
    A Fungi and animals
    B Animals
    C Plants
    D Fungi

17. Which one of the following structures best differentiates a bacterium from amoeba?
    A Vacuole
    B Cytoplasm
    C Chloroplasts
    D Cell wall

18. Which one of the following statements is TRUE about viruses?
    A Viruses prevent the body cells from any infection
    B Viruses attack living body cells and destroy them
    C Viruses are able to multiply outside and inside the living cells
    D The body of viruses are surrounded by a thick cell wall.

19. Which pair of the following organisms are parasitic eukaryotic?
    A Paramecium and Amoeba
    B Euglena and Plasmodium
    C Trypanosome and Plasmodium
    D Amoeba and Brown Algae

20. One of the distinguishing characteristics of bryophytes is
A True roots and, stems or leaves
B No true roots, stems or leaves
C Many roots, stems or leaves
D Fewer roots, stems or leaves

21. Why soil bacteria are useful?
A They produce food for animals which live in the soil
B They keep the soil moist
C They help the breakdown of dead plants and animals
D They produce oxygen in the soil

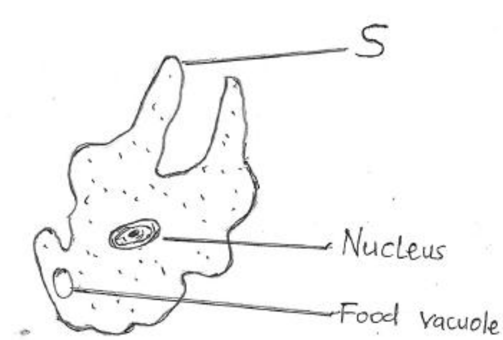
22. Which one of the following features best represents the flat body of a liverwort?
A Seta
B Involucre
C Leaf
D Thallus

23. Which one of the following group of organisms can interbreed and give rise to viable offspring?
A Species
B Genus
C Class
D Species and Genus

24. The system used by scientists to assign the two names for each living organisms is called
A Nomenclature
B Binomial nomenclature
C Classification
D Taxonomy

25.

The structure labelled ‘**S**’ in the diagram is used for
A Movement
B Excretion
C Reproduction
D Movement and feeding



Appendix C12: School-based follow-up questionnaire

Dear Teacher,
The purpose of this questionnaire is to determine your opinions and experiences about the school-based coaching sessions which were carried out during implementation of the professional development programme in your school. Your feedback will provide valuable information for improving teachers' professional development.
Please indicate the extent to which you agree or disagree with the following statements by ticking **(√)** the appropriate box.

1) Please indicate your perceptions to the following statements

Statements about school-based coaching	**Strongly disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
As a result of coaching sessions, I understand the activity-based approaches band the 5Es instructional sequence much better					
Feedback from the research's classroom contributes to the improvement of my teaching					
Provision of the examples of the activity-based lessons help me to plan and organise students' activities in my class					
Sharing of my teaching plans with the researchers and other teachers enhanced my competence to implement the new approaches					
The discussion and reflection on my teaching with a researcher inspired me to implement the new approaches					
After implementing the new approaches I have a better understanding about teachers' guiding roles					
I planned and teaching biology lessons differently as a result of the support from the coaching sessions.					

Note: 5 = Strongly agree and 1 = Strongly disagree

2) Are there any changes in the implementation of the new approaches took place as a result of the school-based coaching sessions? What are they?

____

____

Appendix D1

Southampton UNIVERSITY OF

Mrs Wadrine Maro
School of Education
University of Southampton
University Road
Highfield
Southampton
SO17 1BJ

RGO Ref: 7464

05 August 2010

Dear Mrs Maro

Project Title Designing Professional Development Program to Support Activity-Based Biology Teaching and Learning in Tanzanian Secondary Schools

This is to confirm the University of Southampton is prepared to act as Research Sponsor for this study, and the work detailed in the protocol/study outline will be covered by the University of Southampton insurance programme.

As the sponsor's representative for the University this office is tasked with:

1. Ensuring the researcher has obtained the necessary approvals for the study
2. Monitoring the conduct of the study
3. Registering and resolving any complaints arising from the study

As the researcher you are responsible for the conduct of the study and you are expected to:

1. Ensure the study is conducted as described in the protocol/study outline approved by this office
2. Advise this office of any change to the protocol, methodology, study documents, research team, participant numbers or start/end date of the study
3. Report to this office as soon as possible any concern, complaint or adverse event arising from the study

Failure to do any of the above may invalidate the insurance agreement and/or affect sponsorship of your study i.e. suspension or even withdrawal.

On receipt of this letter you may commence your research but please be aware other approvals may be required by the host organisation if your research takes place outside the University. It is your responsibility to check with the host organisation and obtain the appropriate approvals before recruitment is underway in that location.

May I take this opportunity to wish you every success for your research.

Yours sincerely

Dr Lindy Dalen
Research Governance Manager

Tel: 023 8059 5058
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Appendix D2

UNIVERSITY OF DAR-ES-SALAAM

OFFICE OF THE VICE-CHANCELLOR

P.O. BOX 35091 ♦ DAR ES SALAAM ♦ TANZANIA

Ref. No: AB3/12(B)
Date: 7th September, 2010
To: The Regional Education Officer,
Iringa Region.

UNIVERSITY STAFF AND STUDENTS RESEARCH CLEARANCE

The purpose of this letter is to introduce to you **Mrs. Wadrine Maro** who is a bonafide student of the University of Dar es Salaam and who is at the moment conducting research. Our staff members and students undertake research activities every year especially during the long vacation.

In accordance with a government circular letter Ref.No.MPEC/R/10/1 dated 4th July, 1980 the Vice-Chancellor was empowered to issue research clearances to the staff and students of the University of Dar es Salaam on behalf of the government and the Tanzania Commission for Science and Technology, a successor organization to UTAFITI.

I therefore request you to grant the above-mentioned member of our University community any help that may facilitate her to achieve research objectives. What is required is your permission for her to see and talk to the leaders and members of your institutions in connection with her research.

The title of the research in question is **"Designing and Evaluating a Professional Development Programme to Support Activity-based Biology Teaching and Learning in Tanzanian Secondary Schools".**

The period for which this permission has been granted is **September, 2010** to **April, 2011** and will cover the following areas/offices: **Iringa Region.**

Should some of these areas/offices be restricted, you are requested to kindly advise her as to which alternative areas/offices could be visited. In case you may require further information, please contact the Directorate of Research and Publications, Tel. 2410500-8 Ext. 2087 or 2410743.

Prof. Rwekaza S. Mukandala
VICE-CHANCELLOR

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