THE IMPLEMENTATION AND EVALUATION OF A CONSTRUCTIVIST INTERVENTION IN SECONDARY SCHOOL SCIENCE TEACHING IN SEYCHELLES

by

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PROMOTER: PROF. E. O. MASHILE

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Declaration

I declare that The implementation and evaluation of a constructivist intervention in secondary school science teaching in Seychelles is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

................................. ..............................................

R. N. ANYANWU                                     Date
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The Almighty Immortal and Invisible God – the Creator of the Universe; for using me as a tool in demonstrating once more to mankind that none of His words would go unfulfilled.
Dedication

To the learner who is assiduously ‘searching’ for new ideas
THE IMPLEMENTATION AND EVALUATION OF A CONSTRUCTIVIST INTERVENTION IN SECONDARY SCHOOL SCIENCE TEACHING IN SEYCHELLES

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Summary

Recent studies on human cognition have presented credible evidence that learners are not *tabula rasa* as previously conceived by traditional theorists, rather they enter new lessons with some preconceptions, most of which are resistant to change in spite of teachers’ efforts to assuage them. As such the challenges confronting science educators and educational psychologists are to understand the nature of learners’ preconceptions, designing and implement appropriate instructional interventions that would enable the learners become aware of and reconcile their conceptions that are inconsistent with accepted views of science.

Several perspectives have been advocated on how learners’ preconceptions can be modified through instructions. While traditional theorists subscribe to substitution of inaccurate conceptions with accurate ones, the constructivists identify with giving the learners autonomy to inquire and re-evaluate their own ideas. The former has been confronted with widespread criticism and is becoming less and less tenable. This research identifies with the latter.

Conceptual change entails restructuring of ideas. It is a cognitive process that involves change in attitude toward learning. Based on the theoretical assumption that learning is facilitated through teaching that give the learners autonomy search to new ideas, verify them, and restructure existing ideas, I developed a model of conceptual change from where I
deduced the four sub variables of the conceptual change that this study explored. The sub variables include formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge. My assumption was that conceptual change can be facilitated through instructions that engage learners in experiences relevant to the four sub variables that I have mentioned. This conceptual framework served as my reference point for the designing of the Constructivist Teaching Model that consists of four instructional phases.

Judging that I was resident and working in Seychelles as a teacher trainer at a time I developed the Constructivist Teaching Model, I chose to implement and evaluate it first in Seychelles. Hence this study is titled ‘The implementation and evaluation of a constructivist intervention in secondary school science teaching in Seychelles’.

The purpose of this study is to investigate the effect of the constructivist teaching model as an intervention to facilitate conceptual change. Basically, there are two main aims of this study. First, to investigate to what extent the constructivist teaching model facilitates conceptual change. Secondly, to investigate if the paradigms shift from the traditional method to the constructivist method of science teaching is welcomed in Seychelles.

This study was carried out in two phases Pretest and Evaluation. Pretest was aimed at identifying the weaknesses of the initial version of my model of constructivist teaching
with a view to eliminate those weaknesses to further strengthen the model. In a nutshell, pretest was a step taken to enhance the validity of the model. Evaluation on the other hand was aimed at making a judgment whether a difference actually exists between the learners that received constructivist instruction and those that received traditional lecture instruction in terms of the four sub variables of conceptual change. To enable for this judgment necessitated an experiment.

The experiment was conducted with a total of six secondary schools selected from the ten secondary schools on the island. The participants included 178 learners, 6 science teachers and 8 independent persons. The learners were constituted into three Bands; 1, 2 and 3. Each Band consisted of a Control group and an Experimental group. Altogether six groups were formed, with 3 Control groups and 3 Experimental groups. There were 59 learners in Band 1, comprising of 29 learners in the Control group and 30 learners in the Experimental group; Band 2 comprised a Control group of 25 learners and an Experimental group of 28 learners; and Band 3 consisted of 33 learners in each group. The learners in Band 1 were used for pretest that lasted for five week. The learners in Bands 2 and 3 were used in the evaluation that lasted for thirteen weeks.

The groups were non-equivalent, suggesting that randomisation was not possible as the learners were in intact classes. Learners in the experimental groups received constructivist instruction while their counterparts in the control groups
received traditional lecture instruction. Both groups were exposed to the same experimental conditions except in the methods of teaching. Data was collected through teacher interviews, independent observation, measurement of learners’ achievement, and analysis of documents. Quantitative data was analysed using descriptive and inferential statistics. Qualitative data was analysed on the basis of content or meaning of the information given by the respondents. Following the design of this study the performance and achievements of learners that received constructivist instruction were compared with their counterparts who received traditional instruction.

Guiding this study are two main assumptions. The first is the assumption of equality of the variance, and the second is the assumption of normality of the distribution. The results of Levene’s test of equality of variances indicated a violation of the assumption of homogeneity of the variances of TI and CI groups while the results of test of skewness and kurtosis give the indication of normality of distribution of scores in both groups.

The results of descriptive statistics analysis showed that the learners who received constructivist instruction performed better than the learners that received traditional instruction in terms of formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge. The results of inferential statistics showed that the difference in the means of the two groups on each of the sub variables of conceptual
change is significant. This evidence indicates that my model of constructivist teaching produced an effect measuring 0.86 and a power of 0.85 based on Cohen’s Blueprint, and a reliability of 0.72 based on Cronbach’s test of internal consistency. Besides statistical evidence, analysis of the opinions of science teachers who implemented the Constructivist Teaching Model in their respective classes and the independent persons who observed teaching and learning in both the experimental and control groups showed a preference for the constructivist approach over the traditional approach.

On the grounds of the evidence gathered through observation and measurement this study concludes that the constructivist approach to science teaching is more effective than traditional lecture approach in facilitating the ability of secondary school learners in Seychelles to reconstruct ideas. This study also found that science educationists in Seychelles welcome the paradigm shift from the traditional approach to the constructivist approach.

**Key words:** Constructivist teaching method, traditional teaching method, conceptual change, formulation of ideas, search for new ideas, review of meaning, transfer of knowledge.
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CHAPTER 1

INTRODUCTION

This research is the implementation and evaluation of a constructivist intervention in secondary school science teaching in Seychelles. This chapter presents the orientation to the study, which shows that the traditional knowledge transmission approach of science teaching is becoming less and less relevant in the new Millennium, essentially in facilitating conceptual change. The various views shared among scholars on how learners’ preconceptions can be modified are explored. Following the different perspectives on conceptual change are the theoretical framework of the study and a preliminary review of recent empirical studies that evaluated the effects of constructivist teaching of science on conceptual change. The justification of the study, delimitation, purpose/aims, problem statement, research design, and research hypotheses are also presented in this chapter. The key terms used in defining the problems and stating the research hypotheses are clarified. The chapter concludes with an outline of the programme of the study.
1.1 Orientation to the study

The scientific and technological advancements that characterise the 21st century have inspired widespread reforms in education. Consequently there is a shift of paradigm. New models of instruction have been developed as traditional methods are becoming less and less tenable to achieve the goals of education in general and science education in particularly.

Prior to the 1980s the models of science teaching were inclined to knowledge transmission-absorption paradigm. Emphasis was on knowing rather than the process of knowing. Instruction was aimed at enabling the learners to absorb objective to knowledge that have already been verified by other people, usually the experts, and transmitted by teachers to the learners (Caprio 1994; Hake 1998; Prophet 1990). In the circumstance of this approach teachers are regarded as the precursors of knowledge and the learners as empty vessels waiting to be filled with knowledge. This approach to teaching least recognises the learners’ preconceptions and the cognitive processes that induce individual construction, reflection, and review of ideas.

The waning of the traditional approach does not only impact on education in general, it also impacts on science education. The traditional approach to science education, according to Duschl (2000), emphasizes ‘knowing’ but ignores the context on which meaning is constructed. In the context
of the traditional method, learning is judged effective by the amount of information the teacher is capable of transmitting to the learners and how much of that information the learners are capable of absorbing and recalling. This approach, although gaining less and less relevance following recent research on human cognition, still prevails in most classes and schools across the globe.

The word ‘Science’ connotes different meanings to different people. In schools in Seychelles, science is regarded as the study of the biological and physical elements of the environment; an organised body of knowledge through which individuals investigate phenomena and the interconnected processes underlying the universe (Ministry of Education 2001). Through school science learners study facts, explore concepts, verify principles, apply rules, and solve problems of varying complexities. Nevertheless the learning of concepts and solving of problems of greater complexities place profound cognitive demand on learners. The extent to which this burden is felt and the cognitive conflict that is associated with it, is a function of the personal and environmental variables influencing the learner and the learning process.

Research has shown that since the mid 1980s there has been a widespread reform in science education around the globe, stimulated by contemporary research on human learning and models of science teaching (Hinrichsen and Jarrett 1999, Jonassen 1994; Lewin 1992). Recent studies focusing
predominantly on the process of knowing have provided compelling evidence to substantiate that learners enter new lessons with some well-established preconceptions of science concepts. The preconceptions the learners hold vary in terms of clarity, breadth, coherence, ambiguity, and tenacity in relation to the accepted views of the scientific community (Duit 2003; Peterson 2002; (Baser 2002, Tytler 2002; Shepard 2000; Bransford, Brown and Cockling 1999; Driver 1983).

The fact that learners enter science lessons with some preconception of science concepts create a mismatch between instructional intent and what the learners themselves already have in their conceptual repertoires. In this circumstance a conceptual conflict is bound to set in, which instruction must strive to reconcile. If instruction fails to do so during or before the end of a given lesson, learners leave the classroom without pondering over their own thoughts. The implication of this is that rather than instruction motivating conceptual change, it fortifies misconception that the learners have already constructed.

1.2 Perspectives on the Problem

Dealing with learners’ misconceptions is one of the challenges confronting science educators and psychologists in recent decades. One of the characteristic features of learners’ misconceptions of science concepts are that they are resistant to change (Baser 2006; Peterson 2002; Stromdahl 2002; and Vosniadou 2002). Consequently a number of
theoretical conjectures have been postulated to elucidate how learners’ preconceptions of science concepts can be modified. The two main perspectives are assimilation or substitution theory and accommodation theory.

Assimilation theory conceives learning as the substation of ideas. Stemming from this is the notion that learning is a change of conceptual status or conceptual exchange achieved through substitution (Driver 1989; Osborne and Freyberg 1985; Posner, Strike, Hewson and Gertzog 1982; Hewson 1981). This perspective regards learning as the substitution of an inaccurate conception with an accurate one. As such a change in conception is said to occur when a new conception is absorbed into existing cognitive structures. Underpinning assimilation theory is presumption that the factors that influence learning are externally induced (Anderson and Nashon 2006, Nashon and Anderson 2004, and Duschl 2000).

Being externally induced means learners have no control over their learning. The fact that learners do not have any control over what they learn qualifies learning in terms of absorption of objective knowledge as a Black Box Approach (Cascales, Solano and Leon 2001). Instruction that favours assimilation relies on passive lectures, laboratory recipes and algorithmic problem examination (Hake 1998). The conditions of learning and assessment of learning outcomes in this perspective remains the onus of the teacher rather than the learner (Weimer 2002).
Besides assimilation theory, the second perspective is referred to as accommodation theory. Accommodation is the modification of cognitive structures as the result of an experience that could not be assimilated into existing cognitive structures (Hergenhahn and Olson 2005; Agarkar 2005; Alsop and Hicks 2003; Mayer 2003; Tsai 2001; Borko and Putnam 1998; Cobern 1993; Tobin and Tippins 1993; Ibanez 1992; Vygotsky 1978; Piaget 1970). Scholars who identify with this perspective conceive learning as the modification or restructuring of existing conceptual schemes rather than substitution, and change in learners’ preconception occurs when an existing conception integrates with new concepts, and is modified to give rise to a new understanding.

Although each of these two perspectives to conceptual change cited presents an approach to learning, the results of most recent empirical studies tend to favour the latter. In order for learners to modify their preconceptions successfully, certain conditions must be fulfilled. First, the new concept must be intelligible. This means that the learner should be able to grasp meaning from the new concept. Secondly, the new concept must be plausible; meaning that it should be consistent with other knowledge. And thirdly, the new conception must be fruitful; meaning that knowledge gained from it must be extended or applied to other areas of learning (Mortimer 1995; Posner et al 1982). Meeting the three conditions that have been highlighted above to enable the learners to change inaccurate ideas to appropriate ones and in doing so construct new ideas would necessitate a
change in the culture of learning – redefining who assumes what role in the class.

Considering for now only these two perspectives for dealing with learners misconceptions have implications for instruction. The assimilation model uses direct instructional methods such as a lecture where there is a lot of emphasis on teachers’ skills of transmitting knowledge. Accommodation, on the other hand, requires different skills from teachers and the teaching and learning process is much more involved than mere transmission of knowledge. Given the foregoing, this study scanned the predominant teaching perspectives in Seychelles (see section 1.3) before interrogating suitable perspectives that take into account the context of the country.

1.3 Theoretical framework

Conforming to the three conditions that facilitate change in learners’ preconception of science concepts as described in section 1.1, several models of instruction have been developed with a view to facilitate science learning with particular focus on construction of ideas. Among these include the Science Activity Model of Linn, Lewis, Tsuchida and Songer’s (2000), which emphasizes collaboration and personal responsibility; the Interactive Engagement Model of Biddulph (1990), which was popular in Australia and New Zealand; and the Learning Cycle model which was quite popular in the United States (Glasson 1993; Lawson 1983). A common
feature of these models is their departure from the traditional approach. Ownership of learning is shifted from the teacher to the learners. The learner is recognized as a meaning maker rather than an empty vessel waiting to be filled with knowledge. The idea that knowledge which learners construct on their own is more enduring than that which is transmitted to them by the teacher underpin constructivist teaching (Loveless 1998). This fact that learning is more enduring when the learners construct their own ideas has inspired the radical shifting away from traditional knowledge transmission-absorption models of teaching that we have witnessed since the middle of the last decade.

Science means different things to different people. While some conceive it as the study of physical and social phenomena through observation and experiment in search for universal natural laws and explanations (Reber 1995; Jary and Jary 1991; Sand and Hull 1996), others conceive it as the application of scientific principles to arrive at truth by logical inference from empirical observations (Koul 2003 and Chauhan 1991).

In the context of the Seychelles National Curriculum Framework (Ministry of Education January 2001a; 2001b), science is a universal discipline through which people investigate matter – living and non-living, energy and the interaction between matter and energy. It is an active and continuous process of exploration of the physical and biological aspects of the universe, a body of knowledge and theories, which provide a framework of concepts that enable
human beings to better understand the world around them. From the perspective of this study, science refers to a universal discipline through which learners investigate matter.

On assumption of duty as a teacher trainer at the National Institute of Education (NIE), Seychelles in August 2002, part of my duty was providing professional support to newly qualified secondary and primary school teachers on the island. Discharging this duty offered to me the opportunity to look into the classrooms and observe science teaching and learning in Seychelles. During the period, I observed that instruction in general, and science teaching in particular, is predominantly teacher-centred. The culture of learning is entirely a departure from the constructivist approach. The knowledge transmission approach is predominant. Instructions are characterized by note-taking instead of note making, absorption instead of construction of ideas, answering of lower-order questions instead of critical and analytical reasoning, laboratory-based experiments with rigid guidelines instead of exploring and making sense of this environment.

The Schools’ Audit Reports and National Assessment Reports on secondary school learners’ performance and achievements on science from 1997 to 2005 have also confirmed the fact that science teaching in Seychelles is monotonous. Lessons are teacher-centred. Instructions do not draw out the existing knowledge, skills and interest from the learners; learners are not actively involved in their learning and hardly achieve their targets. Learning motivation is low. Most of
the learners are unable to attempt questions that demand critical thinking. A larger number of them encounter difficulties on problems involving interpretation of data, spelling common terms/concepts, drawing/identification of structures. Their responses also lacked clarity and accuracy. The reports blamed science teachers for not doing enough to expose the learners to making of sound judgment (Ministry of Education 1999a; 2000a; 2000b 2001c, 2001d 2001e; 2003a; 2003b; 2005). One of the National Assessment Reports on learners’ performance and achievement in science remarked that “Year after year comments are made about the poor academic performance of learners, and yet nothing has been done which had redressed this situation” (Ministry of Education 2003a:13).

To reverse the dismal trend, a paradigm change is advocated on science teaching in Seychelles. Consequently, I have designed a constructivist instructional intervention aimed at improving science teaching in Seychelles, an attempt motivated by the notion that constructivist instructions offer to the individual the opportunities to learn by the dint of matching new against given information and establishing meaningful connections among ideas, rather than by internalizing mere facts to be regurgitated later on (Thanasoulas 2001).

To facilitate this matching, teaching should curtail direct and immediate supervision by teachers and allow learners to take ownership of their own learning (Beck, Hart and Kosnik
Taking ownership will enable learners to develop confidence in using the conceptual tools of the scientific community to verify the limitations of their preconceptions (Leach and Scott 2003). My view therefore is that any instructional approach or method that aims at facilitating the learner’s ability to modify their conceptions should aim at stimulating the cognitive tools and processes that incite change. Consequently, this study advocates instructions that give the learners control over their own learning. When learners take ownership of their own learning they are in a better position to plan, execute, and manage their own learning.

Shifting ownership of the learning process from the teacher to the learners implies a departure from tradition. But in situations where this change is slow would necessitate an intervention. The credit to any intervention depends not only on the quantitative change but also the willingness of the practitioners to abandon convention and embrace new approaches (Brooks and Brooks 1993). This implies that the effect of an intervention depends on the extent to which the individual for whom it was designed is willing to abandon traditional practices. Therefore, a paradigm change is a shift from the old to the new. In his book *The Structure of Scientific Revolution*, Kuhn (1970), referred to paradigm change as a change in the way of looking at a subject or a point of view commonly shared by a group of individuals. To bring about a paradigm change necessitates an intervention. An intervention is any preventive, remedial or compensatory
procedure implemented to facilitate learning (Tardif 1984). An intervention is therefore judged effective to the extent it brings about improvement in situations where previously performance was perceptibly unimpressive.

1.4 Evidence from Empirical Studies

Recent empirical studies have shown that the constructivist approach to science teaching produces more positive effects than the traditional approach. Their results suggest that constructivist instructional models produce significant gains over traditional instruction in learners’ understanding of science concepts and principles.

In a comparative study of the cognitive and metacognitive differences between modelling and non-modelling high school physics learners, Malone (2006) found that the constructivist approach facilitates the development of problem-solving skills and the identification of misconceptions. The results of this study also showed that teaching methods that provide opportunities for learners to evaluate their own learning also facilitate their ability to modify their misconceptions, even with minimal guidance from the teacher.

Baser (2006) found that constructivist instruction facilitates conceptual change more than traditional instruction. Baser’s study was conducted using the pretest-posttest experimental design, involving thirty-eight learners exposed to constructivist instruction and thirty-six taught
with traditional instruction. Both groups received identical instruction but the experimental group was exposed to conceptual change conditions. When both groups were assessed and performance compared, Baser found that the conceptual change group performed better than the traditional group.

Zohar and Aharon-Kravetsky (2005) evaluated the effects of Inducing Cognitive Conflict (ICC) on learners’ academic achievement and compared it with Direct Instruction using a total of 121 learners. The main research problem of the study was to determine whether the effects produced by the intervention are consistent across the sample compared to the traditional approach in a heterogeneous school. The learners were of different ability levels.

In their study, Zohar and Aharon-Kravetsky divided the learners into four groups in a $2 \times 2$ design. The control group was exposed to traditional instruction while the experimental group was exposed to Inducing Cognitive Conflict instruction. The results further showed that learners who have high academic achievements benefited from the Inducing Cognitive Conflict teaching method while the Direct Teaching method slowed down their advancement. Conversely, learners with low academic achievements benefited from the Direct Teaching method while the Inducing Cognitive Conflict teaching method hindered their progress. From the results of this study it was apparent that teaching method does not have specific effects on learners’ achievement but there was a significant interaction effect between academic achievement and teaching method.
The results of an experimental study involving 192 learners, which compared interactive instruction and traditional instruction to determine the effect of peer instruction on high school learners’ achievement and attitudes towards physics in Turkey (Eryilmaz 2004), showed that peer instruction was more effective than traditional instruction in enhancing learners’ achievement in physics. This study involved two groups of learners - the control group and the experimental group. Learners in the control group received traditional instruction while their counterparts received interactive instruction. This study however did not find any significant difference between the experimental and control groups’ attitudes towards physics, it was rather found that peer-oriented learning provided opportunity for crossbreeding of ideas among learners and as such produced better results than the traditional method.

The results of the studies that I have cited in this section provide obtrusive evidence that constructivist instructions have more positive effect on science learning than traditional instruction, and it is this preference that motivated the shifting away from traditional instruction in most parts of the world.
1.5 Justification of the Study

Although previous research has shown that learners enter science lessons with their preconceptions of science concepts and that those preconceptions are resistant to modification, my own view is that the stiffness inherent in learners’ misconceptions can be mitigated or softened through effective instruction. Such instructions should aim at exposing learners to formulating and testing the validity of their own ideas. The results of empirical studies that I have presented in section 1.4 suggest that constructivist methods of instruction have a more positive effect on science learning than traditional instructions.

The problem of overcoming the resistance inherent in learners’ preconceptions is compounded by lack of common understanding of what conceptual change actually is. Various theoretical positions have been maintained, each with its own model of conceptual change. While some scholars conceive conceptual change as conceptual exchange or substitution, others understand it as modification of existing conception. Apart from the absence of a common theoretical framework, the interventions also vary. The former evaluates conceptual change from a quantitative perspective and others from a qualitative dimension. Most of the conclusions were drawn from a single-case comparison and none investigated the effect of the constructivist approach using multiple samples.
Furthermore, most of the previous empirical studies confined their investigation of the effect of constructivist instruction on one variable - academic achievement, while the cognitive, social, affective, or metacognitive variables that incite and sustain conceptual change were ignored. This study however is not designed to investigate these variables as isolated elements of conceptual change as shown in “Figure 2.1” but rather are implicitly accommodated as measures of the sub variables of conceptual change. Most essentially, none of such studies has been conducted in Seychelles.

To bridge these empirical gaps, this research is the implementation and evaluation of a constructivist model of teaching on secondary school science in Seychelles. It is hoped that if the model proves effective when tested, it will be recommended not only for science teaching but will suffuse other domains of the national curriculum.

1.6 Delimitation of Study

This study adopted the empirical approach to investigate the effect of constructivist instruction on science learning with specific reference to conceptual change. Conceptual change is the modification of inaccurate concepts into accurate or appropriate concepts (Chi and Roscoe 2002). To investigate conceptual change in depth this study operationally defined it in terms of four sub variables, which include formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge. These variables are derived from the
conceptual change model in “Figure 2.1”, which are the criteria to judge the effect of the constructivist teaching method that I have designed to improve the teaching of science.

In the circumstance of the Seychelles educational structure, the Lower Secondary comprises Secondary Classes 1 and 2, while the Upper Secondary comprises Secondary Classes 3, 4 and 5. Science is taught at the Lower Secondary Level as Integrated Science, and in the Upper Secondary Level as specialized subjects such as Biology, Chemistry, Physics, and Combined Science. The approaches to science teaching at these two levels also vary. For instance, at the Lower level science is taught as an integrated subject. Here learners study the fundamental concepts and principles of science before they proceed to the Upper secondary where they learn science in greater depth as specialized subjects such as Biology, Physics, and Chemistry (Ministry of Education 2001). Hence, the target population of this study was learners in the Lower secondary. The time allocation to science teaching at the Lower secondary is six hours per week. Each science lesson is a double-period contact of eighty minutes. In addition, this study spanned over the duration of eighteen weeks.
1.7 Purpose/Aim of the Study

The purpose of this study was to evaluate the effect of the constructivist approach to the teaching of science on conceptual change in secondary schools in Seychelles. There are two main aims of this study. First, to compare the performance and achievements of secondary school learners who were taught science using the constructivist model (constructivist approach) and the performance and achievement of their counterparts taught with the traditional lecture method (traditional approach) with reference to the four sub variables of conceptual change which I have stated in section 1.6. Secondly, to find out to what extent the paradigm shift from the traditional approach to the constructivist approach is welcomed by science educators in Seychelles.

1.8 Problem Statement

The problem of this study is stated in terms of research question as main questions (MQ1 and MQ2) and sub questions (SQ1, SQ2, SQ3, and SQ4) as shown in sections 1.8.1 and 1.8.2 respectively.

1.8.1 Main Questions

The main questions are as follows:

MQ1: What is the effect of the constructivist method of teaching on conceptual change in science at secondary school level in Seychelles?
MQ2: To what extent is the paradigm shift from the traditional approach to science teaching to the constructivist approach welcomed in Seychelles?

1.8.2 Sub Questions

In order to explore the main questions in greater depth the following sub questions derived from the main questions are examined:

SQ1: Is there any difference on formulation of ideas between learners taught science using the constructivist method and their counterparts taught with the traditional lecture method?

SQ2: Is there any difference on search for new ideas between learners taught science using the constructivist method and their counterparts taught with the traditional lecture method?

SQ3: Is there any difference in terms of review of meaning between learners who were taught science using the constructivist method and their counterparts taught with the traditional lecture method?

SQ4: Is there any difference in terms of transfer of knowledge between learners taught science using the constructivist method and their counterparts taught with the traditional lecture method?
1.9 Hypotheses

The sub questions in section 1.8.2 are investigated by testing the following hypotheses stated in null terms:

**Ho1**: There is no significant difference in the formulation of ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

**Ho2**: There is no significant difference in the search for new ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

**Ho3**: There is no significant difference in the review of meaning between learners taught with the constructivist method and learners taught with the traditional lecture method.

**Ho4**: There is no significant difference in the transfer of knowledge between learners taught with the constructivist method and learners taught with the traditional lecture method.
1.10 Research Design

With reference to the purpose of this study in section 1.7, which is to investigate the effect of a constructivist instructional intervention on conceptual change, and how far this shift in approach to science teaching is welcomed in Seychelles, it consequently necessitated data gathering from individuals who directly experienced the effect of the intervention and the opinions of individuals who directly observed the effect of the instructional process. To observe the effect of the intervention necessitated the experiment. Experimental methods offer some advantages when the investigator wishes to identify the effect of some intervention, and is able to exercise some control in a research situation (Lawson 1997). This method is used for gathering information through direct experience and observation. Implementing experimental method in this study was not possible and hence pseudo-experimental methods were used.

To accommodate the two facets of the problem of this study as outlined in section 1.8, I deemed it pertinent to conduct the empirical study using the mixed methods. Mixed method is a research approach where the qualitative and quantitative methods are implemented concurrently in a single study. The quantitative approach adopts the scientific method and explains the effects of the independent variable on the dependent variable and draws inferences based on facts, whereas the qualitative approach draws inferences based on
other people’s experience and their analysis of events (Morrison 2003; Blaxter, et al 2005, and Burns 2000). I chose this integration with the notion that any inherent weaknesses of the quantitative method would be offset by the qualitative method and vice versa. One main advantage of the mixed approach is that it draws conclusions based on corroborated evidence (Creswell 2003; Morgan 1998).

The participants in this study included 178 lower secondary learners and 6 science teachers selected from 6 secondary schools in Seychelles, 3 independent observers, 3 examiners, and 2 cameramen. The science teachers were those teaching science to the learners. The independent observers were experienced science teachers and teacher trainers from the National Institute of Education Seychelles. The examiners were science teachers who have been accredited as Examiners by the Ministry of Education. The purpose of involving the learners, teachers, as well as experts was to gather sufficient evidence from multiple sources to evaluate the effect of the constructivist methods.

The science content that was taught was selected from the National Science Curriculum. Judging that the learners in the experimental and control groups were homogenous, this study assumes that any observed difference between the group that received traditional instruction and their counterparts that received constructivist instruction was due to the effect of the instructional methods.
Judging that the constructivist model implemented in this study is a product of this research, it was pertinent to subject it to tests prior to evaluation. For this reason this study was conducted in two main phases - Pretest and Evaluation. Pretest provides opportunities to detect or remove ambiguities, to ascertain the range of possible responses and to ensure that questions asked yield the information sought (Lietz and Keeves 1999). The purpose of pretest in the context of this research was to identify the limitations of the constructivist teaching model and take necessary steps to strengthen it before subjecting it to final scrutiny. The second phase, which followed after pretest, was aimed at determining whether the constructivist method was to any effect on secondary school learners, and how far the paradigm shift is welcomed by science educationists in Seychelles.

To accommodate for the two phases the participants were organized into three distinct Bands - Band 1, Band 2, and Band 3. Bands 1 and 2 consisted of learners from secondary Class 1 while learners in Band 3 were learners in secondary Class 2. Each Band consisted of a control group and an experimental group. The schools/classes were randomly selected but the learners were in intact classes and as such were not randomly assigned to experimental and control groups. Learners in Band 1 were used for the pre-test, while those in Bands 2 and 3 were used for evaluation. The use of more than one class or group qualifies this study as a multi-case experimental research. In as much as the learners were
selected from two different classes – secondary Classes 1 and 2. Although two different classes are involved, Bruner (1983) emphasized that any group of learners can be taught the same concept using the right method. Simply put, every child would benefit from teaching so long as the appropriate teaching method is applied. The design of this study therefore provides opportunity to determine if any difference exists between learners who received constructivist instruction and their counterparts who received traditional instruction.

Due to the fact that this study adopted mixed methods with a view to enable for collaboration of evidence, multiple strategies were used for data collection. These include measurement of learners’ performance and achievements, observation, interviews, and analysis of documents. The fact that this study adopted mixed approach, the data consisted of a mix of figures (quantitative) and text data (qualitative). Quantitative data was analysed using descriptive and inferential statistics while qualitative data was analysed on the basis of the content of the text or information that was provided by the respondents. The use of multiple methods of data collection and techniques of data analysis offered opportunity to confirm, cross-validate or corroborate quantitative evidence with qualitative evidence.
1.11 Clarification of key Terms

The key terms used in defining the problem and stating the research hypotheses are clarified as follows:

- **Constructivist teaching method**: An approach to teaching and learning whereby the students learn by the dint of matching new against given information and establishing meaningful connections, rather than by internalizing mere factual knowledge to be regurgitated later on (Thanasoulas 2001).

- **Traditional teaching method**: An approach to teaching that recognises teachers as conduit for transmitting their thoughts and meanings to passive learners, and the goals of the learners is to regurgitate the accepted explanations or methodology expostulated by the teacher (Caprio 1994).

- **Formulation of ideas**: Deriving a tentative understanding of a concept or problem following the integration of new experience and prior knowledge (Mayer 2003).

- **Search for new ideas**: a multifaceted activity that involves the ability to make observations; pose questions; examine books and other sources to see what is already known on a given subject (The National Science Education Standards 1992).
Review of meaning: The ability of the learner to critique, reflect and assess his own learning (Dede 2000).

Transfer of knowledge: The ability to apply new concepts and skills in multiple contexts (Georghiades 2000).

1.12 Programme of the Study

Having introduced the problem of the study, its purpose/aims, and hypotheses, it is essential that the entire programme of this study is provided at this juncture to give the reader an idea of what the rest of the chapters focused on.

Chapter Two discusses the conceptual underpinning of the metacognitive teaching model. It explains the meaning, origin and varieties of constructivist experience such as personal constructivism, radical constructivism, empirical constructivism, pragmatic constructivism, social constructivism, and contextual constructivism. It also presents the concept of metacognition and some theories highlighting constructivist learning such as Piaget’s Cognitive Adaptation Theory, Bruner’s Discovery Learning Theory, Atkinson and Shiffrin’s Information Processing Theory, Eysenck and Calvo’s Processing Efficiency Theory, Sweller’s Cognitive Load Theory, Festinger’s Cognitive Dissonance Theory, Craik and Tulving’s Level of Procession Theory, and Collins, Brown and Newman’s Cognitive
Apprenticeship Theory. Other theories that inform constructivist learning that were discussed in this Chapter Two include Spiro, Feltovic, and Coulson’s Cognitive Flexibility Theory, Barsalou’s Concept Instability Theory, Novak’s Concept Formation Theory, Murray’s Achievement Motivation Theory, Gagne’s Conditions of Learning Theory, Vygotsky’s Social Learning Theory, and Papert’s Theory of Constructionism. The principles of constructivist instruction are also highlighted. Furthermore, the meaning of conceptual change, my model of conceptual change, and the process of conceptual change which include construction of ideas, search for new ideas, review of meaning, and transfer of knowledge are discussed. In addition, attention is drawn to the factors influencing conceptual change and the effect of constructivist teaching on conceptual change. The chapter ends with summary of findings from the review of literature.

Chapter 3 presents the model of constructivist teaching which I designed for science learning with a view to facilitating conceptual change. The chapter commences with an explanation of what we mean by instructional models. An attempt is made to fuse the tenets of constructivism, metacognition and conceptual change into a model to derive the principles of my constructivist teaching model. This chapter also describes the application of the Constructivist Teaching Model in the teaching of science. The main variables of the study are identified and operationally defined.
Chapter Four describes the methodology of this study. It commences by clarifying the two research traditions underpinning this study. These include positivist and hermeneutic paradigms. It also provides justification for a two-phase empirical study consisting of pretest and evaluation. It describes the population of the study and the selection of the participants. The research instruments and procedure, including my role in this research are described. The main assumptions of the study. The chapter concludes with a summary.

Chapter Five presents the techniques for data analysis and the results of the empirical study, consisting of results the test of the assumptions, the pretest phase and the evaluation phase. It presents the results of descriptive and inferential analysis. The means difference between the traditional group and the constructivist group and the distribution of the scores on each of the sub variables of conceptual change are presented. The results of test of the two main assumptions of the study which include test of skewness and kurtosis of the scores and homogeneity of the variances of groups are provided. In addition, the results of hypotheses testing are also presented. The effect size, power, and reliability of the constructivist teaching model are presented. In addition the results of qualitative analysis which include the perceptions of independent observers, teachers, and my own observation on the effect of the constructivist teaching model are presented. The chapter concluded with a summary of the results of the study.
Discussion of findings, recommendations and conclusion are presented in Chapter Six. This chapter consists of findings and conclusions from the literature study, findings and conclusions from the empirical study, the internal and external validity of the study, and the reliability of Constructivist Teaching Model are discussed. In addition, the implications of the results and suggestions for further research are presented. The chapter ends with closing remarks.
CHAPTER 2

CONSTRUCTIVISM, METACOGNITION, AND CONCEPTUAL CHANGE

2.1 Introduction

This chapter presents the conceptual framework of the constructivist teaching model designed with the aim of bringing about change in the approach to teaching and learning of science in secondary schools in Seychelles.

2.2 Constructivism

2.2.1 Origin and meaning of Constructivism

When Giambattista Vico, an Italian philosopher, postulated in his 1710 treatise that the only possible knowledge an individual has is that which he or she personally constructed, least did he know that three hundred years after, his assertion would serve as a framework for designing a model of instruction to facilitate the teaching of secondary school science.

Prior to the time of Vico, however, the notion that knowledge comes from sensory experience had earlier been postulated by scholars such as Socrates, Plato, Aristotle, Kant, and Locke (Crowther 1997). For nearly 200 years after Vico’s assertion, constructivism was extricated from the pedagogy until in 1916 when John Dewey, in his essay titled ‘Education and Democracy’ (Dewey 1916) declared that education is the constant restructuring of experience. Dewey’s thesis
stimulated the intellectual debate that eventually steered constructivism into pedagogy. Fifty-four years after John Dewey, Jean Piaget, a Swiss philosopher, was renowned as the father of modern constructivism following his work on genetic epistemology or the development of knowledge (Piaget 1970). While Vico’s constructivism was fine-tuned to philosophy, Dewey’s was pitched towards pedagogy. Common to the two schools of thought is the conjecture that the human mind can only know that which the human mind has constructed. Although Dewey’s constructivism was introduced into educational practice between 1910 and 1920, its classroom application was traced to John Dewey and Jean Piaget (Brooks and Brooks 1995; von Glasersfeld 1995, 1993; and Novak 1977).

2.2.2 Different camps of Constructivism

Constructivism, a concept which Vico brought into general philosophy, brought into pedagogy by Dewey, and translated into contemporary psychology by Piaget, has generated diverse and competing interpretations among scholars that have had astounding influence on education in general and science education in particular. Today we have what Neimeyer (1993:224) referred to as “varieties of constructivist experience” or camps of constructivism (Chiari and Nuzzo 1996; Derry 1992; Howard 1986). The following camps of constructivism have been explained in the context they relate to this research: Personal, Radical, Empirical, Pragmatic, Social, and Contextual Constructivism.
2.2.2.1 Personal Constructivism

The origin of personal constructivism was traced to Jean Piaget based on his popular work on genetic epistemology or the development of knowledge which he published in 1970. This philosophical thinking explains how humans construct knowledge. Personal constructivism conjectures that individuals do not absorb objective ideas rather they construct their own ideas through experience, and cumulatively building new knowledge upon existing ones (Kilpatrick, 1987; Lerman, 1989; Hamlyn 1987; Piaget 1971; 1970).

Cumulative building of knowledge is an active cognitive process and its success largely depends on the ability of the individual to adapt his/her own knowledge structures to environmental stimuli and also to adapt the environmental stimuli to his/her own knowledge structures. What I could deduce from Piaget’s Genetic epistemology is that individuals construct new knowledge as they interact with the environment. Interacting with the environment implies making sense of the environment and using the new experience generated from this interaction to restructure existing knowledge structures. For individuals to learn effectively they must be exposed to experiences which also impact on them. In a nutshell, personal constructivism emphasizes discovery learning, sensitivity to the environment, learning readiness, and individual differences.
2.2.2.2 Radical Constructivism

The radical constructivist view is that individuals can construct their own knowledge by interpreting their perceptual experiences of the external world as it makes sense to them. Construction of knowledge is an active and adaptive process involving organization of the individual’s experiential world (Jonassen 1991; Kilpatrick 1987). Radical constructivism was illustrated metaphorically as a key and a lock system. If the key opens the lock, it is not illogical to conclude that the key corresponds to the lock; it is possible to find another key that can as well open that same lock. Explaining the nature of knowledge from a radical constructivist standpoint, Riegler (2001:1) states, “we construct our own world rather than it being determined by an outside reality”. This is exactly the nature of knowledge.

Radical constructivism holds that human knowledge is a construction built through adaptation of cognition. Cognition involves thinking. We keep thinking until we arrive at a better interpretation of that reality. In this sense one would say that knowledge depends upon the structure of the knower. Relating this to instruction, students construct new knowledge by thinking about the concepts and principles that the curriculum presents to them. To restructure their misconceptions, students should be engaged in activities that involve thinking and reflecting over their own thoughts and by so doing they illuminate their illogical conceptions.
2.2.2.3 Empirical Constructivism

Empirical constructivism stemmed from the Kantian conception that whatever idea or knowledge an individual has is a derivation from, in some way, experience, possibly through sensing, action, and thinking. It holds that we know the subject of meaning through an act of identification, and the objects we are interested in are capable of being, and are subject to experience. Empirical constructivism likened verification of meaning to looking at the world and trying to make sense of it to reading a measuring instrument and recording the position of the pointer, whereas the color, shape, and other features of the instrument make little or no sense to the experimenter (Hand, Treagust and Vance 1997).

The empirical constructivist position is that individuals verify reality by observing its attributes. We observe reality with the use of our senses – hearing, seeing, touching, smelling and feeling. Bearing in mind that senses are indispensable tools to observe the attributes of reality, instruction should provide opportunities for students to verify the attributes of their preconceptions and establish whether or not they are valid in the light of new ideas. Instruction must engage the various senses the learner has – their minds, their heads, and their bodies.
2.2.2.4 Pragmatic Constructivism

Pragmatism is an American philosophical theory that explains both meaning and truth in terms of applications of ideas to performance of actions. The epistemology, whose origin was traced to Charles Sanders Peirce and later expanded by William James, upholds that any meaning, inferences, principles, or generalizations that do not have utility or give satisfaction is ultimately invalid (Rockwell 2003 and Kuklick 2001). Knowledge is considered to be valid to the extent it is applied in finding solutions to problems (Thanasoulus 2001 and Shusterman 1997).

A relationship exists between pragmatic constructivism, inquiry, and transfer of knowledge. Inquiry implies search for meaning. Individuals are motivated to search for meaning when they come in contact with a problem situation for which a solution is needed. Inquiry provides reconciliation of conceptual ambiguity or doubt through reflective activities (Brooks and Brooks 1995). Reconciling an ambiguity is like closing a conceptual gap. Individuals do not apply meaning where there is no gap to close. This implies that in order for learning to take place, the learner must identify a conceptual gap that must be filled. Misconception is a gap that learners must close but the success of this depends on how far the student is aware that a gap exists. The role of instruction therefore is not to keep transmitting more and more information into the heads of the learners but rather to
engage them in activities that will enable them to become aware of the limitations of their preconceptions.

2.2.2.5 Social Constructivism

Social constructivism is the philosophical notion that reality is constructed through human activity. The constructivist view is that meaning is not out there to be discovered rather it has to be constructed by a group of people. It suggests that meaning is a product of human construction. Advocates of social constructivism are of the view that teachers should not just stand by and watch children explore and discover ideas; they should rather guide and encourage them to work in groups, think about issues and questions, and provide them with guidelines where and when necessary. If one wishes to know whether something is as good as something else we need to access different versions of reality (Ibanez 1992).

Social constructivism also advocates that knowledge is socially and culturally constructed and not transmitted. As such cultural and social interactions are fundamental aspects of cognitive activity (Ernest 1999; Derry 1992; Borko and Putnam 1998; and Brown, Collins and Duguid 1989; Chalmers 1982; Vygotsky 1978). This implies that there is interconnectedness between culture and knowledge. A people’s culture defines to a large extent how its members make sense of reality.
2.2.2.6 Contextual Constructivism

Contextual constructivism is concerned with how ideas are applied. The contextual constructivist view is that experience should relate to real world situations. Kuhn (1970) stressed that true knowledge should aim at yielding calculations which agree with the problems that the scientific community felt it should address, otherwise an alternative paradigm which promises to solve those problems should be sought. The Kuhnian conception laid the foundation of contextual constructivism. Conceptual constructivism emphasizes meaning making and the application of meaning in the society. In science teaching learners should be encouraged to connect meaning to real life situations. This is also why the Conceptual Change Model I developed stressed knowledge application in real life situations. Knowledge application, according to Berns and Erickson (2001), enhances reconstruction of meaning.

Contextual constructivism also emphasizes situated experiences. It argues that knowledge is embedded in social and physical contexts. It is based on the notion that human beings have ability of arranging perceptions on the basis of constructs, and this explains how we perceive different events in similar or different contexts, and how we construct similarities and identify differences in given situations (Resnick and Hall 1998; and Kelly 1991).
Bruning, Schraw and Ronning (1999:215) defined contextual constructivism as “a process of knowledge building that involves individual’s contribution to meaning through the individual himself and social activity”. One can deduce from this definition that individuals construct meaning based on the ideas they generate. Translated to teaching and learning, contextual constructivism emphasizes construction of knowledge using problem solving, cooperative learning, and project-based approaches. Constructivists believe that learning is affected by the context in which an idea is taught and the beliefs and attitudes of the learners.

2.3 Metacognition and Learning

2.3.1 The concept of metacognition

As mentioned earlier, learning is a cognitive process of construction of meaning. Like in physical processes, certain tools or elements are required for construction to take place. From the cognitive perspective, one of these tools is metacognition. Metacognition is one of the concepts in psychology whose meaning has been broadened over time. Flavell referred to it as knowledge that regulates cognitive endeavours and broadens it to encompass all conscious cognitive and affective experiences required to accomplish a given task (Flavell 1979; 1978).
In recent time the concept has further been broadened to include being aware of and regulating one’s own thinking processes. Papaleontiou-Louca (2003) defined metacognition as sensing something about one’s own thinking, thinking about one’s thinking, and responding to one’s own thinking by monitoring and regulating it. Paris and Winograd (1990) referred to metacognition as self appraisal and self-management. According to these scholars, self-appraisal refers to a person’s judgment of his/her own thinking and abilities and taking decisions when and how to apply one’s thinking and abilities to achieve set goals. On the other hand, self management, refers to how the individual engages his/her cognitive tools and processes in finding solution to problems. Self-appraisal and self management involves two important processes leading to successful accomplishment of tasks. These are decision taking and execution.

Metacognition also refers to metacognitive awareness and metacognitive control (Baird 1999; Schraw 1998; Ertmer and Newby 1996; Kluwe 1982). While metacognitive awareness refers to an individual’s awareness of a task and how to go about solving it, metacognitive control refers to decision making, that is, determining the approach to use in dealing with problems. Both dimensions of metacognition encompass intellectual skills that the individuals require to direct, control, and reflect on their own learning (Butler and Winne 1995; Flavell 1979).
Putting together the various definitions of metacognition given by the various scholars, one would infer that metacognition is the ability of the individual to identify, control, and modify the limitations of his own knowledge. Bearing in mind that individuals learn through interaction with the environment - objects, people or events - it is likely that our interpretation of reality may not exactly represent the true nature of that reality. Individuals construct knowledge based on the basis of how they perceive reality at the time of the interaction. This means that sometime we misconstrue reality. The ability to identify when, how, and why reality has been misconstrued, and what, when and why we should restructure our conception of that reality is what I refer to as constructivist learning.

2.3.2 Theories of Constructivist Learning

There are several theories that explain the role of individual autonomy on learning. The theories can be classified into two broad groups, namely cognitive theories and social learning theories. The cognitive theories that identify with the constructivist approach to learning include Piaget’s Genetic Epistemology, Bruner’s Discovery Learning Theory, Novak’s Concept Formation Theory, Atkinson and Shiffrin’s Information Processing Theory, Eysenck and Calvo’s Processing Efficiency Theory, Festinger’s (1957) Cognitive Dissonance Theory, Craik and Tulving’s Level of Procession Theory, Sweller’s Cognitive Load Theory, Spiro, Feltovic and Coulson’s Cognitive Flexibility Theory; Barsalou’s Concept Instability Theory;
Gagne’s Conditions of Learning Theory; Achievement Motivation Theory; and Papert’s theory of constructionism. I have examined how each of these theories explain knowledge and how they relate to constructivist teaching.

2.3.2.1 Piaget’s Cognitive Adaptation Theory

One of the scholars whose work influences understanding of how humans construct knowledge is Jean Piaget. His theory of cognitive adaptation explained the influence of direct or authentic experience with the environment on learning (Piaget 1970 and 1972). Through authentic experience individuals come face to face with reality, scuffle with it, hypothesise about it, move on to search for further meaning to clarify thoughts, and turn back to test if the initial propositions are tenable. Piaget (1966) also recognized the role of social environment on learning and argued that the human being is immersed in a social environment which affects him just as much as his physical environment. Following Piaget’s theory, human beings are constantly learning as they interact with the environment. Through interaction individuals adapts to the environment. Learning is a process of adaptation to the environment and making sense of new events with reference to existing knowledge. Simply, adaptation entails fitting new ideas into an existing cognitive structure.

Another cognitive process which Piaget emphasised is accommodation. Accommodation is the restructuring of existing mental schemes in order for them to be adapted to
new situations. If new information cannot be made to fit into existing schemes, a new and more appropriate structure must be developed to fit it in. Each individual is responsible for what he fits into his schema; no one should fit in ideas into another’s schema. Based on this notion, instruction that emphasize transmission of knowledge from the teacher to the learner is feeble and unproductive in the sense that it attempt to fit the teacher’s thoughts and beliefs into the learner’s schema. This contradicts the views of Dewey and Vico, who argued that true knowledge consists of that which the individual constructs by himself; not that transmitted into his head by someone else. Each time one prematurely teaches a child something he could have discovered for himself the child is kept from inventing it and consequently from understanding it completely (Piaget 1970:715).

Most classroom teachers though unintentionally have denied the learners the opportunity to discover and invent ideas by doing what the learners themselves should do and thinking what the learners should have been allowed to think. Following Piaget’s views, instruction should provide the learners with opportunity to apply all the senses in search for meaning. It is only through seeing, hearing, touching, smelling, and tasting that an individual interacts with the environment. With these messages from the senses the individual builds a picture of the world (Lorsbach and Tobin 1992:5). The views of Lorsbach and Tobin imply that the senses are essential tools for probing into the environment and making sense of it. To facilitate
the learners to modify their preconceptions, instruction must stimulate in them the willingness to live the science they learn. To live the science they learn entails formulating new ideas, searching for new meaning, verifying their initial formulations, and applying new ideas in finding solutions to problems.

2.3.2.2 Bruner’s Discovery Learning Theory

Jerome Bruner’s (1961) theory states that the learners construct new ideas by selecting and transforming ideas, propounding tentative views, and by taking ownership of the learning process and outcomes. For this reason, instruction must be concerned with presenting experiences and contexts that make learners willing and able to learn through discovery of meaning. Teaching should recognize the importance of learning readiness and the way to organise and present learning activities in order for the ideas to make sense to the learners (Bruner 1966). Bruner also argued that instruction should be designed in ways that promote extrapolation of ideas (Bruner 1996; 1990; 1986). Extrapolation of ideas means shifting from information transmission to knowledge construction.

Bruner (1956) said that individuals learn concepts by formulating and testing their ideas about the concepts. He argued that learning is an active process that involves construction of new ideas based upon prior and present experiences. Bruner also stressed the importance of discovery in learning. Searching for meaning entails
tracing new links, patterns, and consistencies in one’s ideas or the ideas put forward by other people. Discovery-oriented learning re-activates the mental structure or schema that the learner had already constructed. Bruner argued that apart from reactivation of existing cognitive schemes, discovery-oriented activities facilitate the formation of new mental structures as the learner makes sense of his or her environment. Making sense of the environment entails active search for ideas, verification of ideas, and reconstruction of ideas. There are two essential elements that facilitate discovery learning. These are prior knowledge and motivation.

2.3.2.3 Atkinson and Shiffrin’s Information Processing Theory

Atkinson and Shiffrin (1968) used the Information Store Model to illustrate how information is processed by individuals. The theory recognises that the learner is not an empty vessel waiting to be filled with ideas but rather an active organism that seeks and constructs meaning as he interacts with the environment. Atkinson and Shiffrin likened knowledge construction to a library shelving system. Shelving is a hypothesis testing process. Shelving provides opportunity for review of meaning. Ideas cannot be shelved without being re-examined. Instructions that facilitate shelving are those that provide opportunities for student to review alternative conceptions. One of the ways to facilitate review of alternative conception is learning by doing rather than transmission and absorption.
of factual knowledge. Through shelving the learner retrieves and reconstructs meaning. Shelving of meaning is not facilitated by teacher-centered instruction. Knowledge transmission instruction is ineffective to activate the existing mental schemes to stimulate the shelving process. Instructions that facilitate shelving are those that recognise the learner as a meaning maker.

2.3.2.4 Eysenck and Calvo’s Processing Efficiency Theory

Eysenck and Calvo (1992) explained, using their Processing Efficiency Theory, that the effects of anxiety on performance are partly motivational and partly emotional. According to this theory, anxiety creates worry and thus produces positive and negative effects. The positive effects are motivating and results in improvement in learning, which eventually reduces tensions arising from poor performance. The negative effect of tension is that it drains the resources of the working memory system, thus leaving fewer cognitive resources available for task performance.

The Theory of Human Mind (Novak 1977) argued that knowledge construction is a relatively high level of meaningful learning, which uses concepts and propositions as building blocks to construct ideas. One would decipher from the processing efficiency theory that knowledge construction is challenging and exciting. It is challenging because it involves activity, thinking, and reflection. It is also exciting in the sense that the individual feels some sense
of accomplishment and ease of tension when conceptual ambiguity is reconciled. Conceptual change is said to have taken place when an individual reconciles the ambiguity that characterise his or her conceptions.

2.3.2.5 Sweller’ Cognitive Load Theory

Cognitive Load Theory (Sweller 1988) focuses on the level of mental energy that is required to process a given amount of information and to enable the individual to trace interconnectedness among concepts. One of the ways to achieve this is by presenting new concepts in multiple perspectives. Presenting new concepts in multiple provides students with the opportunity to see and realise that a concept may have multiple meanings and applications. The various perspectives presented to the learner constitute a kind of cognitive resource or conceptual bank from which the individual draws and extend ideas. The drawing process involves activity. According to Cooper (1990), the more the load the individual has the more ideas he or she is likely to draw from it. This drawing activates existing cognitive structures and illuminates them with new ideas that have been generated. It is this activation that stimulates the learner’s ability to trace the interconnectedness among concepts. Mere storing of information does not facilitate conceptual change rather conceptual change is enhanced when new information is used to weigh alternative conceptions. Weighing alternative conceptions involves searching for new links, formulating hypotheses, analysing situations, and conducting investigations. Through these activities the
individual weighs the validity of his or her preconceptions.

2.3.2.6 Festinger’s Cognitive Dissonance Theory

Cognitive Dissonance Theory (Festinger 1957) is one of the theories that have explained the factors motivating reconstruction of ideas or attitudes. It postulates that conceptual dissonance occurs when the individual is confronted with situations where choices must be made between conflicting ideas. Learners come in contact with large amount of ideas at a time, both coherent and incoherent ones. The combination of relevant and irrelevant ideas at a given time results in a kind of conceptual dissonance. The linking of new experience with prior ideas results in conceptual dissonance.

Conceptual dissonance occurs when there is incongruence between the learner’s preconception and the new concepts presented by the teacher. Learners enter science lessons with their own conceptions of concepts. During instruction the teacher presents another dimension of the concepts, which is in dissonance with the ideas the learner came with into the class. Definitely, a state of dissonance is created and this can only be reconciled through verification. I believe that some level of dissonance is necessary for effective learning of science as it provides opportunity for learners to identify the limitations of their own conceptions. Through dissonance the learner also realizes that meaning is a hypothetical construction.
Hypothetical construction means that knowledge is tentative until it has been tested or applied.

Festinger (1957) argues that conceptual dissonance arises when two mental experiences or ideas that have nothing in common with each other exist side by side. While conceptual dissonance gives rise to cognitive conflict, cognitive conflict resolution, is the consequence of changing cognitions or adaptation. One of the ways of facilitating the process of adaptation is through active interactions with the environment (Benjamin, Hopkins and Nation 1990, Commons et al 1990), and through this process existing conceptions is weighed in the light of new experiences.

From the point of view of this research, one of the ways to resolve conceptual conflict is providing the individual with activities and opportunities that allow for verification of existing ideas in the light of new meaning. Learners will not be able to verify their preconceptions by absorbing and memorizing information transmitted by the teacher but rather through active search and verification of ideas. The constructivist view is that knowledge should be discovered and verified, not transmitted. By engaging in critical search for meaning learners generate new ideas from multiple sources and use the same to reconstruct existing ideas and construct new understanding. This notion suggest that learning is a process of change and addition; change in the sense that existing ideas must be modified, reconstructed or extended to construct new knowledge.
2.3.2.7 Craik and Tulving’s Level of Procession Theory

The Level of Processing Theory (Craik and Tulving 1975) states that any information that is analysed in a very shallow manner is likely to decay and soon be forgotten while information that is interpreted meaningfully and linked to prior ideas is likely to be retained longer. From the point of view of this theory, retention of information depends on the depth to which the information is processed. From the point of view of the Level of Processing theory, the ability of the individual to construct new meaning depends on how much the individual distributes attention across several activities at a time. To achieve deeper processing students should be actively engaged with multiple, meaningful activities. By so doing students distribute their attention on several activities at a time. The more distribution the more new ideas the individual generates.

2.3.2.8 Collins, Brown and Newman’s Cognitive Apprenticeship Theory

Cognitive Apprenticeship Theory Collins, Brown and Newman (1989) states that learners can construct new ideas if properly guided. Apprenticeship in the context of this theory is referred to doing things as it is done by experts. The role of instruction is to assist and help learners to acquire cognitive and metacognitive knowledge through observation and guided practice. By so doing students think and learn the way experts think and learn.
Relating cognitive apprenticeship to science education implies guiding learners through the culture of science. Instruction should aim at presenting new concepts to the learners in an intelligible and plausible manner. Simplifying new concepts using multiple examples clarifies conceptual ambiguity, and once this is achieved students can construct new understanding independently, or can request clarifications when the need arises.

Cognitive apprenticeship instruction, according to Wilson and Cole (1994), is characterised by heuristic content, situated learning, modeling, coaching, articulation, reflection, exploration, and order in increasing complexity. This suggests that instructions that are apprenticeship oriented facilitate progressive development from procedural knowledge to production knowledge as well as autonomy. In a constructivist learning environment, the role of the teacher is restricted to facilitating instruction while construction and restructuring of ideas is entirely the onus of the learner.

2.3.2.9 Spiro, Feltovic, and Coulson’s Cognitive Flexibility Theory

Cognitive flexibility refers to the ability to learn in complex and ill-structured domains. Cognitive Flexibility Theory (Spiro, Feltovic, and Coulson 1991) argues that learning should not focus on developing intact mental schemes but should rather on multiple schema representations. The development of multiple schemas
facilitates transfer of knowledge. Based on this theory it is important to present new concepts in multiple perspectives. Multiple examples or illustrations should be used to clarify new concepts. In addition, learning activities should be organized logically to enable the learner to trace the link between ideas (Spiro, Feltovic, and Coulson 1992). Although clarification of conceptual ambiguity enhances conceptual understanding, teachers should exercise caution so as not to oversimplify new concepts; otherwise what is left after oversimplification may not be adequate to motivate or stimulate the learner to seeking new ideas. This may impair the review of existing ideas.

2.3.2.10 Barsalou’s Concept Instability Theory

The Concept Instability Theory (Barsalou 1982) states that individuals represent concepts in different ways under different circumstances. Barsalou argues that some of the concepts or categories that the individual forms are ad-hoc. Since they are ad-hoc, these concepts are not structured or organized, and are not stored in the long-term memory. Judging that learners sometimes form ad-hoc conceptions, it requires more than traditional instruction to modify such conceptions. According to Kelly (1991), knowledge is a representation erected by a living creature and then tested against the reality of that universe. Since the universe is essentially a course of events, the testing of a construct is a testing against subsequent events.
Kelly’s view suggests individuals construct new knowledge through the process of hypotheses formulation and testing, and in this way conceptual ambiguities are reconciled. My view is that learners’ misconceptions will remain resistant to change unless instruction engages the learner in meaningful activities that stimulate critical thinking and reflective analysis which consequently provoke change in conception.

2.3.2.11 Novak’s Concept Formation Theory

The underlying assumption of Novak’s theory of concept formation (Novak 1977) is that individuals learn new concepts by associating specific responses with a variety of stimuli that define the concepts. Novak (1993) argued that each learner has his or her ‘idiosyncratic conceptual hierarchy’. Learning is the activation of existing conceptual hierarchy and the extent to which one hierarchy is activated determines how much new learning will occur. Novak believed that the first concepts that children form are acquired during the ages of birth to three years, as they recognize patterns of events in the environment, and in the course of interacting with the environment children begin to identify language labels or symbols to the patterns they have observed. The ability to identify patterns in the environment and try to label them is genetically propelled. New concepts are learned as the individual constructs new mental patterns or regularities. Novak argued that construction of new knowledge requires that the individual should demonstrate commitment to
persist in searching for new meanings (Novak 2000; 1998; 1993; and 1990). From the constructivist point of view, the central purpose of education is to construct and apply new knowledge to solve problems. In the metacognitive sense, knowledge is not something that an individual transmits to another; individuals construct and reconstruct their own knowledge.

2.3.2.12 Murray’s Achievement Motivation Theory

Murray Theory of Achievement motivation (Murray 1938) argued that humans have the desire to manipulate and organize or overcome obstacles, to attain a high standard and to excel. Academic success demands cognitive engagement on the part of the learner. Cognitive engagement refers to the amount of effort spent in either studying or completing assignments. It is the result of motivation, not its source. Achievement outcomes is a function of skill" and will (McCombs and Marzano 1990). Skill refers to ability while will is the motivation. Individuals who have the skills and are more willing to learn are likely to excel than those than lack the will even if they have the skills. Willingness is not achieved through teacher-centered passive-learner instruction. The extent to which an individual is motivated to learn is influenced by the value/nature of the activity and the value of the outcomes (Tuckman 1999; Pintrich and Schrauben 1992).
2.3.2.13 Gagne’s Conditions of Learning Theory

Gagne’s (1985) theory of the conditions of learning advocates that learning is influenced by internal and external conditions. This means that internal conditions of learning refer to the psychological state of the learner such as attention, motivation, and recall. On the other hand, external conditions of learning refer to environmental factors that determine how learning events are arranged and the timing of stimulus events in any learning endeavor. These two factors jointly interact to account for differences in ability to learn.

Gagne’s Conditions of Learning provide a framework for analysing the place of problem solving in learning. This theory problem solving from the cognitive point of view is not simply a matter of applying previously learned rules but rather it encompasses all process that yield new learning. When learners are confronted with problems, they quickly recall previously learned rules in a bid to reach a solution to the problem. They test hypotheses to judge the applicability of new propositions. Gagne further stressed that when individuals find the appropriate combination of rules that fit into logical propositions they not only have solved the problem but also have learned something new (Gagne 1985). Gagne’s theory identifies problem-solving as consisting not only of the learning of rules but also the application of cognitive strategies in finding solutions to problems.
2.3.2.14 Vygotsky’s Social Learning Theory

Lev Vygotsky’s social learning theory (Vygotsky 1978) focuses on the impact of social interaction on learning. This view shares some commonalities with Bruner’s Discovery Learning Theory and Piaget’s Cognitive Adaptation Theory that I have presented earlier. Vygotsky emphasised that other people such as parents, teachers, peers or other adults who interact or live with the learner play an essential role in his or her learning. Vygotsky argued that there is a limit to which the individual can perform given tasks alone. Beyond that limit his success depends on support from other people. Vygotsky refers to this limit as Zone of Proximal Development. The zone of development is the boundary between what a learner can successfully do without support and what he or she will be able to do in the future as new skills are acquired (Shrum and Glisan 2000).

The implication of Vygotsky’s theory to instruction is that learner’s ability to restructure ideas is enhanced through interaction and exchange of ideas with other people. This theory recognises that learners can modify their preconceptions through social negotiation of ideas. Social negotiation of meaning implies exchanging or sharing of ideas, weighing alternative conceptions from multiple perspectives. Through negotiating meanings learners identify the pitfalls of their preconceptions and modify them in the light of shared meaning.
2.3.2.15 Papert’s Theory of Constructionism

The theory of Constructionism (Papert 1993) states that individuals learn by actively constructing or designing personal meaningful artifacts or models rather than by absorbing information transmitted to them by someone else. This theory stresses that knowledge is generated by experiencing the environment and sharing of ideas with other people. Its assumption is that Papert’s doctrine has a remarkable influence on education in recent times, and essentially science education for its departure from the traditional view of learning which purports the learner as a tabula rasa, an empty vessel waiting to be filled with knowledge.

Crucial to Papert’s constructionism is his revulsion of the emphasis that the school places on abstract reasoning while little is done to promote learning from concrete experiences. This view is consistent with Piaget (1970) and Vygotsky (1978), who conceived learning as construction of new knowledge. If we advocate that knowledge is constructed, therefore instruction should aim at guiding the learners to modify their preconceptions rather than transmitting knowledge to them. For this reason it is important for teachers to recognise need for learners to live the science they learn. Living the science they learn implies constructing new knowledge as their contributions to the social and economic development of their communities. This form of learning could be referred to as science for society; science for sustainable development.
2.3.3 Principles of Constructivist Teaching

From the constructivist standpoint, learning is the modification or restructuring of exiting mental schemes in the light of new experience. Individuals acquire new experience through interactions with their environments. In this connection, the role of instruction is to facilitate learning, while the students actively engage in formulating new ideas, making predictions, constructing models, and verifying hypotheses and connecting the seemingly disconnected (Wilson 1998; American Association for the Advancement of Science 1993).

One of the instructional approaches that enhance learners’ ability to reorganise their preconceptions is metacognitive instruction. This approach to instruction provides opportunities for learners to seek alternative views and to reflect on their own learning (Savery and Duffy 1995). It promotes inquiry (Huber and Moore 2001) and promotes conceptual change (Stables 2003; Ravenscroft and Matheson 2002; Mercer 2000; Gillies 2000). A crucial role of the science teacher in metacognitive instruction is to guide the learners to weigh their own constructions against the accepted view of the scientific community. The teacher therefore should not take over the learners’ role (Zimmerman 1998). To do so will deprive the learners the opportunity to restructure their misconceptions. Hein (1991) argued that learning does not only involve construction of new knowledge but also constructing the systems of meaning.
Savery and Duffy (1996) outlined a number of instructional principles underpinning instruction. They argued that in order for instruction to achieve its intent learners should be provided with relevant experience. This implies that instructional goals should be consistent with the learner’s goals. When learning goals are compatible with the learner’s own goals the cognitive demands for the given task becomes consistent with the learner’s capabilities to carry on with the task.

Savery and Duffy (1995) outlined nine constructivist teaching design goals as follows:

- giving the learner ownership of the process used to develop solutions;
- encouraging testing ideas against alternative views and alternative contexts;
- anchoring all learning activities to a larger task;
- designing an authentic task;
- designing the task and the learning environment to reflect the complexity of the environment the learner should be able to function in at the end of learning;
- supporting the learner in developing ownership for the overall problem or task;
- encouraging testing ideas against alternative views and alternative contexts;
- designing the learning environment to support and challenge the learner’s thinking;
• provide opportunity for and support reflection on both the content learned and the learning process.

Honebein (1996) and Cunningham, Duffy and Knuth (1993) have presented what they referred to as the goals of constructivist instruction. They recommended that instruction should provide learners with opportunities to experience and appreciate multiple perspectives. In addition, new concepts should be presented in realistic and relevant contexts. This implies that the concepts should relate to the experiences of the learners or their environments. Learners should also be given a voice in the learning process as well as self-awareness of the knowledge construction process. Learners should also be encouraged to set their own goals and work assiduously to attain them. Brook and Brooks (1993) also emphasised the importance of learner’s insights, beliefs, and ideas on learning, and the need to provide learning environments that enhance the application of new knowledge to solve problems in everyday life.

Yager (1991) also provided what can be described as one of the comprehensive guidelines for constructivist teaching. The author stressed that instruction should:

1. Seek out and use learner questions and ideas to guide lessons and whole instructional units;
2. Accept and encourage learner initiation of ideas;
3. Promote learner leadership, collaboration, location of information and taking actions as a result of the learning process;
4. Use learners’ thinking, experiences, and interests to drive lessons;
5. Encourage the use of alternative sources for information both from written materials and experts;
6. Encourage learners to suggest causes for events and situations and encourage them to predict consequences;
7. Seek out learners’ ideas before presenting teacher ideas or before studying ideas from textbooks or other sources;
8. Encourage learners to challenge each other’s conceptualisations and ideas;
9. Encourage adequate time for reflection and analysis;
10. Respect and use all ideas that learners generate;
11. Encourage self-analysis, collection of real evidence to support ideas and reformulation of ideas in light of new knowledge;
12. Use learners’ identification of problems with local interest and impact as organisers for the course;
13. Use local resources (human and material) as original sources of information that can be used in problem resolution;
14. Involve learners in seeking information that can be applied in solving real-life problems;
15. Extend learning beyond the class period, classroom and the school;
16. Focus on the impact of science on each individual learner;
17. Refrain from viewing science content as something that merely exists for learners to master on tests, and;
18. Emphasize career awareness - especially as related to science and technology.

Highlighted in Savery and Duffy’s (1996); Honebein’s (1996); Cunningham, Duffy and Knuth’s (1993); Brook and Brooks’ (1993); and Yager’s (1991) guidelines for constructivist teaching is the conception that a shift in the culture of learning is necessary if learners are to become meaning makers. A shift in the culture of learning denotes giving the learners greater responsibility over their own learning, thinking for themselves, reflecting over their own actions and thoughts, evaluating their knowledge, and applying new ideas to solve problems in multiple contexts. The new pedagogy advocates the learner should take the lead in the learning process while the teacher plays the role of a coach or a facilitator. Fundamentally it is this change in the role of the learner from one who absorbs knowledge transmitted by the teacher to one who constructs new knowledge, that distinguishes the constructivist approach from the traditional approach.
2.4 Conceptual Change

2.4.1 Meaning of Conceptual Change

Conceptual change, like constructivism, is a concept with multiple meanings based on who offers the definition and the theoretical underpinning of such definition. Before proceeding further some definitions of conceptual change were examined. Conceptual change is the modification of misconception into correct or appropriate scientific concepts (Chi and Roscoe 2002). Underlining this definition is the fact that conceptual change is said to have occurred when an inappropriate conception is modified to an appropriate one. By implication, new knowledge is formed when a misconception is modified. However, this definition does not identify the conditions that provoke modification or change.

Conceptual change is the appropriation of intellectual tools (Ivarsson, Schoultz, and Saljo 2002). This definition refers to conceptual change as the application of cognitive tools. From the perspective of this definition, inaccurate concepts are changed when the appropriate cognitive tool is applied. This definition also recognises that the factors that cause this appropriation may be externally motivated but internally executed.
Vosniadou (2002) defined conceptual change as the synthesis of models in the mind, beginning with their existing explanatory frameworks. This definition recognises that change does not occur in a vacuum. Taylor (2001) defined conceptual change as the restructuring of pre-existing conceptual structures that the learner has in order to promote understanding of desirable or intended knowledge. These two definitions recognise the learner’s preconceptions as an essential element of the learning process. In this sense, learning is said to have occurred when new knowledge is formed. Without misconceptions the individual is left with nothing to change, and it is the desire for change that sustains the curiosity to search for new knowledge. Conceptual change here refers to construction of a new way of looking at reality.

Conceptual change is defined as the reorganisation of diverse kinds of knowledge into complex systems in a learner’s mind (diSessa 2002). This definition is in some way related to that given by Vosniadou above. Here conceptual change is conceived as a reorganisation process and not substitution. Duit (1999) defined it as the integration of new information into the already existing mental structures. This definition varies from the ones before it in the sense that it conceives conceptual change as substitution of one idea (an illogical idea) with another (a logical, plausible and fruitful idea).
Each of the definitions presented and analysed above illustrate different opinions of what conceptual change is and how that change can take occur. Conceptual change is synonymous with learning. Broadly, conceptual change connotes change in conception. It is underpinned by the assumption that individuals construct new mental structures as they interact and make sense of the environment. Learning is the product of interaction between the individual and the environment. As the interaction progresses, more and more conceptual structures are constructed. Some of the structures are so unstable that they undergo further restructuring. Learning is said to have taken place when pre-existing conceptual structures are restructured or modified through experiencing. Conceptual change is not confined to any specific subject area.

2.4.2 A model of Conceptual Change

2.4.2.1 Meaning of Model

A model is a hypothetical formulation that attempts to explain how solutions to a problem can be attained. It is a set of hypotheses formulated in the abstract to describe a process or a sequence of events (Davis 1998; Kaplan 1997; Lefrancois 1997; Nuthall and Alton-Lee 1992; and Dorin, Demmin and Gabel 1990). A model serves as a blueprint for explaining how a solution to a problem can be reached or the role of the elements in a system. As a blueprint it
conceptualizes events or processes that cannot be seen or experienced directly with human senses. In general, models are mental suppositions that are derived from theories or propositions that represent how the way the world is or should be. Simply put, models are mental representations of how individuals perceive phenomena. Each individual constructs that which represents his or her view of the phenomenon. It is possible that a phenomenon can be represented in different models such that each represents a perspective of that phenomenon.

2.4.2.2 The process of conceptual change

Like learning, conceptual change is one of the psychological concepts that have been interpreted in an assortment of way by different scholars. From my own view learning is conceptual change. It is a cognitive process of construction and reconstruction of ideas as the individual interacts with the environment and makes sense of it. Consequently conceptual change can be defined as a cognitive process that involves formulation and testing of hypotheses. Although this learning is a complex cognitive process that cannot be adequately explained in terms of concrete illustrations I have provided in “Figure 2.1” a hypothetical model of the elements and process of conceptual change.
The model of the process of conceptual change in Figure 2.1 shows that there are two elements that must interact in order for learning to occur. These include new experience and prior knowledge. New experience refers to new learning or interaction with the environment. This implies that as individuals interact with the environment they are confronted with facts, concepts, principles, rules, and problems. These variables constitute the building-block of learning. Through interaction with the environment individuals learn from experience (Spires and Dougley 1998; Carr and Thompson 1996; and Tobias 1994).

**Figure 2.1**

*Figure 2.1 - A model of the process of conceptual change*
Prior experience or prior knowledge on the other refers to previously learned facts, concepts, principles, rule or problems. It is that ideas or knowledge that the individual has prior to new experience. Prior knowledge as all the knowledge learners have when entering a learning environment that is potentially relevant for acquiring new knowledge (Biemans and Simons 1996; Dochy and Alexander 1995; Schallert 1982; Stevens 1980). It consists of the preconceived ideas that the individual has constructed in previous interaction with the environment. One of the characteristics of prior knowledge is that they are resistant to change and as such interfere with new learning.

2.4.2.3 Description of the process of conceptual change

Conceptual change is a process of restructuring of ideas. The model in Figure 2.1 presents my blueprint of the four basic cognitive events that that inspire conceptual change. These events are as follows:
1. Formulation of ideas
2. Search for new ideas
3. Review of meaning
4. Transfer of knowledge
2.4.2.3(a) Formulation of ideas

Learning begins with the integration of new experience and prior knowledge. The product of this integration is a new knowledge. This new knowledge is frail and tentative. It is important to note that mere fusion of new experience and prior knowledge does not mean that learning has taken place but rather it is an important phase of the learning process. Any idea formulated at this phase is qualifies as a proposition, an assumption, or a hypothesis. In order to qualify as authentic knowledge it should be subjected to test or verification. In order for the integration of new experience and prior knowledge to occur successfully, the former must be comprehensible, credible, and gratifying (Mortimer 1995; Joyce and Weil 1991).

The role of instruction is to strengthen the new experience-prior knowledge bond. To achieve this goal the teacher should ensure that the learning activities should be designed and presented to the individual in ways that are relevant to their everyday life. It is important to present new science concepts to the learners in multiple modes (Savery and Duffy 1996; Honebein 1996; Cunningham, Duffy and Knuth 1993; Brook and Brooks 1993; Yager 1991).

Apart from besides present new concepts in multiple modes, the ability of the learner to formulate new ideas depends on the extent to which the new experiences are meaningful and logical. Meaningful experiences facilitate the
construction of new mental models or cognitive representations of reality. Conceptual understanding is promoted when learners actively engage in meaningful activities (Dolin, 2001; Russell and McGuigan 2001, and Ainsworth 1999).

2.4.2.3(b) Search for new ideas

The second phase of the learning process from conceptual change perspective is inquiry. Inquiry here refers to critical search for new ideas with a view to illuminate the propositions that have been constructed in the earlier phase.

The constructivist view is that knowledge is not static, it must be sought for. Searching for meaning promotes meaningful engagement of the learner in the learning process. To promote understanding among learners, they should be given plenty of opportunities to engage in problem solving, apply their learning to real-world phenomena, and talk with each other and their teachers about issues and methods (Beck, Hart and Kosnik 2002:179). The authors argued that active engagement promotes discovery of new ideas. New ideas are essential elements for reconciling alternative conceptions. Savery and Duffy (1995) have also pointed out that students’ ability to think critically and reflect on their own learning enhanced through active engagement in learning.
Inquiry-based instruction is also characterized by enjoyment, fulfillment, ownership and engagement, and flourishing in mutual respect between the teacher and learners (Chua 2004 and Goodrum, Hackling and Rennie 2000). Instructions that are inquiry-based facilitate learners’ ability to trace the interconnectedness among concepts, invent procedures, and provide explanations to why and how phenomena respond the way they do.

2.4.2.3(c) Review of meaning

The third phase of the conceptual change process is hypothesis testing. It is the phase where ideas are illuminated, extended, modified, or abandoned in the light of new evidence. This phase is also referred to as verification phase. This phase is crucial in the learning process in the sense that any misconception that the individual could not reconcile at this point is further strengthened and becomes more resistant to subsequent effort to modify it.

Review of meaning simply means reasoning from causes to effects and from effects to causes. Research has shown that the learner’s ability to make predictions and realistic generalisations is enhanced as he or she explores multiple sources in search of information (Allen 1997; Kober 1993; Bybee and DeBoer 1994; 1993). Making prediction is the hypothesis testing phase of the conceptual change process. Hypotheses testing is enhanced through activities such as
one-sentence summary of paragraphs, use of analogies, similes and metaphors to induce the appropriate schemata, drawing of inferences, paraphrasing difficult passages and drawing meaning from pictures (Aleven and Koedinger 2002; Siegler 2002). These activities, when properly applied, induce the appropriate schemata and enhance the ability of the learners to clarify their preconceptions.

Research has shown that face-to-face dialogic resolution of conceptual incongruity is essential for effective learning of science (Stables 2003; Ravenscroft and Matheson 2002; Mercer 2000; Gillies 2000). Through collaborative argument learners share their own ideas with other people. In the course of sharing of ideas they identify inherent inconsistencies in their own ideas and other people alike. Collaborative discovery facilitates interpretive talk and the request for more explanations (Okada and Simon 1997; Teasley 1995).

2.4.2.3(d) Transfer of knowledge

The last phase of the conceptual change process according to the model in Figure 2.1 is application of knowledge. It means that the facts, concepts, principles, and rules that have been learned must be demonstrated or applied to solve problems in everyday life – at home, at school, or in the community where the individual is a member. Constructivist teaching emphasises that learning is not mere memorization of factual knowledge but rather a process of transfer or
applying new concepts and principles learned in one situation to another.

The results of an investigation into the impact of collaborative learning tasks on elaboration of conceptual knowledge (Boxtel, Linden and Kanselaar 2000) showed that learners who give elaborate answers are in a position to apply new knowledge in different contexts than those that do not. With this finding in mind, Kesidou and Roseman (2002) recommend that instruction should take into account learners’ beliefs, engage them in relevant activities so as to make abstract scientific ideas plausible, model the use of scientific knowledge so that they (learners) could apply what they learned in everyday situations.

2.4.3 Factors influencing conceptual change

The learner’s ability to plan, execute, and appraise own learning is determined by various factors. Some factors are related to the learner’s cognitive disposition, while others are environmental. One of the crucial factors influencing the learner’s ability to plan, execute, and appraise own learning is prior knowledge (Chi 2002; Barnett and Ceci 2002). Prior knowledge refers to the previous knowledge or experience that the learner has prior to new learning that are relevant to the new experience. To a large extent the prior experience that an individual has determines how he responds to specific situations. It is a function of the degree of consistency between one’s cognitive structures and the physical environment that the
individual interacts with. To facilitate learning it is essential that instruction confronts learners with activities that challenge what they have seen or touched previously. Such activities are necessary to enable the learner to trace the relationship between what is being taught and what he/she had learned prior to the new experience, for without such stimulation it will be difficult for the restructuring to take place. Prior knowledge therefore is a resource for knowledge construction and reconstruction. It is a resource for hypothesis building and testing. It is an essential resource for intellectual growth.

Apart from prior knowledge the amount of information presented at a time is another important factor. Like any other form of reorganization, restructuring of existing cognitive structures does not occur incidentally rather it takes time. Learners should be allowed time to reflect and evaluate their own ideas. Doing so enables them to organise the new concepts, make sense of them, use them in everyday life, and determine whether their ideas are consistent with accepted view of the learning community. Therefore, presenting too many topics too quickly hampers ability of the individual to apply what has been learned in multiple contexts (Mestre 2002; Caine and Caine 1991).

In a study of the factors preventing the development of process skills in Biology among secondary school learners in South Africa, Jager and Ferreira (2003) found that certain factors undermine teachers’ efforts to apply the
process approach during science lessons. These include large classes; a lengthy syllabus; an inflexible and irrelevant biology curriculum; a lack of clearly stated outcomes related to process skill development in curriculum; additional demands on teachers as regards workload and lesson planning; lack of equipment and infrastructure; avoidance of inquiry activities such as field work, laboratory work, and practical; negative attitude of teachers; the emphasis on examination results; ineffective school management; and preference for teacher-centered approach to teaching. In a similar study, Padilla, Okey and Garrard (1983) observed that complex process skills and concepts in science cannot be learned in a two-week unit in which science content is typically taught. As such instruction should provide learners with sufficient time to interact with phenomena, reflect on them, and come up with new ideas.

An important factor influencing restructuring of ideas is practice. Practice provides opportunities for learners to involve all their senses - head, mind, and body in learning. Hands-on learning provides opportunity for learners to work in teams to explore real-world problems. When learners do things on their own their ability to strives for achievement, the duration the effort they put in, the ability to remain on course, choose by themselves, work collaboratively, discuss their ideas, and gain conceptual understanding is enhanced (Pajares 2002; Huber and Moore 2001; and Cavallo and Shafer 1994). Another variable that is essential in restructuring of ideas is
insight. To facilitate the development of insight, instruction should aim at in-depth rather than fleeting coverage of numerous science topics. Eylon and Linn (1988) provided four main perspectives of science teaching that impact on the development of insights. These include conceptual teaching, developmental teaching, differential teaching, and problem solving teaching.

If we go by thinking that conceptual change is not mere substitution of one idea with another but rather the restructuring of existing cognitive structures, it is essential that teachers becomes aware of the experience or knowledge that the learners have prior to instruction. It is also important to take into account the fact that it takes practice and time for conceptual change to occur. For this change to take place instruction should expose the learners to multiple experiences that would enable for the development of new insight. In addition, the curriculum should not be heavily-loaded otherwise it will add enormous pressure on the learners and obstruct rather than facilitate learning.

2.4.4 Effect of constructivist teaching on conceptual change

instructions are more effective than traditional knowledge transmission-absorption methods in facilitating conceptual change in science. Results of an investigation into the influence of explicit and reflective versus implicit inquiry-oriented instruction on sixth graders’ views of nature of science (Kishfe and Abd-El-Khalick 2002) showed that an explicit and reflective inquiry-oriented approach was more effective than an implicit inquiry-oriented approach in promoting learning. The participants in this study were 62 sixth-grade learners organised in two intact groups. The researchers engaged the intervention or explicit group in inquiry activities followed by reflective discussions, while the comparison or implicit group was engaged in inquiry activities only. Both groups were exposed to the effects for a period of two and half months. For the fact that the groups were intact, there was no guarantee that the two groups were homogenous. This would have been compensated for by using more than two groups to allow for comparison across groups.

Zarotiadou and Tsaparlis (2000) conducted a longitudinal study where they compared the Piagetian constructivist Method and Ausubelian meaningful-Receptive Method in teaching of Chemistry in Lower Secondary level. In the constructive learning method, the learners had an active involvement, while the Meaningful-Receptive Method was applied as a teacher-centered method. A total of 144 learners of an urban experimental lower secondary school in Athens were divided into two groups and taught. Two tests
were administered to them – one test on knowledge and simple application of basic chemical theory, and another test on stoichiometric calculations. At the end of the two grades, the learners were compared. The results showed that although the overall learners’ achievement was low, the constructivist method group scored statistically higher in grade nine, and generally expressed a preference for the constructivist method.

In a study of the effect of metacognitive learning cycles on learner’s understanding of science concepts, Blank (2000) found that metacognitive instruction provides opportunities for learners to formulate their ideas. To enhance this skill, Blank proposed a revised learning cycle model, termed the Metacognitive Learning Cycle, which lays emphasis on providing opportunities for teachers and learners to talk about their science ideas. This study was conducted with a 3-month ecology unit where two science classrooms studied identical ecology content using different instructional approaches. One class was taught with the conventional approach while the other was taught using the metacognitive approach. Learners in the metacognitive group were asked to reveal their science ideas and to discuss the status of their conceptions throughout the instruction. Results showed that learners in the metacognitive group did not gain a greater content knowledge of ecology, but they did experience more permanent restructuring of their ecology understandings.
Hake (1998) compared the effect of Interactive Engagement and Traditional Instruction in Physics to investigate if there is any achievement difference between students taught using traditional lecture methods and students taught through interactive engagement. Interactive engagement, which is similar to the think-pair-share method, centers on having a small group of learners work collaboratively to solve problems provided by the teacher that are based on the instructional content of the particular lesson taught. The underlying theoretical assumption is that learners who have more involvement in their own learning will better grasp the covered concepts. Additionally, by breaking up learners into small teams, a wider variety of problem-solving techniques and peer-teaching strategies may help learners become more effective problem solvers. To test these assumptions, Hake surveyed physics education colleagues and asked them to send him pre- and post-test scores for their classes, as well as self-identify the type of instructional strategy they used (lecture or interactive engagement). To ensure comparability in gain scores, he specified the tests to be used: Halloun-Hestenes Mechanics Diagnostic test (MD) or the Force Concept Inventory (FCI) to measure concept knowledge, as well as the problem-solving Mechanics Baseline (MB) to measure problem-solving ability. Instructors of 62 courses (48 interactive engagement and 14 traditional courses) responded to the call for data. The courses covered a wide range of settings (including high school, college, and university) and student abilities (ranging from a pre-test average between
18 and 71 on a 100-point scale). To determine the relative gain for each class, Hake divided the gain in each course (the post-test score minus the pre-test score) by the maximum possible gain (the maximum possible score minus the pretest score). Using this formula, Hake calculated that the average gain score across the interactive engagement classes was more than twice that of the traditionally taught courses (0.48 to 0.23).

Hake found that learners in the interactive engagement courses also had higher average scores on the Mechanics Baseline test, suggesting that problem-solving ability is strengthened through interactive engagement strategies. Hake found that Physics students taught using interactive engagement strategies significantly out-performed peers who were taught using traditional lecture methods.

However, Hake did not observe actual teaching and learning sessions but rather drew his conclusion on the basis of self-reported evidence from a self-selected population. This renders the conclusion non-generalisable to the larger population. Hake did not substantiate the degree to which each instructional strategy was effectively implemented. However, he found that while interactive engagement classes significantly out-performed those that used conventional instruction, none of the class averages on the post-test could be said to be high. Based on these findings, Hake recommended that further investigation into the teaching of introductory physics is needed.
Caprio (1994) evaluated the effectiveness of a constructivist-oriented instruction in comparison with a traditional lecture-lab-based instruction, with two groups of students who were as homogenous as possible in terms of academic ability and basic knowledge of science. There were 44 students in the constructivist group and 40 students in the traditional group. The students were from a community college. The research was conducted during the second semester of a two-semester anatomy and physiology series. The courses were night classes. Most of the students were opting for specialisations in health-related fields. A test was administered to both groups at the middle of the term. The students in the constructivist group scored a mean of 69.7% while their counterparts taught with the traditional lecture-lab group scored a mean of 60.8%. A t-test of the difference between the mean scores proved significant. The results showed that the students taught with the constructivist instruction scored higher than those taught using traditional instruction.

Von Secker and Lissitz (1999) used the hierarchical linear model (HLM) to estimate direct and indirect effects of instructional practices on individual achievement. Their results showed that laboratory inquiry, increase emphasis on critical thinking, and reduced amount of teacher-centered instruction account for variability in school mean achievement. They recommend that theoretical expectations about the impact of instructional practices on academic excellence and equity needs to be thoroughly investigated.
2.4.5 Summary of findings from literature

The conceptual foundation of this study is rooted in constructivism; the assumption that the individual is a meaning maker. Although there are different camps of constructivism, all the camps recognise the knowledge that the individual constructs by him/herself is more enduring than that transmitted to him or her by someone else. This study recognizes that learners can modify their misconceptions by themselves rather than by someone else. The instructional phases of the constructivist teaching model in “Figure 3.1” is drawn with reference to the model of conceptual change in figure 2.1 which conceives conceptual change as the process of restructuring of ideas.

Although empirical evidence has shown that constructivist teaching methods produce more positive effect on learners’ attitudes toward science, it is equally important to note that a multiple of factors influence the learner’s ability to reconstruct ideas. Some of the factors include the prior knowledge that the learner has, time allowed for reflection on previous and new learning, teaching and learning strategies, organization of the curriculum, and opportunities for practice.
CHAPTER 3

PRESENTATION OF THE CONSTRUCTIVIST TEACHING MODEL

3.1 Introduction

Chapter 2 presented the framework from where the concepts and principles that underpinning the constructivist instructional model aimed at promoting conceptual change. This Chapter presents the instructional model derived from the conceptual framework, and the main variables of the study and the sub variables. The instructional phases of the model, activities for the teacher and the learners were specified. An example of the application of the constructivist teaching model is also provided. The sub variables of conceptual change as implied in this study are operationally defined.

3.2 Instructional Models

Models of teaching are influenced by the prevailing culture of the education system and the generic and particular needs of the learner (Briggs and Sommefeldt 2003:38). A model of instruction explains how teaching is viewed and valued. Explanations and observations derived from models lead to propounding a theory, the purpose of which is to explain and predict behaviour and is subject to modification (Dorin, Demmin and Gabel 1990). Constructivist
theories and models of conceptual change recognize that time as an important variable influencing change. When we want to introduce a new model of instruction it is pertinent to integrate modern teaching methods with traditional teaching methods, initially, and gradually change the emphasis of our approach over time (Xiaoyan 2003:57).

3.3 Unifying constructivism, metacognition, and conceptual change

Following the literature reviewed on constructivism, metacognition, and conceptual change, it is apparent that there is commonality of tenets in relation to learning. Constructivism is underlined by the assumption that knowledge should not be transmitted to individuals but rather constructed by them. It postulates that knowledge construction is an inquiry-based activity that involves active search for new knowledge rather than passive absorption of meaning (Bruner 1996; Campbell 1995 and Noddings 1990). In addition, metacognitive and conceptual change theories emphasise that new understanding is attained when existing ideas undergo a process of verification. The triad recognises that there are two fundamental activities essential for effective learning to occur. First, the thinking subject must understand his own thinking and the thinking of other persons. Secondly, the thinking subject should be able to monitor and regulate the course of his own thinking, that is, acting as the causal
agent of his own thinking. These notions give the impression that learning is a cognitive process where every grasp of meaning involves three fundamental processes, namely a selection, structuring, and judgment (Mayor 2003 and Kluwe 1982). This point denotes that learning is a process of formulation and testing of ideas.

Constructivism, metacognition, and conceptual change theories hold the assumption that natural laws are mere human interpretations and as such can be probed and comprehended when its attributes are defined (Jonassen 1991 and Rousseau 1967). All recognize learning as hypothesis formulation and hypothesis testing. Independent realities can be hypothesised, only if the underlying tenets of reasonable argument are followed (Schmidt 1992:303). Reasonable argument demands that inquiry should aim at providing true knowledge, and true knowledge should arise from the integration of reason with experience. Reason alone is inadequate to offer all the evidence required to explain the nature of reality (Randrup 2002; Barnell and Garrett 1997; Mosenthal and Ball 1992; Black and Ammon 1992).

Conceptual change theories, like constructivism and metacognitive theories, emphasise that learners enter new learning with some preconceptions that are resistant to change. Overcoming this resistance necessitates that instruction should emphasize the activation of intellectual tools that would enable learners to modify inaccurate concepts into appropriate ones. To enable learners to
modify their own ideas, instruction must de-emphasise transmission of knowledge through the lecture-discussion method. Teachers should act as catalysts, creating the possibilities for learners to invent and discover knowledge, while the learners take ownership of their own learning. Duckworth in Dembo (1988:366) elaborated what effective instruction should emphasise, stating:

Good pedagogy must involve presenting the child with situations in which he himself experiments, in the broadest sense of that term – trying things out to see what happens, manipulating things, manipulating symbols, posing questions, and seeking his own answers, reconciling what he finds at one time with what he finds at another, comparing his findings with those of other children.

Duckworth's view supports the notion that learners' personal conceptions and awareness of themselves as individuals and the control they have over their own learning influence how much they could learn. He also recognises that the conditions that stimulate learning, although they may be externally motivated, are internally executed.

The model presented below is underpinned by four fundamental tenets:

- Learners possess the cognitive tools to plan, execute, and reflect over their own learning. The role of instruction is to activate these abilities.
• Learners’ preconceptions of ideas can be modified through instructions that facilitate construction and reconstruction rather than mere absorption and regurgitation of knowledge;
• The role of the teacher in the instructional process is to arouse the learners to identify and modify the inadequacies of their own ideas.
• All knowledge is constructed from previous knowledge in the course of interaction with the environment.

These four tenets guided the selection and organization of the instructional phases and activities prescribed in the model.

3.3 The Constructivist Teaching Model (CTM)

As mentioned in Chapter 2, models are mental illustrations of reality. They explain or conceptualise the way a phenomenon is, can, or should be. They serve as tools for understanding what is obscure or complicated (Hergenhahn and Olson 2005; Lefrancois 1997; Kaplan 1997). This suggests that the primary purpose of model building is to illustrate how the idea or thought conceived by an individual is like the reality it attempts to represent. From a pedagogical perspective, a model of teaching is a representation of the sequence of teaching/learning activities or experiences designed with a view to attain a set of intended learning outcomes. It is a representation of the how teaching/learning should be sequenced or
conducted with clearly defined role for both the teacher and the learners.

Instructional models encompass the curriculum, courses, units, and lesson planning as well as the design of instructional materials. To qualify as an instructional intervention, a model of instruction should provide the learning tools for learners whose learning histories are cause for concern (Joyce and Weil 1996). My thinking in terms of designing a model of constructivist teaching was influenced by the assumption that since learners’ misconceptions are resistant to change, any planned set of learning experiences that provide opportunity for the learners to evaluating their own ideas rather than the substitution of ideas is likely to induce conceptual change. To induce conceptual change, teaching should be concerned with facilitating the learners’ ability to identify relationships and contrasts among concepts (Papaleontiou-Louca 2003; Hake 2002). This can be achieved when the learners are given autonomy to sense, monitor, and regulate their own thinking.

The Constructivist teaching Model “Figure 3.1” is a set of teaching and learning activities carefully selected to facilitate learners’ ability to become aware of the limitations of their preconceptions and illuminate them using new evidence to arrive at new understanding. The model recognises that the learner is a thinking organism and should be allowed to exercise autonomy over his/her own cognition.
Figure 3.1

Constructivist Teaching Model

<table>
<thead>
<tr>
<th>Instructional Phase</th>
<th>Teacher Activity</th>
<th>Learners’ Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td>Survey learners’ prior knowledge in relation to new concept. Present main features of new concept in multiple perspectives. Challenge students to provide other examples of the concept as it manifests in real life. Encourage students to speculate the tentative nature of the concept in varied contexts. Accept students’ conflicting views.</td>
<td>Relate new concept with previous ones. Trace conceptual links among related concepts. Provide examples of new concept as applied in real life situations. Formulate tentative propositions on the nature of the concept and the underlying principles.</td>
</tr>
<tr>
<td><strong>Inquiry</strong></td>
<td>Facilitate learner search for information from multiple sources to the tentative questions they raise (students should search for ideas from primary and secondary sources). Encourage crossbreeding of ideas among students. Provide activities that encourage independence and insist on completion of task in scheduled time.</td>
<td>Search for information from different sources such as books, resources, persons, natural sites, media, etc., in relation to new concepts. Share views with other learners and with the teacher.</td>
</tr>
<tr>
<td><strong>Review</strong></td>
<td>Encourage re-examination of initial conceptions based on new ideas gathered. Encourage students to keep personal summary of what they have gathered and insist on logical presentation of ideas and the use of scientific terms to express ideas. Facilitate challenge of other students’ opinions. Call for different views on new concepts and principles can be applied to solve problems in society.</td>
<td>Provide summary of main ideas discussed during the lesson, ensuring that ideas are in logical order. Evaluate initial conception using new evidence. Use scientific terms when clarifying ideas. Use models to show the principles of the concept learned as it applies in real life. Identify the limitations of other people’s opinions. Suggest new ways to apply the concepts to solve problems in society.</td>
</tr>
<tr>
<td><strong>Application</strong></td>
<td>Present problems involving identification/labeling, drawing, application of formula, interpretation of data, and tracing of relationships among phenomena or events</td>
<td>Attempt problems involving identification, application, interpretation, diagrammatic representation, and relationships among concepts.</td>
</tr>
</tbody>
</table>
The Constructivist Teaching Model consists of four instructional phases, namely:

i. Construction Phase,
ii. Inquiry Phase,
iii. Review Phase,
iv. Application Phase

The role of the teacher and the corresponding role of the learners in each phase of the instructional process are prescribed below. It is important to note that these phases do not represent the steps of a single lesson but rather the events of learning.

3.4 Application of the Constructivist Teaching Model

Prior to the lesson the teacher explores the topic in-depth to broaden understanding of the underlying, principles and applications of the new concept to be taught, and ensures that relevant material and human resources that will be required during the lesson are available and accessible.

The first phase of the lesson is the construction phase. Here the teacher reviews prior lesson using simple and interesting activities or questions to arouse interest and thinking in the learners. A link is built between these activities and the new concept. The learners are allowed to carefully examine the characteristics of the concept and generate local examples of it. Each learner is given the opportunity to make his or her own input and writes down in
the exercise book the principles of the concept. The teacher goes round to check and ensures that each learner has written down his/her own ideas or have provided a sketch to illustrate how the concept functions. Then the teacher informs the learners that their answers will not be judged right or wrong until they have been verified. All ideas or answer provided at this stage are tentative and subject to proof or verification. To verify the ideas the learners are to engage in critical search for new ideas from multiple sources.

The next phase of the instructional process is critical search for meaning otherwise referred to as inquiry. It requires the learners to conduct experiments, gain access to books, internet websites, their peers and teachers with a view to gathering more information to verify the hypotheses they have already postulated. This search could be done as whole class, individually or in groups depending on availability of materials and class size. As the learners search they also note down important ideas they have come across that are consistent with their propositions as well as those that contradicts them.

The third phase is review of meaning. The teacher provides opportunities for each learner to share their findings with other members of the class. The teacher identifies ambiguities in the learners’ ideas and clarifies them using multiple examples or illustrations. This sharing of ideas provides opportunities for learners to modify, extend, or
replace their prior conceptions to arrive at new meaning. In addition, all new terms or terminologies that the learners came across while presenting their own views should be explained by the teacher while the learners are required to provide some local examples of those terms. With these clarifications the learners develop new insights, modify their initial conceptions and form new mental patterns. Each learner is given opportunity to summarize their present understanding of the new concept in his or her own words and compare same with what they had initially thought of about the concept when it was earlier introduced.

The last phase is transfer of knowledge. At this phase the learners are required to apply the concepts and knowledge they have constructed to solve problems. To do this the teacher challenges the learners with tasks or questions that test their understanding of the concepts, its principles and application in local context.

3.5 Identification of variables

Variables are the conditions or characteristics that the experimenter manipulates, controls, or observes. The independent variables are the conditions or characteristics that the experimenter manipulates or controls in his or her attempt to ascertain their relationships to observed phenomena. The dependent variables are the conditions or characteristics that appear, or change as the experimenter
introduces, removes, or change independent variables” (Best & Kahn 2002: 137). Following the example application of the model, the effect of the constructivist method of teaching is determined by how much effect it has on conceptual change. To investigate the effect of constructivist instruction on conceptual change would necessitate a comparison with the conventional lecture method instruction. On the other hand conceptual change, being a cognitive process was defined in terms of variables that could be expressed, observed and measured. Consequently four sub elements of conceptual change have been identified based on the conceptual change model in Figure 2.1. The elements include formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge.

Figure 3.2

Model of the variables
Figure 3.2 shows there are three categories of variables of interest to this study. These include Independent or Predictor variable, Dependent Variables, and Intervening Variables. The independent variable is the methods of teaching while the dependent variables are conceptual change and its sub variables. There are also mediating or intervening variables. These are variables that stood between the Independent and Dependent variables, such that when they are ignored could alter the effect or direction of the independent variables on the dependent variables. In the context of this study, the intervening variables include conditions such age, ability, and prior experiences of the learners. The strategies applied in pacifying the effects of these variables are presented in Chapter 4.

3.6 Operationalising the variables

An instructional model is judged effective by the extent it maximises the process and product of learning. The constructivist teaching model “Figure 3.2” designed in this study is intended to facilitate conceptual change. In order to inspire conceptual change, the learner should engage in a set of prescribed learning activities to be able to demonstrate the behaviours that indicate that conceptual change is occurring or has occurred. The sub variables of this study and their corresponding prescribed learning activities are as follows:
a. Formulation of ideas
1. Relate new concept to previous learning
2. Predict the outcomes or consequences of events
3. Generate original or innovative ideas
4. Use sketches to illustrate concepts
5. Give examples of the application of concept in everyday life

b. Search for new ideas
1. Gather new information from different sources
2. Share ideas with other students
3. Use learning time judiciously
4. Perform tasks independently
5. Show curiosity to complete given tasks
6. Ask higher level questions

c. Review of meaning
1. Summarize main ideas learned during the lesson
2. Organize ideas in logical order
3. Elaborate ideas using new evidence
4. Use appropriate science term to clarify meaning
5. Deduce meaning from scientific terms
6. Construct models of concept in real life
7. Identify the limitations of other people’s opinions
8. Suggest how new concepts can be applied to solve problems in society
d. Transfer of knowledge

1. Solve problems involving identification of structures
2. Solve problems involving application of formula
3. Solve problems involving interpretation of data
4. Solve problems involving diagrams
5. Solve problems involving tracing of conceptual links

The research traditions, methods, and techniques used in investigating the effect of constructivist teaching model on each of the dependent variables of conceptual change compared to the traditional teaching method are described in Chapter Four.
CHAPTER 4

RESEARCH METHODOLOGY

4.1 Introduction

Chapter 3 presented the constructivist teaching model, the instructional phases and corresponding instructional activities aimed at facilitating the learners’ abilities to evaluate the validity of new concepts during science lessons. This chapter discusses the research paradigms, the rationale for a two-phase study, population and selection of participants, research instruments, procedure of the study, and assumptions of the study.

4.2 Research Paradigms

After careful reading of different evaluation models and approaches, I realised that no single research tradition would satisfactorily provide all the data I required to evaluate the reliability of the MI in facilitating the conceptual change process. Judging that my focus was on mixed evidence, I opted for an integrated methodology – methodology that combines the positivist and hermeneutic traditions to find solutions to a problem.
4.2.1 Positivist Paradigm

The positivist paradigm relies on knowledge obtained through articulated observation and controlled experiment. The assumption of this paradigm is that “truth is established by looking at the hard facts” (Higgs and Smith 2006:1). This implies that all results must be substantiated with evidence. This research tradition allows for manipulation of independent variable (in this case the constructivist teaching method) in order that its effect on the dependent variable (here teaching method) could be observed and measured. It is concerned with objectivity, what is or how things are, and not how things should be.

To actually observe and measure the effect of the constructivist teaching method this study compared the performance of the learners who were taught with it in comparison with those who received conventional instruction (referred to here as Traditional Instruction). The differences on the performance of the two groups would provide objective or quantitative evidence to judge whether the constructivist model is more effective than traditional model and by how much. This would allow for analysis of data by means of mathematical tools and allows for generalizing the findings beyond the location or circumstance where the study was conducted (Blaxter, Hughes and Tight 2005; Morrison 2003; Denscombe 2003; Burns 2000; Black 1999; Crotty 1998). Data gathered from empirical study was used to calculate if a difference exists between
the learners taught with the traditional method and those that were taught with the constructivist method.

4.2.2 Hermeneutic Paradigm

The hermeneutic paradigm is concerned with understanding based on interpretations of events from different contexts. It draws conclusions by going beyond actions to looking at the value of things or events based on what other people say, the opinions of strangers or experts, their perception of the worth of a thing or event from their own experience (Morrison 2003, Cohen, Manion and Morrison 2000, Black 1999; Odman and Kerdeman 1997). Consequently this study was designed in such a way that a group of science educators experienced the effect of the constructivist teaching model with a view to judge its merit. Data for this judgment was collected through observation, interviews and analysis of documents, and were analysed on the basis of their content and were used to corroborate quantitative data.

4.3 Rationale for the two-phase empirical study

Judging that the constructivist teaching model is a product of this research, it is important to evaluate it before it can be recommended for teaching of science. For this reason this study adopted a two-phase model consisting of Pretest and Evaluation.
Pretesting is an attempt to check, and if necessary revise the instruments in readiness for the final phase of the study (Lietz and Keeves 1997). As a result it was pertinent that an opportunity be provided to carry out a trial test to identify the weaknesses of the constructivist teaching model and to further strengthen it. This step was an attempt to enhance the construct validity of the teaching model. Construct validity is a measure of the extent to which the data collected can be interpreted as indicative of the construct under investigation (Black 1999; Cronbach 1990).

**Table 4.1**

**Phases of the empirical study**

<table>
<thead>
<tr>
<th>Phase</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest</td>
<td>Identify the weaknesses of the constructivist teaching model with a view to make necessary modifications to strengthen it.</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Determine the effect of the constructivist teaching model in facilitating conceptual change in comparison with traditional teaching method.</td>
</tr>
</tbody>
</table>
On the other hand, the Evaluation phase was designed to generate the data for the purpose of judging the merits of the constructivist teaching method. Evaluation aims at determining if the intents for which the model was developed have been attained (Smith 1997). While data gathered from pretest were used to identify, modify and strengthen the teaching model, data from evaluation were used for answering the research questions and testing the hypotheses.

4.4 Population and Sample

4.4.1 Population of study

As at the time of this study, there were 4917 lower secondary students and 66 science teachers in the ten state-owned secondary schools in Seychelles. Two of the ten schools are in the inner islands of Praslin and La Digue. The former has 446 and the latter 128 Lower secondary learners respectively. The two locations are quite far away from the main island, Mahe. A trip to any of these destinations takes several hours of travel by boat or air over the vast waters of the Indian Ocean. Consequently these schools were not included in this study on the grounds of accessibility. The accessible population of this study was 4343 students in the 8 secondary schools located on Mahe. As at the time of this study, Secondary Class 3 was preparing for qualifying exams and was not involved in this study.
4.4.2 Criteria for the selection of participants

The selection of the participants took into consideration the two phases of this research – Pretest and Evaluation. This implies that different samples were selected and used in each phase. In conformity with the assumptions of the positivist and hermeneutic traditions of participants, two methods of selection of samples were adopted. These include systematic random selection and purposive selection.

The participants comprised of 178 learners and 6 science teachers selected from 6 classes in 6 different schools. Others include 3 designated observers and 2 video cameramen. The sampling process began with selection of schools, followed by classes, then the streams, groups, and finally the learners.

Firstly, six schools were selected from the eight schools in Mahe. From the six schools, classes and streams were selected using the stratified random sampling technique, one after another. Firstly a list of all the levels was drawn. Representatives of each group were selected. The name of each member was written on a strip of paper. All the strips were placed in an opaque cardboard box, with a narrow perforation or hole to allow for dipping of one hand at a time, which was specially designed for this purpose. An opaque material was chosen in constructing the box so as to guide against any form of manipulation. The narrow perforation provided space for dipping of a hand, and leaving no space for peeping through. I referred to this sampling as ‘Lucky Dip’. All learners and teachers in the
selected classes were used for the study. This option was taken to ensure that all representatives have equal chance of being selected. The six schools and classes selected were randomly grouped into Control and Treatment groups.

A total of six groups were constituted and further organized into three bands. Each band consisted of two groups – an Experimental group and a Control group. At the end of sampling a total of three Control groups and three Experimental Groups were formed. The two groups in Band 1 were used for the Pretest while the groups in Bands 2 and 3 were used for evaluation purpose. Judging that the learners were in intact classes it was not possible for me to disband the classes so as to achieve randomization.

The teachers equally were not randomly allocated to groups but rather in intact classes. Consequently all the science teachers in the selected classes automatically were chosen since they were the ones teaching science in those classes. This implies that a total of 6 science teachers participated in this study.

Apart from learners and teachers, the next group of participants involved was independent persons. These individuals were purposively chosen based on their backgrounds, experiences, and the nature of their duties in their various places of work. These included three lecturers from the National Institute of Education, 3 science teachers accredited as Examiners by the Ministry of Education, and 2 cameramen from Video Unit of the National Audio Visual Centre in the Ministry of Education. The
selection of this group was purposive in the sense that those selected were individuals who possess the professional skills and readiness to participate in this study. Altogether a total of 192 participants were involved in this study. The distribution of the participants according to phases of the experiment is shown on Table 4.2.

All learners in Band I were used for Pretest. There were 29 learners in the control group and 30 learners in the experimental group. Each group had one teacher. Band 2 and 3 were used for Evaluation purpose. Band 2 comprised 25 learners in the control group and 28 learners in the experimental group, while in Band 3 had 30 learners in each group. All learners in the control group received traditional instruction while those in the experimental group received constructivist instruction.

4.5 Research Instruments

The following instruments were used for data collection:

- Rating Scale
- Anecdotal Records
- Interviews
- Video-recorder
- Achievement Test
- Documents
4.5.1 Rating Scale

The Rating Scale used in this study was designed by me and referred to as the Teaching Effectiveness Scale (TES). The TES is a Likert type of scale that ranges from 1 to 5 (5 = Very Good, 4 = Good, 3 = Fair, 2 = Poor, 1 = Very Poor). It consists of 19 traits that assess the learners’ ability to formulate their own ideas, search for new ideas, and review of meaning, by which each learner was assessed. Assessment of learners’ performance was carried out bi-weekly.

To conduct the assessments effectively the teacher should observe each learner carefully. Observation is one of the techniques of assessing the behaviour of individuals in controlled or uncontrolled situations (Blaxter et al 2005; Koul 2003). Behaviours or characteristics assessed through observation are essentially those related to personal, social and scientific attitudes or skills. In empirical research observation is usually carried out by the researcher or persons designated by the researcher to watch, record, and analyze events of interest according to some planned scheme.

For the purposes of this study the events of interest consisted of the attitudes the learners demonstrated during science lessons. The learners were observed and assessed by their science teacher using the Teaching Effectiveness Scale (TES) based on the quality of responses, clarification, demonstrations, presentations, projects,
interaction with learners, and notes kept. A separate TES sheet was kept for each learner with the name and class clearly shown. The variables assessed and their corresponding items on the TES are as follows (Appendix 6):

A. Formulation of ideas (items 4, 11, 8, 14, and 19), which consisted of ability to:
   • Relate a new concept to previous learning
   • Predict the outcomes or consequences of events
   • Generate original or innovative ideas
   • Use sketches to illustrate concepts
   • Give examples of the application of concept in everyday life

B. Search for new ideas (items 1, 9, 5, 13, 15, and 6), which include ability to:
   • Gather new information from different sources
   • Share ideas with other students
   • Use learning time judiciously
   • Perform tasks independently
   • Demonstrate curiosity to complete given tasks
   • Ask/answer higher level questions

C. Review meaning (items 18, 7, 10, 3, 2; 17; 12, 16). These include ability to:
   • Summarize main ideas learned during the lesson
   • Organize ideas in logical order
   • Elaborate ideas using new evidence
• Use appropriate science term to clarify meaning
• Deduce meaning from scientific terms
• Construct models of concept in real life
• Identify the limitations of other people’s opinions
• Suggest how new concepts can be applied to solve problems in society

4.5.2 Anecdotal Records

This instrument was used by the three independent persons to observe and record events in both the experimental and control groups. It consisted of three sections: Sections A, B, and C representing formulation of ideas, search for new ideas, and review of meaning. Each section comprised a set of traits that the learners are expected to demonstrate which the observers should watch out to identify. The Anecdotal Record also contained some other detail such as Name of School, Group, Date of Observation, and Duration of observation (see Appendix 7). With the use of this instrument data was gathered through direct observation. During each visit the observer sat in one corner of the class watching the teacher and learners as the session progressed from beginning to the end of the lesson. The duration of most lessons were 80 minutes. In addition to observing, where necessary during the session the observer asked questions, demanded clarification, perused notebooks, assignment books, and other learning materials kept by the learners.
4.5.3 Video recorder

Video recorder was used for filming of teaching and learning sessions in the two groups. The purpose of filming the sessions was to supplement the classroom observation by the designated persons. The filming was done by the two staff of the National Audio Visual Centre in the Ministry of Education. Approval to involve these men in this study was secured through the Director of the Centre. Video-recording supplies permanent visual and sound records which can be played and replayed and then edited to examine non-verbal behavior (Galton 1997; Keats 1999). These attributes of video recording of information enabled for collection of data on some behaviours which the learners and teachers unconsciously demonstrated during the lessons. Two sessions were recorded in each group.

4.5.4 Interview

Interview is one of the most commonly used method of data collection in qualitative research (Anastasi and Urbina 2005; Koul 2003). It gathers data through direct verbal interaction between two or more individuals, and allows respondents to express themselves at length (Cohen, Manion and Morrison 2000; Wragg 2002). An interview also provides information in addition to that obtained by other research methods (Cardwell, Clark, and Meldrum 2004).
For the purpose of this study, only the teachers in the experimental groups were interviewed. The purpose of this interview was to elicit the perception of teachers in the experimental groups on the effectiveness of MI. The interview was semi-structured. It made use of prompts such as Why, How, etc. Apart from what the observers found out, the teachers were in a better position to say how far the students benefited from the model and the problems militating against effective use of the model in science teaching.

The items of the interviews were as follows:

- What impact did the constructivist method have on student learning of science, and how?
- What problems did you and the students encounter while implementing the constructivist method?
- Would you recommend the constructivist method for science teaching in other classes and schools in Seychelles? Why?

The interviews were filmed by the staff of the National Audio Visual Centre. This method of data collection also allowed for replay, thereby enhancing the dependability of the data collection.
4.5.5 Achievement Test

One of the traditional ways of evaluating instructional effectiveness is through Achievement Tests. Achievement tests are used in evaluating the effectiveness of a course of study (Best and Kahn 2002). In the context of this study, the purpose of testing was to assess learners’ ability to transfer new knowledge. An achievement test jointly designed by both the CI and TI teachers and vetted by the designated observers was designed and administered to each band. Band 2 consisted of learners in Secondary Class 1 while Band 3 consisted of learners in Secondary Class 2. The items of the test were drawn from the content agreed upon by the CI and TI teachers to have been covered in both groups. Each test comprised of five sections testing involving the following skills:

- Ability to solve problems involving identification of structures
- Ability to solve problems involving application of formula
- Ability to solve problems involving interpretation of data
- Ability to solve problems involving diagrams
- Ability to solve problems involving the tracing of conceptual links.

Each section of the Test was weighted 20 marks. Hence the total weighting of the test was 100. The time allowed for testing was 2 hours. The tests were administered to all the
groups on the same day and time. The scoring guide in Table 4.2 was designed to allow for conversion of test scores in conformity with the rating scale of the TES.

Table 4.2

<table>
<thead>
<tr>
<th>Scoring Scale</th>
<th>18-20</th>
<th>15-17</th>
<th>11-14</th>
<th>6-10</th>
<th>1-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Numerical value</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Description</td>
<td>Very Good</td>
<td>Good</td>
<td>Fair</td>
<td>Poor</td>
<td>Very Poor</td>
</tr>
</tbody>
</table>

4.5.6 Documents

Documents consist of information written or recorded on papers and kept for reference purposes. In research, document analysis provides to the researcher the opportunity to examine, analyse, and make inferences about how individuals communicate ideas (Cortazzi 2002; Anderson 1997). In the circumstance of this study the documents that were analysed include the learners’ Achievement Test papers, learners’ note books, teacher recording documents, and evaluation reports. The Test papers for both groups were analyzed on item basis by the three examiners. The
dependent variable assessed was transfer of knowledge. The analysis process involved going beyond looking at the scores to determining how well each group performed on each item of the test in comparison with the other group.

4.6 Procedure of the Study

4.6.1 Securing Approval

Having got the Constructivist Teaching Model and the tools for data collection ready for use, the first step I took was to contact appropriate authorities for approval to conduct the experiment in the selected schools. To do this, a formal letter was forwarded to the Principal Secretary in the Ministry of Education through the Director General (DG) Schools Division. A formal approval was conveyed to me to proceed with the study (see authorization note in Appendix 1).

4.6.2 Human resource development

With approval obtained, I proceeded to the head of the selected schools. Reaching the schools I found that the DG Schools Division had already communicated my request to the head teachers of the selected schools. The schools assured me of every necessary support to successful completion of this study. At the end of my discussion with head teachers, I proceeded to organize the workshops for the selected teachers.
The purpose of the workshops was to train the teachers and independent persons on how to implement the MI, and the strategies for data collection. To achieve this purpose I organised two workshops. The first was organized for the teachers in the Control groups while the second was for those in the Experimental groups. All the workshops were held at the Conference Room of the National Institute of Education with the consent of the Director of the Institute. See letter of request to use venue in Appendix 3). The first workshop was held on 26th February 2005 while the second session was held on 3rd March 2005. In both instances the independent judges were in attendance.

The training sessions for the control groups focused mainly on the methods of data collection and ethical issues. The use of MI was not discussed with this group since they were to use the traditional approach which they were quite familiar with. Copies of the data collection tools were distributed to the participants and the methods of data collection were discussed. The teachers were asked to plan their lessons in their usual manner and deliver same to their students. The scheme of work for the period was provided and discussed to ensure that the same contents were taught to both groups. The groups for pretest and those for actual implementation were mentioned to the participants. In addition, the designated observers were introduced and their roles were defined. The date for commencement of the Pretest was agreed.
The second training session was attended by teachers in the experimental groups, during which the constructivist teaching model was presented and its application was discussed. Each teacher in the experimental group was given a copy in addition to the tool data collection. The instructional phases, objectives and activities were discussed and questions clarified. A format for planning of lessons was provided to each of the three teachers in the experimental groups (see lesson plan format in Appendix 5). Furthermore, tools and procedure of data collection were discussed and doubts clarified. The schedule for observation for the designated persons was drawn and discussed, with their roles clearly defined. Ethical issues were highlighted. The participants were reminded of the need for confidentiality, commitment, and to avoiding any activities that would disrupt teaching and learning in their respective classes. They were also reminded to ensure that their personal prejudice did not override their judgment. At the end of the session the date of commencement of the Pretest was fixed.
4.6.3 Field Experimentation

4.6.3.1 Pretest

4.6.3.1 (a) Participants

Pretest commenced on Tuesday 15th February 2005 and was concluded on the 15th April 2005. The participants were learners in Band 1, consisting of 59 learners. There were 29 learners in the Control group and 30 learners in the Experimental group. There were two science teachers; one for each group. Also involved in pretest were 3 independent observers, three examiners, and 2 cameramen. The sample for pretest is shown in “Table 4.3”.

Table 4.3

Sample for Pretest

<table>
<thead>
<tr>
<th>Band</th>
<th>Quantitative</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Schools</td>
<td>Class</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
4.6.3.1 (b) Unit/topics taught

The instructional Unit taught during pretest was ‘Nature of Matter’, comprising the following topics:
1. Nature of matter in terms of its state and properties;
2. Elements, compounds, and mixtures;

4.6.3.1 (c) Procedure

The Control group was taught with traditional lecture method while the Experimental group received constructivist instruction. Each group was taught by the science teacher of that class. Assessment was based on the items on the TES. In addition each group was observed by the independent persons designated and tutored to conduct this activity. Each group received one visit per week from each of the designated persons, implying that each group received one visit per week from each observer, totaling 15 visits. All observations were recorded on the Anecdotal Records. In addition to observation by the independent persons, I also observed the sessions. The purpose of observation at this stage of the study was to determine the weaknesses of the metacognitive instructional model that I designed so that necessary step could be taken to strengthen it prior to evaluating it.
4.6.3.1 (d) Debrief

At the end of Pretest all the participants including the teachers, observers, and examiners were invited for debriefing with their reports and suggestions on how the model could be strengthened to achieve the purpose for which it was designed. During the session the following suggestions were raised by the participants:

1. CI learners should be encouraged to initiate and carry out projects (self-initiated projects). The purpose of this is to encourage individual construction of knowledge rather than teacher initiating projects for learners. To accommodate this suggestion the 19th item on the TES was included.

2. The duration of the evaluation phase should be extended to one academic term to allow the teacher more time to adapt to the model and for its effect to become more perceptible.

3. Measurements should be conducted at the end of each topic rather than on weekly basis as was the case during pre-test. The teachers suggested that doing so would minimize the pressure on them and allow for thorough assessment of the learners. To this end a total of five measurements were agreed for the evaluation phase. The teacher should sum up the scores for each learner after five measurements so that at the end of the experiment each teacher
should hand in the average score for each learner on each item of the TES.
4. Ethical concerns were emphasized. The Teachers were reminded the need to be genuine and sincere in their measurement and recording of data.
5. Each learner should be provided a separate notebook for note writing. The researcher mentioned he would provide an exercise book, a pen, and a pencil for each learner participating in this study.
6. The duration of Evaluation was pronounced; from 16th May 2005 for a duration of 13 weeks.

The results of pretest are presented in Chapter 5 along with the results of Evaluation.

4.6.3.2 Evaluation

4.6.3.2 (a) Participants

Evaluation of the constructivist teaching model commenced on 16th May 2005. The participants comprised learners in Bands 2 and 3, 4 science teachers, 3 independent observers, and two cameramen. Each Band consisted of a Control group and an Experimental group. In Band 2 there were 25 learners in Control group and 28 learners in the treatment group. Band 3 comprised of 33 learners in each group (“Table 4.4”)
### Table 4.4

**Sample for Evaluation**

<table>
<thead>
<tr>
<th>Bands</th>
<th>No. of Schools</th>
<th>Class</th>
<th>Group</th>
<th>No. of Learners</th>
<th>No. of Teachers</th>
<th>No. of Observers</th>
<th>No. of Examiners</th>
<th>No. of Camera men</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>Control</td>
<td>25</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>Experimental</td>
<td>28</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>Control</td>
<td>33</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>Experimental</td>
<td>33</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>119</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

#### 4.6.3.2 (b) Unit/topics taught

The Unit covered was Characteristics of Living Things and Cells Activity. From this Unit the following topics were taught during the Evaluation:

1. Characteristics of living and non-living things;
2. Cell as the basic unit of life including the structure of a Cell;
3. Similarities and differences between Plants and Animals;
4. Basic process of photosynthesis and the conditions necessary for it to occur;
5. Presentation and analysis of data.

The Unit and contents were drawn from the Seychelles National Science Curriculum.

### 4.6.3.2 (c) Procedure

Learners in the Control groups were taught the same content as their counterparts in the Treatment group. Learners in Control groups irrespective of class were taught with the traditional lecture method while their counterparts in Experimental groups were exposed to constructivist learning. Both groups had equal number of instructional periods. The method of assessment was formative. This implies that the assessment was continuous. During lessons questions were asked to test learners’ understanding. The learners were required to illustrate their ideas using sketches and other forms of illustrations to clarify their ideas. In addition, the learners were assessed based on responses to questions, projects, oral presentations, interactions with other learners, and their notebooks. Each learner was assessed and scored on each item on the TES.

Each Group was also observed by the designated persons who recorded their observation in the Anecdotal Records. In addition, two sessions from each of the groups were filmed by the two cameramen from the National Audio Visual Centre.
When and wherever used, the cameras were mounted prior to commencement of the session.

The two science teachers in the constructivist groups were also interviewed on the last week of the experiment to elude their judgment on the effectiveness of the MI. The interviews were video-recorded to allow for replay during analysis. At the last week of the experiment a Test of Achievement was administered to learners in both groups on the same day and time. The papers were swapped among the four science teachers for correction. The swap was done such that teachers in the Control groups corrected the scripts for the Experimental groups and vice versa. The score obtained by each learner on each item was recorded against the name of that learner. At the end of the corrections, all the test papers were forwarded to the 3 examiners for cross-checking and comments on each group’s performance per item of the test using a Report Sheet designed for this purpose. The Test Paper for each Band is shown below in Figures 4.1 and 4.2 respectively.
Figure 4.1

Achievement Test (Band 2)

SECTION A

QUESTION 1

Observe carefully the diagrams below and answer the questions that follow.

Diagram A

Diagram B

a. What is diagram A? .................................................. 2 marks

b. Label the parts of diagram A, the cell numbered 1, 2, 3, and 4 8 marks

c. Name one part of diagram A that is not found in diagram B. 4 marks

d. Write down one function of the parts of diagram B numbered 5, 6, and 7.

i. .................................................................................. 8 marks

ii. .................................................................................. 8 marks

iii. .................................................................................. 8 marks
SECTION B

QUESTION 2

a. A student observed a living organism under a microscope and found that the organism has become 8 times larger than its actual size. If the actual size of the organism is 0.0025 mm, the size of the organism under the microscope is

i. $0.0025 \text{mm} \times 8$

ii. $0.0025 \text{mm} \div 8$

iii. $0.0025 \text{mm} \times 8$

iv. $0.0025 \text{mm} \div 8$

10 marks

b. The mass of three substances A, B, and C were mixed together to give a total of 24.5 grams. The mass of A was 5.7 grams and the mass B was 13.9 grams. Find the mass of C using the formula below:

\[ \text{Mass of C} = \text{Total mass of mixture} - (\text{Mass of A + Mass of B}) \]

10 marks
SECTION C

QUESTION 3

a. The weight and height of three students in a class were recorded as follows:

<table>
<thead>
<tr>
<th>Property</th>
<th>Name of student</th>
<th>Total</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Evans</td>
<td>Tony</td>
<td>Zenia</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>46.5</td>
<td>48.2</td>
<td>44.5</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.2</td>
<td>1.4</td>
<td>1.24</td>
</tr>
</tbody>
</table>

i. What is the total weight of the students?  4 marks

ii. Find the average weight of the students.  3 marks

iii. Find the average height of the students  3 marks
SECTION D

QUESTION 4

a. Draw a flower and label clearly the following parts: Style, Stigma, Anthers, Petal, Ovary, Stalk.
   6 marks

b. Write down one function of each of the following parts:
   i. Stigma .................................................................
   ii. Petal .................................................................
   iii. Anthers ............................................................
   6 marks

c. Draw a diagram of a dicotyledonous plant showing the following: leaf, stem, root.
   6 marks

d. Write down two characteristics of the leaf of a monocot.
   2 marks
   i. ..............................................................................
   ii. .............................................................................
SECTION E

QUESTION 5

a. Observe carefully the diagram below to answer questions i, ii, and iii.

i. What is the name of this method of separation of substances?

ii. Why should heat be applied at H?

iii. What do you think will happen if C is not tightly fitted?

b. Write down four uses of plants to human beings.

i. 

ii. 

iii. 

iv. 

5 marks
Figure 4.2

Achievement Test (Band 3)

SECTION A

QUESTION 1

Observe the diagrams A and B and answer the questions that follow.

A

B

a. Diagram A shows ........................................ 2 marks

b. Diagram B shows ........................................ 2 marks

c. Label any four parts of A above 8 marks

d. Name two parts of A that are not found in B.

i. ................................................................. 8 marks

ii. ................................................................. 8 marks
SECTION B

QUESTION 2

Four seedlings A, B, C, and D were potted and left to grow in open air. All of them received sufficient sunlight and water. After four weeks the heights of the plants were recorded as shown below:

<table>
<thead>
<tr>
<th>Type of plant</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of plant (cm)</td>
<td>27</td>
<td>---</td>
<td>15.5</td>
<td>18</td>
</tr>
</tbody>
</table>

a. If the B was 4.5 cm taller than A, how tall was B?  

7 marks

b. Find the difference in the height of B and the shortest plant in the group.  

8 marks

c. Which of these formulas will you use to calculate the average height of the plants?

i. \[ \frac{A + B + C + D}{3} \]  
ii. \[ \frac{A - B + C + D}{3} \]  
iii. \[ \frac{A \times B \times C \times D}{4} \]  
iv. \[ \frac{A + B + C + D}{4} \]

5 marks
SECTION C

QUESTION 3

Jane nursed a bean plant over a period of six weeks. She recorded her findings as follows:

<table>
<thead>
<tr>
<th>Week number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of plant (cm)</td>
<td>25</td>
<td>50</td>
<td>70</td>
<td>90</td>
<td>115</td>
<td>125</td>
</tr>
</tbody>
</table>

a. Plot a graph using the grid below to show the heights of the bean plant over six weeks.

b. State the period when Jane recorded the lowest rate of growth.

c. Calculate the difference in the height of plant in Week 2 and Week 5?
SECTION D

QUESTION 4

a. Draw a monocot plant, and label any three parts of it.  

b. Draw a diagram showing the structure of the leaf of a dicot plant.  

c. From your diagram write down two characteristics of the leaf of a dicot plant.

i. .................................................................................................................................

ii. .................................................................................................................................

2 marks
SECTION E

QUESTION 5

a. A small orange plant is growing under a big mango tree. The mango tree has many branches and leaves. Explain any two likely conditions the orange plant will find itself in (use diagrams to make your points clearer).

10 marks

b. Write down five uses of plants to human beings.

i. ..............................................................................................................................

ii. ..............................................................................................................................

iii. .............................................................................................................................

iv. ..............................................................................................................................

v. ..............................................................................................................................

10 marks
4.6.3.2 (d) Debrief

At the end of the experiment, a period of four weeks was allowed for all the participants to compile and forward the data they collected to me. A debriefing was held a week later. During the session, appreciation was conveyed to the participants for their painstaking contributions to the study. In addition, letters of appreciation were forwarded to the Principal Secretary of the Ministry of Education, Director General (Schools Division), Director of NAVC, and all the head teachers of schools that were involved in the study.

4.7 My role

Looking at the nature of this study, there were two main phases – Pretest and Evaluation. Since the pretest was designed as the first test of MI aimed at identifying its weaknesses with a view to strengthen it, my role at this phase was prominent. I observed the classes, clarified the teachers’ doubts while the model was implemented, and ensuring conformity to ethical standards. All these were aimed at ensuring that the instructional model is tight.

My role shifted during the evaluation phase. I deemed it logical not to judge the efficacy of an instructional model I designed. I rather involved individuals who have background in science education and were trained during the workshop to observe the classes based on the criteria stipulated in this study. This shift in role is explained
by Best and Kahn (2002), who stressed how important it is for a researcher not to judge the merits of his own model. In the views of Best and Kahn, where the researcher (one who designed an instructional intervention) conducts the observation himself, it is likely that the researcher unconsciously tends to see what is expected. This implies that it is likely that researcher’s personal values, feelings, and attitudes, based on past experience, may distort the results of the study. In a situation such as this, it may be desirable to engage others who are well-prepared as researchers’ to conduct the observation, while the researcher’s role is restricted to interpretation of data. Based on this advice, my role was more pronounced during pretest where I engaged in classroom observations with a view to detect the limitations of the model for necessary modification, if need be.

4.8 Validity and reliability

4.8.1 Ethical considerations

Ethical concerns were taken into account. Ethics refers to conformity to standards for doing what is right (Timpane 1997; Fraenkel and Wallen 1993). In any given research it is pertinent that the activities or conduct of the researcher and the rest of the participants do not violate the rights of institutions and the individuals they serve. In this study quite a number of steps were taken to ensure
that ethical concerns were not breached. Prior to stepping into the schools, the consent of the authorities in the Ministry of Education was sought and secured. All heads in the school selected for this study were also contacted and the purpose and design of the study discussed. Measures were also taken to ensure that the conducts of the teachers and independent persons conformed to ethical requirements. Data collection was conducted in ways that did not violate the right of the individual. All the teachers interviewed were informed before hand. The filming of sessions was done in a professional manner that it did not cause any disruptions to teaching and learning. Apart from acknowledgement, all names of individuals wherever they were mentioned are pseudo. In addition, all references cited on this work were acknowledged. Should there be any instance where this was not the case I declare it is not intentional.

4.8.2 Validity

Validity refers to the extent to which the outcomes of a research accurately describe the phenomenon or issues it is supposed to measure (Bush 2003; Burns 2000; Bell 1987). In this study, the validity of the Constructivist Teaching Model was judged from the perspectives of its internal validity and external validity.
4.8.2.1 Internal validity

Internal validity refers to the extent to which we can be sure that the research findings are due to the mechanisms suggested (Cardwell, Clark and Meldrum 2004). Internal validity is concerned with the question 'Do the experimental treatments make a difference in the specific experiment under scrutiny or can the difference be ascribed to other factors (Burns 2000). For this study internal validity refers to the extent to which we can be sure that the findings of this research are due to the advantage constructivist instruction has over traditional instruction. Put simply, is the difference between TI ad CI learners due to the effect of the treatment given to CI learners or is the difference the consequence of other factors beyond my control?

This empirical study adopted the experimental method using the pseudo-experimental design with non-equivalent groups. This design suggests that the learners were not randomly assigned to experimental and control groups but were in intact classes. However the groups were randomly assigned to treatment conditions. Although randomisation of subjects was not achieved the experimental procedure applied in this study allows for making comparison between two groups - experimental and control groups. Although the groups are from different schools, the learners in both groups were in the stream. It is assumed that learners in the same stream
have similar academically. The fact that the learners in TI and CI groups were from different schools eliminated the question issue of diffusion effect where learners in the two groups talked or discussed with each other. To further eliminate the question of diffusion of ideas, the teachers were advised not to inform the learners that other schools are involved in the study. To further guarantee validity the same instruments, persons and procedure were used for data collection in both groups.

The design of this study also enabled for the identification and isolation of intervening variables such as class, academic ability, and prior experience, whose presence would have altered the effect if unchecked. This was achieved by ensuring that classes selected were as homogenous as possible. In addition treatment conditions were randomly allocated to the groups.

Prior to evaluation, the constructivist teaching model was subjected to pretest for 5 weeks with a view to identify and eliminate inherent weaknesses of the model prior to evaluation. This measure was taken to ensure that the model produces the effect for which it was designed. While pretest provides opportunity to check, and if necessary revise the instruments in readiness for the final phase of the study (Lietz and Keeves 1997:123), evaluation aims at determining if the intents for which the model was developed have been attained (Smith 1997).
Another measure that I took to enhance the validity of my study was adopting the mixed methods approach which integrates the qualitative and quantitative methods. This integration enabled me to investigate the effect of constructivist teaching model using different categories of participants as well as multiple tools and strategies for data collection. This integration enabled for validation or corroboration of evidence from multiple sources.

Training sessions, briefings and debriefs were organized for the science teachers and independent persons who participated in the implementation and evaluation of the constructivist teaching model model. The purpose of organizing those sessions was to acquaint the participants with the application of the constructivist teaching model, and the tools and strategies for data collection. The sessions were organised in such a way that teachers in the experimental groups did not attend the same sessions with their counterparts in control groups. This decision was taken to avoid blending or any practice that may conceal the difference between the two methods of teaching. These measures were also taken to ensure that the effect of the constructivist teaching model was not overshadowed by factors errors.
4.8.2.2 External validity

External validity refers to the extent to which the results of a research can be generalized to other settings beyond that where the study was conducted. The external validity of this study was determined from two perspectives; namely population validity and ecological validity. Whereas population validity refers to the extent to which results from a research can be generalised to other groups or people, ecological validity refers to the extent to which the results of a study can be generalised to situations outside the research setting (Cardwell et al 2004; Fraenkel and Wallen 1996).

4.8.2.2 (a) Population validity

As at the time of this study, there were ten State secondary schools in Seychelles. However, only eight were accessible to this study. The other two schools are located in the inner islands of Praslin and La Digue. Accessibility to the two schools would involve several hours of travel on the vast waters of the Indian Ocean. From the eight accessible schools located on Mahe, six were selected, representing 60 per cent of the target population and 75 percent of the accessible population of schools in Seychelles. The target population of learners was 4917 but the accessible population was 4343. From the accessible population of learners a sample of 178 learners was selected, representing 4.1 per cent of the accessible
population of Lower secondary level learners. Although the number of learners selected was low compared to the entire population of learners in the schools (178 out of 4343), the number of schools chosen was representative of the population of schools (6 schools from a total of 10 schools or 60 percent of the population of schools in Mahe).

The population of learners involved in this study represented only 4.1 per cent of the entire population of learners in the Lower secondary in Seychelles. Since the learners were selected from 6 out of the 10 secondary schools in Mahe it could be inferred that this study has a high population validity and as such its findings can be generalised to the other 4 schools in Mahe that were not selected and the two schools in the inner islands of Praslin and La Digue that were not accessible.

4.8.2.2 (b) Ecological Validity

Ecological validity as I have stated earlier is a measure of the extent to which the findings of a research can be interpreted to be true in settings different from the one in which it was conducted. This empirical study was conducted under normal classroom conditions. All lessons were conducted during normal lesson periods. In addition, all measurements were conducted during normal class time as the school had scheduled. All learners in the six state schools that were used in evaluating the effect of the metacognitive instructional model were exposed to the same
ecological conditions irrespective of whether they were in the experimental or control groups. It is expected therefore that the rest of the four schools that were not involved in the study have similar ecological conditions as the six that were involved. Therefore the findings can be generalized to all the ten state schools on the island since the schools that were not selected have similar setting and conditions as those that were selected and used for this research.

4.9 Assumptions of the study

This study was conducted with two main assumptions in mind. The first assumption is that the scores are expected to be normally distributed in all four sub variables of conceptual change if CI and TI learners are homogeneous and observations and assessments done as honest as it were planned. The second assumption is that if the groups are homogenous, and observations and assessments carried out as honest as it were planned, the variances of TI and CI groups are expected to be equal or near equal in all the sub variables under investigation (equality of variances). Results of test of these two assumptions are shown on Tables 5.5 and 5.6 in Chapter 5.
4.10 Summary of the Chapter

This research adopted a mixed method research strategy to investigate the problem. The strategy enabled the integration of the positivist and hermeneutic traditions to probe the problem. The tenets of the paradigms of this study necessitated the involvement of different categories of participants drawn from learners, teachers, and independent persons in Seychelles. In addition, multiple strategies were used for data collection. The purpose of adopting the integrated approach, and using multiple samples and strategies was to corroborate evidence.

The design of the study is pseudo-experimental with non-equivalent samples since randomisation was not tenable. The experiment was conducted in two phases – Pretest and Evaluation. The purpose of pretest was to identify the weaknesses of the constructivist teaching model that I have designed with a view to strengthen it prior to evaluation. Evaluation was predominantly for the purpose of decision taking or judgment by comparing the performance and achievement of the learners taught using the constructivist teaching model and the learners taught using the traditional lecture method.
CHAPTER 5

ANALYSIS AND PRESENTATION OF RESULTS

5.1. Introduction

The previous chapter described the research approach, phases, and methods of the selection of participants, methods of data collection, the procedure of the study, and the assumptions guiding the study. In this chapter the techniques of techniques for data analysis and the results are presented.

The results are presented in three Sections, starting with the results of descriptive analysis; followed by the results of test of the two assumptions stated in section 4.9. The results of inferential statistics and the results of qualitative analysis are also presented.

The results of pretest are presented side by side with the results of the evaluation, a choice I made so that the reader will be able to see at glance the difference in the performance of TI and CI learners on each of the sub variables that this study explored in both phases.

The effect size, power, and internal consistency of the constructivist teaching model are calculated and presented. A summary of my findings is presented at the end of this chapter.
5.2 Data Analysis techniques

As I mentioned earlier in section 1.10, this research adopted mixed methods. Consequently both quantitative data and qualitative data were collected. In the light of the nature of data collected, two techniques of data analysis were employed. These are:

i. Quantitative techniques;

ii. Qualitative techniques.

5.2.1 Quantitative techniques

All quantitative data collected were entered in SPSS. Two statistical techniques were used in the analysis, namely descriptive statistics and inferential statistics.

5.2.1.1 Descriptive statistics

Descriptive statistics were used to obtain the difference between Means, Standard Deviation, Skewness, and Kurtosis of the scores for each group on each dependent variable.

5.2.1.1 (a) Mean

The means for TI and CI groups were used in determining whether the group who received constructivist instruction performed better than their counterparts who received traditional instruction.
5.2.1.1 (b) Standard Deviation

The Standard Deviation provides an indication of the degree of variability of the scores in TI and CI groups. This study assumed the standard deviations of the groups are equal or near equal. For this study, the equality of the variances of TI and CI scores were verified using the Levene’s test (Gastwirth, Gel, and Miao 2006; Lim and Loh 1996; Brown and Forsythe 1974). If the Levene’s statistic is significant at 0.05 alpha level, this research rejects that assumption that the variances of TI and CI groups are not equal. On the other hand, a calculated p-value exceeding 0.05 suggest that the variances for TI and CI groups are equal, and this would imply that assumption of homogeneity of the variances is tenable.

5.2.1.1 (c) Skewness

Skewness refers to the extent to which a distribution of scores or values deviates from symmetry around the mean. A value of zero means the distribution is symmetric or not balanced with reference to the mean. A positive skewness indicates a greater number of smaller values, and a negative value indicates a greater number of larger values. Values for acceptability for psychometric purposes (+/-1 to +/-2) are the same as with kurtosis.
5.2.1.1 (d) Kurtosis

Kurtosis on the other hand is a measure of the "peakedness" or "flatness" of a distribution. A kurtosis value near zero indicates a shape close to normal. A negative value indicates a distribution which is more peaked than normal, and a positive kurtosis indicates a shape flatter than normal. An extreme positive kurtosis indicates a distribution where more of the values are located in the tails of the distribution rather than around the mean. A kurtosis value of +/-1 is considered very good for most psychometric uses, but +/-2 is also usually acceptable.

5.2.1.2 Inferential statistics

The Inferential statistic used for testing the research hypotheses is the One-Way Analysis of Variance (ANOVA). With this statistic the significance of the difference between the Means of the two groups on each of the dependent variables, namely formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge are obtained. Conclusions are drawn at significance level of 0.05. The null hypotheses tested are as follows:

\textbf{H}_{01}: There is no significant difference in the formulation of ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.
**Ho2:** There is no significant difference in the search for new ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

**Ho3:** There is no significant difference in the review of meaning between learners taught with the constructivist method and learners taught with the traditional lecture method.

**Ho4:** There is no significant difference in the transfer of knowledge between learners taught with the constructivist method and learners taught with the traditional lecture method.

### 5.2.2 Qualitative Techniques

The qualitative part of this research is concerned with evaluating how far the constructivist approach to secondary school science teaching is welcome in Seychelles. To address this purpose, data was collected through direct observation of teaching and learning session and interviews for the teachers that implemented the model that was designed for this study. Analysis of data was based on the content of information that was provided by the respondents. Content analysis is a method used in finding meaning from text data by identifying and classifying themes and concepts, which involves reading between lines and noting down regularities and recurring ideas in a text (Blaxter, Hughes and Tight

The meanings drawn from the data were used in judging how the independent persons and science teachers involved in this study perceived the effect of CI on science teaching with reference to the four dependent variables identified in this study. The opinions of the designated observers are analysed with reference to the following questions:

**Question 1:** Is there any difference between learners who received constructivist instruction and those that received traditional lecture method with reference to formulation of ideas?

**Question 2:** Is there any difference between learners who received constructivist instruction and those that received traditional lecture method with reference to search for new ideas?

**Question 3:** Is there any difference between learners who received constructivist instruction and those that received traditional lecture method with reference to review of meaning?

**Question 4:** Is there any difference between learners who received constructivist instruction and those that received traditional lecture method with reference to transfer of knowledge?
In addition, the opinions of the two science teachers who implemented the constructivist method in their respective classes are analysed to determine their perception of the paradigm change.

- What impact did the Constructivist Teaching Model have on learners’ attitudes towards science?
- What problems did you and the learners in your class encounter while implementing the Constructivist Teaching Model?
- Would you recommend the constructivist approach to the teaching of science to other classes and schools in Seychelles? Why?

5.3 Triangulation

Triangulation is a research strategy where more than one method is used for data collection in a single study. The purpose of triangulation is to allow for comparison, corroboration, and conclusions based on evidence from multiple sources (Cohen et al 2000; Bush 2002; Denzin 1997). In the context of this study triangulation was achieved as follows. I adopted the integrated methodology which allowed for the use of multiple bands of participants and a variety of tools for data collection to judge the effect of MI. For instance, the effect of MI on formulation of ideas, search for new ideas, and review of meaning was judged respectively based on the learners’ performance, the opinions of the designated persons and the perceptions of the science teachers, while its effect on transfer of knowledge was on
the basis of learners’ scores on achievement tests and the opinions of the examiners. It is apparent that different tools were used by different participants, thus enabled for both methodological triangulation and respondent triangulation.

5.4 Presentation of the Results

5.4.1 Results of Descriptive Analysis

5.4.1.1 The difference in the Means of TI and CI groups on formulation of ideas

Table 5.1 presents the results of descriptive analysis for the two phases of this empirical study. Following the table, the results of Pretest indicate that learners that received traditional instruction scored a mean of 9 and their counterparts that received constructivist instruction scored a mean of 11.6. The difference between the means is 2.6. While the minimum and maximum scores for the constructivist group are 8 and 16, an indication that the least score on this test is in the traditional group while the constructivist group got the highest score.

Table 5.1 further shows wider dispersion of scores in the constructivist group compared to the traditional group. The standard error of the means gives an indication of low measurement error since none of the values exceeds 0.5.
Although the learners who received constructivist instruction performed better than their counterparts who received traditional instruction on formulation of ideas, the mean difference of 2.6 seems narrow compared to the mean performance of the groups in the evaluation phase.

### Table 5.1

**Descriptive analysis of TI and CI scores on the formulation of ideas**

#### PRETEST

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<thead>
<tr>
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#### EVALUATION

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</table>
The results of descriptive analysis of data on formulation of ideas during Evaluation indicate that the minimum and maximum scores for TI group are 5 and 12 respectively while the minimum and maximum scores for CI group are 12 and 22 respectively. The mean for TI group is 7.95 while their CI counterpart scored a mean of 15.75. The Standard Deviations of TI and CI scores in distribution vary remarkably (1.59 and 2.21 respectively). These figures suggest wider dispersion of CI scores than TI scores with reference to their Means. Apart from the difference in dispersion of scores, the results show a difference of 7.8 between the Means of the two groups, in favour of CI group. The results give evidence that learners who were taught science with the constructivist method demonstrated greater ability to formulate ideas than their counterparts that were taught with the traditional method.
5.4.1.2 The distribution of TI and CI scores on the formulation of ideas

Figure 5.1 (a)

Histograms showing the distribution of
TI and CI scores on the formulation of ideas (Pretest)
Figures 5.1(a) and 5.1(b) show variations in the modal scores of TI and CI groups in both phases of the empirical study. While modal scores for TI and CI groups are 10 and 11 respective in the Pretest, the modal scores for the two groups are 7 and 17 respectively in the Evaluation.
5.4.1.3 The difference in the Means of TI and CI scores on the search for new ideas

Table 5.2

Descriptive analysis of TI and CI scores on the search for new ideas

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</table>

Table 5.2 shows that the minimum scored by CI during Pretest is 6 compared to a minimum of 7 in the Evaluation Phase. On the other hand the maximum for scores for both phases are 15 and 21 respectively. This implies that the maximum score on
search for new ideas is in CI group. Table 5.4 further indicates that the means difference between TI and CI groups are 2.36 for Pretest and 7.5 for Evaluation, to the advantage of the constructivist group. The results further indicate wider spread of CI scores compared to TI scores with reference to the Standard Deviations.

5.4.1.4 The distribution of TI and CI groups on the search for new ideas

Figure 5.2 (a)

Histograms showing the distribution of TI and CI scores on the search for new ideas (Pretest)
Figures 5.2(a) and (b) indicate variations in the modal scores for TI and CI groups on search of new ideas. The clusters in the pretest phase are 8 for those taught with the traditional method and 10 for those that received constructivist instruction. During the Evaluation Phase the scores for most learners taught with the traditional method clustered around 9 while the scores for learners who received constructivist instruction clustered around 18. In spite of
the differences in the modality of the scores, the distribution showed evidence of normality.

5.4.1.5 Difference in the Means of TI and CI groups on the review of meaning

Table 5.3

Descriptive analysis of TI and CI scores on the review of meaning

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<th>Band</th>
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<td>1.95</td>
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</table>
Table 5.3 shows the performance of CI and TI learners on ability to review meaning in both phases of the empirical study. The results of Pretest indicate a common minimum score in both groups but different maximum scores, 13 for learners who received traditional instruction and 17 for their counterparts that received constructivist instruction. Compared to the results of Evaluation, there is evidence that the minimum score for CI groups rose from 5 to 12 while the score for their TI counterparts remained the same. In addition, the maximum score for TI group dropped from 13 to 12 while the maximum score for CI group rose from 17 to 21 out of 25 points. This result is an indication that the constructivist method produced some positive effects on learners’ ability to review meaning compared to traditional instruction.

In addition, Table 5.3 shows the means difference between TI and CI groups in the two phases of this study. The means difference in Pretest is 3.26 while the means difference in the Evaluation phase is 8.91, with narrow differences in the spread of the scores taking into account the standard deviations of each group. In both phases the mean performance of learners who received constructivist instruction is greater than the mean performance of their counterparts who received traditional instruction in terms of review of meaning.
5.4.1.6 The distribution of TI and CI scores on the review of meaning

Figure 5.3 (a)

Histograms showing the distribution of TI and CI scores on the review of the meaning (Pretest)
The histograms in Figures 5.3(a) and 5.3(b) show the distribution of CI and TI scores in both classes on review of meaning in the Pretest and Evaluation. The results of Pretest show that the modal score for TI group is 7 while the modal score for their CI counterpart is 10. In the Evaluation Phase the modal scores are 5 for the traditional instruction group and 18 for the constructivist instruction group. This result shows that most CI learners performed better on review of meaning than their TI counterparts.
5.4.1.7 The difference in the Means of TI and CI groups on transfer of knowledge

Table 5.4
Descriptive analysis of TI and CI scores on the transfer of knowledge

<table>
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</tr>
<tr>
<td></td>
<td>ALL</td>
<td>59</td>
<td>5.00</td>
<td>14.00</td>
<td>9.41</td>
<td>2.61</td>
<td>.34</td>
<td>2.43</td>
</tr>
</tbody>
</table>

**EVALUATION**

<table>
<thead>
<tr>
<th>Band</th>
<th>TI</th>
<th>N</th>
<th>Min score</th>
<th>Max score</th>
<th>Mean</th>
<th>SD</th>
<th>SE</th>
<th>Mean diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>25</td>
<td>2</td>
<td>2</td>
<td>11</td>
<td>6.72</td>
<td>2.25</td>
<td>.45</td>
<td>9.99</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>7</td>
<td>7</td>
<td>24</td>
<td>16.7</td>
<td>3.74</td>
<td>.71</td>
<td>9.99</td>
</tr>
<tr>
<td>3</td>
<td>33</td>
<td>3</td>
<td>3</td>
<td>19</td>
<td>9.67</td>
<td>3.46</td>
<td>.6</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td>33</td>
<td>6</td>
<td>6</td>
<td>21</td>
<td>12.94</td>
<td>3.83</td>
<td>.67</td>
<td>3.27</td>
</tr>
<tr>
<td>ALL</td>
<td>58</td>
<td>2</td>
<td>2</td>
<td>19</td>
<td>8.74</td>
<td>4.21</td>
<td>.55</td>
<td>5.93</td>
</tr>
<tr>
<td></td>
<td>61</td>
<td>6</td>
<td>6</td>
<td>24</td>
<td>14.67</td>
<td>4.28</td>
<td>.55</td>
<td>5.93</td>
</tr>
</tbody>
</table>

Table 5.4 shows the lowest score, highest score, Mean, Standard Deviation, and Mean Difference of TI and CI groups on ability to transfer knowledge. While the lowest score in the distribution is 2, the highest score is 24. The lowest
score is found in TI group while the highest score is in CI group. The differences in the Means of CI and TI scores in classes 1 and 2 are 9.99 and 3.27 respectively. The Standard Deviations of TI and CI scores are 4.21 and 4.28 respectively, an indication of homogeneity in the dispersion of scores around the mean. In total, there is a variation of 5.93 between CI and TI scores. Mean scores of the two groups vary by 5.93 in favour of CI group, an indication that CI group performed better than their TI counterparts on ability to transfer knowledge.

5.4.1.8 The distribution of TI and CI scores on the transfer of knowledge

Figure 5.4(a) and 5.4(b) gives the indication of the distribution of TI and CI scores on transfer of knowledge. It is discernible from the histograms that the scores in the four classes are normally distributed. There is also evidence of variations on the modal score. All the histograms appeared normal.
Figure 5.4 (a)

Histograms showing the distribution of TI and CI scores on the transfer of knowledge (Pretest)

- Traditional Instruction
  - Scores
  - Mean = 8.2
  - Std. Dev = 1.69
  - N = 29.00

- Constructivist Instruction
  - Scores
  - Mean = 10.6
  - Std. Dev = 2.81
  - N = 30.00
Figure 5.4 (b)

Histograms showing the distribution of TI and CI scores on the transfer of knowledge (Evaluation)
5.4.2 Test of the Assumptions

5.4.2.1 Skewness and Kurtosis of the distribution

Table 5.5
Results of test of normality

| DV                          | Method | Skewness | | Kurtosis | | |
|-----------------------------|--------|----------|---|----------|---|
|                             |        | Pretest  | Evaluation | Pretest | Evaluation | ---|
| Formulation of new ideas    | TI     | -.36     | 0.71 | .21 | 1.02|
|                             | CI     | .16      | 0.25 | -.57 | 0.28|
| Search for new ideas        | TI     | .36      | 0.76 | -.19 | 0.75|
|                             | CI     | .32      | 0.31 | .18  | -0.5|
| Review of meaning           | TI     | .39      | 0.05 | -.81 | -0.81|
|                             | CI     | -.16     | -0.18| -.03 | -0.19|
| Transfer of knowledge       | TI     | -.39     | 0.5  | -.48 | 0.53|
|                             | CI     | -.16     | -0.06| -.15 | -0.5|
| Total                       | TI     | -.616    | .203| .089 | .471|
|                             | CI     | .184     | .044| .158 | -.389|

When a group of scores from a population is sharply tilted or peaked the assumption of normality is violated and as such ANOVA cannot be applied. Skewness and Kurtosis values falling
outside the range of +/-1 and +/-2 are tilted and peaked. Table 5.5 shows that all the calculated skewness and peakedness values in both pretest and evaluation phases of this empirical study fall between +/-1 and +/-2 and this is evidence of normality. This evidence gives the impression that the assumption of normality stated in section 4.9 is fulfilled.

5.4.2.2 Homogeneity of the variances of groups

Table 5.6
Results of test of the homogeneity of variances

<table>
<thead>
<tr>
<th>DV</th>
<th>Phase</th>
<th>N</th>
<th>df1</th>
<th>df2</th>
<th>Levene's Stat.</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulation of idea</td>
<td>Pretest</td>
<td>59</td>
<td>1</td>
<td>57</td>
<td>2.535</td>
<td>.117</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
<td>119</td>
<td>1</td>
<td>117</td>
<td>5.621</td>
<td>.019</td>
</tr>
<tr>
<td>Search for new ideas</td>
<td>Pretest</td>
<td>59</td>
<td>1</td>
<td>57</td>
<td>.795</td>
<td>.376</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
<td>119</td>
<td>1</td>
<td>117</td>
<td>16.043</td>
<td>.000</td>
</tr>
<tr>
<td>Review of meaning</td>
<td>Pretest</td>
<td>59</td>
<td>1</td>
<td>57</td>
<td>.786</td>
<td>.379</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
<td>119</td>
<td>1</td>
<td>117</td>
<td>90.735</td>
<td>.000</td>
</tr>
<tr>
<td>Transfer of knowledge</td>
<td>Pretest</td>
<td>59</td>
<td>1</td>
<td>57</td>
<td>5.049</td>
<td>.029</td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
<td>119</td>
<td>1</td>
<td>117</td>
<td>.835</td>
<td>.362</td>
</tr>
<tr>
<td>Total</td>
<td>Pretest</td>
<td>59</td>
<td>1</td>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Evaluation</td>
<td>119</td>
<td>1</td>
<td>117</td>
<td>15.542</td>
<td>.000</td>
</tr>
</tbody>
</table>
The second assumption of this study is that the variances of TI and CI groups are equal or near equal. Equality holds if the observed p-value is greater than 0.05, or is violated if observed p-value is less than 0.05. The calculated significance or p-values presented indicate that the assumption of equality of variances is violated on some of the dependent variables and fulfilled on others.

5.4.2.3 Limitations of the study

This study is underpinned by two main assumptions that were supposed to be met. These include the assumption of normality of distribution of CI and TI scores and the assumption of equality of variances of CI and TI groups. The assumption of normality of distribution of scores was tested by calculating the skewness and kurtosis of the scores for TI and CI groups respectively. The figures on Table 5.5 show that this assumption was fulfilled.

On the other hand, the assumption of equality of variances was tested using the Levene’s Test. The results of this test show on ‘Table 5.6’ give the impression that this assumption was violation. This however has serious implications on the results. This violation may be traced to the fact that the learners (subjects) were not randomly assigned to groups but rather were in intact classes as the school managers had placed them. I could not achieve randomisation because I had not the authority to reassign the subjects into new groups.
Consequently it was not possible to have groups of equal sizes as the classes did not have equal number of learners. However, the six schools and classes involved in this study were randomly chosen, and randomly allocated to treatment and control groups.

The violation of the assumption of equality would however raise question as to whether the observed difference in performance/achievement between CI and TI learners is due to the effect of the constructivist teaching model or whether the difference is due to other factors arising from threat to internal validity that were not controlled due to failure to achieve randomisation. Creswell (2003) trace such threats to experimental procedures, treatments, or experience of the participants that threaten the researcher’s ability to draw correct inferences from the data in an experiment.

Apart from failure to randomly allocate the learners into groups, the three conditions outlined by Creswell were taken into consideration. At this point I will proceed to hypotheses testing and would leave any doubts on the validity of this study to other researchers for replicability.
### 5.4.3 Summary of the results of descriptive analysis

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Method</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>SD</th>
<th>Mean diff</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Formulation</strong></td>
<td>TI</td>
<td>5</td>
<td>12</td>
<td>7.95</td>
<td>0.71</td>
<td>1.02</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CI</td>
<td>12</td>
<td>22</td>
<td>15.75</td>
<td>0.25</td>
<td>0.28</td>
<td>2.21</td>
<td></td>
</tr>
<tr>
<td><strong>Search</strong></td>
<td>TI</td>
<td>7</td>
<td>14</td>
<td>9.4</td>
<td>0.76</td>
<td>0.75</td>
<td>1.43</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>CI</td>
<td>12</td>
<td>21</td>
<td>16.69</td>
<td>0.31</td>
<td>-0.5</td>
<td>2.55</td>
<td></td>
</tr>
<tr>
<td><strong>Review</strong></td>
<td>TI</td>
<td>5</td>
<td>12</td>
<td>7.71</td>
<td>0.05</td>
<td>-0.81</td>
<td>1.87</td>
<td>6.91</td>
</tr>
<tr>
<td></td>
<td>CI</td>
<td>12</td>
<td>21</td>
<td>16.62</td>
<td>-0.18</td>
<td>-0.19</td>
<td>1.95</td>
<td></td>
</tr>
<tr>
<td><strong>Transfer</strong></td>
<td>TI</td>
<td>2</td>
<td>19</td>
<td>8.74</td>
<td>0.5</td>
<td>0.53</td>
<td>4.21</td>
<td>5.93</td>
</tr>
<tr>
<td></td>
<td>CI</td>
<td>6</td>
<td>24</td>
<td>14.67</td>
<td>-0.06</td>
<td>-0.5</td>
<td>4.28</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>TI</td>
<td>46</td>
<td>23</td>
<td>33.45</td>
<td>.203</td>
<td>.471</td>
<td>4.36</td>
<td>30.29</td>
</tr>
<tr>
<td></td>
<td>CI</td>
<td>80</td>
<td>49</td>
<td>63.74</td>
<td>.044</td>
<td>-.389</td>
<td>7.46</td>
<td></td>
</tr>
</tbody>
</table>

(TI; N = 58, CI, N = 61)

Table 5.7 presents a summary of the results of descriptive statistical analysis. It shows that the least and highest scores for TI group are 2 and 19 respectively, while the lowest and highest scores for CI group are 5 and 24 respectively. The assumption of normality of distribution was
fulfilled since the calculated skewness and kurtosis values for each of the dependent variables fell between +/-1 and +/-2. However, the assumption of equality of variances between the two groups was not met. Table 5.7 further shows that learners who were taught with the constructivist method performed better than those taught with the traditional method on all the four dependent variables that were investigated. The means difference between the traditional and constructivist groups in favour of the constructivist group are as follows: formulation of ideas (7.8); search for new ideas (7.5); review of meaning (6.91); and transfer of knowledge (5.93). These values indicate that the population means difference was narrow on transfer of knowledge compared to formulation of ideas, search for new ideas and review of meaning.

5.4.4 Inferential Analysis

5.4.4.1 Rationale for the techniques of inferential analysis

The results of descriptive analysis exposed the results of the tests of the two main assumptions of this research. The tests run in figures 5.5 and 5.6 give the impression that the assumption of normality was met since all skewness and kurtosis values fell between +/-1 and +/-2, which is an acceptable range for normal distribution. On the other hand, this study violated the assumption of homogeneity of variances. This violation could be traced to the fact that the sample sizes of TI and CI groups were not equal. It is
pertinent to note that the learners were in intact classes that were systematized by the school management. It is rare to find in Seychelles schools where the sizes of all classes are equal. Some classes are large and others are small. Ethically I have no authority to reallocate the learners into new groups to achieve randomisation.

Looking at the sample sizes for both pretest and evaluation one would observe that the difference in the size of TI and CI group is small. In the pre-test for instance, there were 29 learners in the Control group and 30 learners in the Experimental group. Here the size of the Experimental group exceeded the Control group by 1. For the evaluation there were 58 learners in the Control group and 61 learners in the Experimental group. The difference between the two sample sizes is 3. Looking at the difference they do not reflect serious violation and therefore could not be avoidable for the reason given above.

The implication of violation of the assumption of equality of variance gives the impression of error due to sampling. It is important to note that the learners used in this study were in intact classes; they were not randomly assigned to groups. The fact that they were not randomly assigned to groups nor were they tested to establish homogeneity nullifies the assumption of homogeneity of TI and CI groups and as such amounts to sampling error. This violation puts the true effectiveness of constructivist teaching model to question. One would argue that since the two groups are not
homogeneous, the difference in their performance may be due to variables other than teaching methods.

However some scholars have suggested how to go about situations where the assumptions of normality of distribution and equality of variances are violated. In the event that the assumption of normality is violated, the independent samples single-factor model of the analysis of variance is replaced with its non-parametric counterparts. If on the other hand the assumption of equality of variances is moderately violated, there isn’t a great damage to the variance between the populations’ means using ANOVA or F-Test (Keller and Warrack 2000; and Burns 2000).

From the statistical point of view ANOVA is a robust test for detecting minor variance between two population means. For this reason I have chosen to test the significance of the difference between the scores for TI and CI groups on each of the dependent variables using the one way ANOVA also referred to as One-Way Analysis of Variance). Here each of the dependent variables is treated as a single factor.
5.4.4.2 Values for decision taking

The null hypotheses and the reliability of the Constructivist Teaching Model are tested on the grounds of values derived from the following:

- F-ratio
- Effect Size
- Statistical Power

5.4.4.2 (a) F-ratio

F-ratio, the results of F-test, is known to be robust in testing for differences between the variances of two or more groups. Its purpose is for hypotheses testing; to verify whether the observed variations on CI and TI mean scores on each of the dependent variables is due to the effects of treatment given to the CI groups or by chance. F-value is a ratio of variance estimate between groups over variance estimate within groups. Within groups variance occurs due to individual differences between members in a group while the between group variance occurs as a results of the mean differences between groups. Higher ratio between the two variances implies higher F and lower ratio implies lower F (Joe 1993).

In education and behavioural sciences, hypotheses are usually tested at 0.01 and 0.05 significance levels. However, 0.01 is considered as conservative for experimental research. This research tested its hypotheses at 0.05 alpha level. Note that
null hypothesis is accepted to be true if the chance probability of an observed F-value is equal or greater at 0.05. However, if the chance probability of an observed F-value is less at 0.05 null hypothesis is rejected.

5.4.4.2 (b) Effect Size

Effect size otherwise referred to as partial eta squared is a measure of the strength of the relationship between the dependent and independent variables in a study. It is a ratio indicating the difference between the means for the levels of the independent variable relative to the within group standard deviation. Simply put, partial eta squared is “a measure of the size of the effect of an independent variable on the dependent variable (Burns 2000). In this study effect size is a measure of the impact of the constructivist teaching method on each of the four dependent variables of conceptual change. Decisions on effect size are based on Cohen’s (1988) blueprint. This blueprint is interpreted as follows: 0.20 = small effect; 0.50 = medium effect; 0.80 = large effect.

5.4.4.2 (c) Statistical Power

Statistical power refers to the sensitivity of a statistic to detect the degree of the variance between two population means (Burns 2000). It is the ability of a statistical tool to correctly reject the null hypothesis when it is truly false and to accept it when it is indeed true (Burns
In situations where sample sizes are unequal for experimental and control groups, a harmonic mean of the two unequal sample sizes should be calculated, as in the case of this study. For the purpose of this research, statistical power was measured using Cohen’s (1988) convention. Since power is a measure of the sensitivity of a statistic to detect the extent of the variance between two populations’ means and validity, a measure of the extent to which a measure of the accuracy to which the prediction of a study is accurate, any measure of power is a measure of validity.

5.5 Hypotheses testing

5.5.1 Null Hypothesis 1

This hypothesis states:
There is no significant difference in the formulation of ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

Table 5.8 shows the results of between-subject effect on formulation of ideas for Pretest and Evaluation. For the pretest, $F (1, 57) = 28.716, p = .000$ indicates that the population means for CI and TI varied significantly. Although a significant difference was found, the partial eta squared value of 0.34 is an indication that CTM produced a minimal effect on the formulation of ideas during pretest, but when strengthened and more time given the model produced a larger effect.
Table 5.8

Between-subject variance on the formulation of idea

<table>
<thead>
<tr>
<th>Source of variations</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>102.254</td>
<td>1</td>
<td>102.254</td>
<td>28.716</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>202.967</td>
<td>57</td>
<td>3.561</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>305.220</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**PRETEST**

<table>
<thead>
<tr>
<th>Source of variations</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1811.541</td>
<td>1</td>
<td>1811.541</td>
<td>485.95</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>436.156</td>
<td>117</td>
<td>3.728</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2247.697</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EVALUATION**

Table 5.8 also shows the results of evaluation. The results indicate $F (1,117) = 485.95$, $p = .000$, which suggests that the difference between TI and CI means on the formulation of ideas is statistically significant since the observed $p$-value is less than .05 and as such $H_{01}$ is rejected. This implies there is a significant in the formulation of ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.
5.5.2 Null Hypothesis 2

The second null Hypothesis of this study states: There is no significant difference in the search for new ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

Table 5.9

Between-subject variance on the search for new ideas

<table>
<thead>
<tr>
<th>Source of variations</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRETEST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>82.432</td>
<td>1</td>
<td>82.432</td>
<td>21.239</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>221.229</td>
<td>57</td>
<td>3.881</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>303.661</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVALUATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>1580.887</td>
<td>1</td>
<td>1580.887</td>
<td>366.293</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>504.961</td>
<td>117</td>
<td>4.316</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2085.849</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The figures on Table 5.9 show the observed difference between the means for learners that received traditional instruction and those that received constructivist instruction on the
search for new ideas in the two phases of the study, including the effect size of the constructivist teaching model. Pretest values indicate as follows: \( F (1, 57) = 21.239, p = .000 \). Here \( p = .000 \) is less than .05. Therefore the difference between the two population means is statistically significant. However, the effect size of the constructivist method is statistically low with reference to Cohen’s (1988) blueprint. Table 5.9 also shows the results of evaluation of the effect of constructivist method of science teaching on the search for new ideas. Comparing the calculated \( p = .000 \) with critical \( p = 0.05 \), where \( F (1, 117) = 366.293, p = .000 \) implies a statistically significant difference between the means of TI and CI groups. Hence \( H_{02} \) is rejected. By this rejection this study concludes that there is a significant difference in the search for new ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

### 5.5.3 Null Hypothesis 3

Null Hypothesis 3 of this study states:
There is no significant difference in the review of meaning between learners taught with the constructivist method and learners taught with the traditional lecture method.

The results of pretest and evaluation presented on Table 5.10 give evidence of significant difference between TI and CI means on review of meaning. The results of Pretest shows that \( F (1, 57) = 25.214, p = .000 \), while the results for evaluation
is $F(1, 117) = 24.206, p = .000$. In both instances a significant difference was found between the population means of TI and CI learners.

**Table 5.10**

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>$F$</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRETEST</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Groups</td>
<td>156.690</td>
<td>1</td>
<td>156.690</td>
<td>25.214</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>354.225</td>
<td>57</td>
<td>5.895</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>510.915</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **EVALUATION**      |                |    |             |      |      |
| Between Groups      | 283.594        | 1  | 283.594     | 24.206 | .000 |
| Within Groups       | 1370.759       | 117| 11.716      |       |      |
| Total               | 1654.353       | 118|             |       |      |

Based on statistical evidence presented on Table 5.10 this research concludes that there is a significant difference in the review of meaning between learners taught with the constructivist method and learners taught with the traditional lecture method.
5.5.4 Null Hypothesis 4

Null Hypothesis 4 states:
There is no significant difference in the transfer of knowledge between learners taught with the constructivist method and learners taught with the traditional lecture method.

Table 5.11

Between-subjects variance on the transfer of knowledge

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>56.700</td>
<td>1</td>
<td>56.700</td>
<td>11.988</td>
<td>.001</td>
</tr>
<tr>
<td>Within Groups</td>
<td>269.605</td>
<td>57</td>
<td>4.730</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>326.305</td>
<td>58</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>1045.756</td>
<td>1</td>
<td>1045.756</td>
<td>58.027</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>2108.563</td>
<td>117</td>
<td>18.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3154.319</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5.11 indicates the results of pretest and evaluation of on transfer of knowledge. The figures show that $F (1, 57) = 11.99$, $p = 0.001$ for pretest and $F (1, 117) = 58.027$, $p =$...
0.000 for evaluation. The p-values in both cases are less than 0.05. Hence Ho4 is rejected in both pretest and evaluation. This rejection of the null hypothesis implies that there is a significant difference in the transfer of knowledge between learners taught with the constructivist method and learners taught with the traditional lecture method.

5.5.5 Main Hypothesis

Main hypotheses that this study states:
There is no significant difference in the ability to restructure ideas between secondary school learners in Seychelles taught science with the constructivist approach and the learners taught with the traditional approach.

Table 5.12

Between subjects variance on conceptual change (Evaluation)

<table>
<thead>
<tr>
<th>Source of Variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Groups</td>
<td>27276.776</td>
<td>1</td>
<td>27276.776</td>
<td>722.008</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>4420.148</td>
<td>117</td>
<td>37.779</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>31696.924</td>
<td>118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results of analysis presented on Table 5.12 indicate that F (1,117) ≤ 0.05. Hence the null hypothesis which states that there is no significant difference in the ability to restructure ideas between secondary school learners in
Seychelles taught science with the constructivist approach and the learners taught with the traditional approach is rejected. Hence the data of this study gives the impression that the constructivist approach of teaching of science is more effective than the traditional approach in facilitating the learner’s ability to restructure ideas.

5.6. Test of validity and reliability

5.6.1 Test of statistical power

Table 5.13 indicates that the power of this study is 0.85, with a harmonic mean of 59. This implies that although the sample sizes for TI and CI groups were 58 and 61 respectively for the evaluation, the power of this study would have been the same if each group had a sample size of 59.

With reference to Cohen’s (1988) convention, a power of 0.85 gives the impression that the sample size (59 learners in the Traditional method group and 61 learners in the constructivist group) was large enough to enable for detecting the variance between their respective means at a significance level of 0.05.
Table 5.13

Power of statistical test

<table>
<thead>
<tr>
<th>Phase of study</th>
<th>Group</th>
<th>N</th>
<th>Equivalent harmonic mean of sample size</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>TI</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CI</td>
<td>61</td>
<td>59.462</td>
<td>0.85</td>
</tr>
</tbody>
</table>

To a large extent statistical power is a measure of validity. A statistical power of 0.85 implies that the sample size is large enough to detect difference between the population means at significance level of 0.05. Hence it could be concluded that from a statistical point of view a power of 0.85 give the impression of a high internal validity.

5.6.2 Test of effect size

Table 5.14 shows the effect size of the constructivist teaching model on each of the dependent variables of conceptual change. The total impact of constructivist instruction on the main dependent variable, conceptual change, is 0.86. Its effect on each of the sub dependent variables are as follows: Formulation of ideas (0.81), search for new ideas (0.76), review of meaning (0.86), and transfer of knowledge (0.41).
<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Partial eta²</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Evaluation</td>
</tr>
<tr>
<td>Formulation of ideas</td>
<td>0.34</td>
<td>0.81</td>
</tr>
<tr>
<td>Search for new ideas</td>
<td>0.27</td>
<td>0.76</td>
</tr>
<tr>
<td>Review of meaning</td>
<td>0.31</td>
<td>0.86</td>
</tr>
<tr>
<td>Transfer of knowledge</td>
<td>0.22</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.46</strong></td>
<td><strong>0.86</strong></td>
</tr>
</tbody>
</table>

During *pretest* the effect size of the Constructivist Teaching Model (CTM) was 0.46 but during *evaluation* the effect size rose to 0.86. Relating the values on Table 5.13 to Cohen’s (1988) blueprint, there are indications of high effect of the constructivist method of teaching on formulation of ideas, search for new ideas, and review of meaning. On the other hand, the constructivist teaching model produced a low effect on transfer of knowledge. It is also important to note that the duration of *pretest* was five weeks while *evaluation* lasted for thirteen weeks. Although some modifications were made on the initial draft of the model after *pretest*, it is likely that time played a crucial role in making the effect
of the model more perceptible in the evaluation. The short duration of pretest may account for the low effect size observed during that period as shown on Table 5.14. It could be concluded that the positive gains on learners’ attitudes toward science during evaluation was a function of the time available for the teachers and learners to become familiar with constructivist model.

5.6.3 Internal consistency of the scores (CI group)

A research instrument or procedure is said to be reliable, if carried out in another location, will yield the same results as in the first instance (Descombe 2003; Best and Kahn 2002; Berkowitz, Fitch, and Kopriva 2000; Cohen et al 2000; Hatcher 1994; Yin 1994). In a research, a measure of reliability is a measure the degree of precision and accuracy of an instrument or procedure. From the quantitative perspective, reliability refers to the extent to which the scores obtained by the learners who received constructivist instruction correlate with each other. This test of internal consistency of scores was computed using Cronbach’s alpha formula. Alpha coefficient ranges from 0 to 1. Values falling between 0.7 and 1.0 indicate high reliability (Cronbach 1990, 1951).

Table 5.15 shows the internal consistence of scores for learners in the constructivist group per dependent variable of the study and the total. Comparing these values with Cronbach’s (1951) blueprint of 0.7, which is still used for psychometrical purposes, gives the impression that the variable where the learners’ scores showed least consistency
is transfer of knowledge. On the other hand, the internal consistency values on formulation of ideas (0.83), search for new ideas (0.8), and review of meaning (0.75) indicate high reliability. In general, the internal consistency of scores for the constructivist group on all the variables put together is 0.72. This value implies that the reliability of the constructivist teaching model in facilitating conceptual change is 0.72.

Relating this value to the total effect size of 0.86 and statistical power of 0.85 gives an impression that the constructivist teaching model that was implemented to facilitate conceptual change in secondary school science in Seychelles produced reliable and valid results.

Table 5.15

Test of internal consistency of CI scores

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Statistic</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>k</td>
<td>Variance of no. of item</td>
<td>Variance of the total score summed</td>
<td>Coefficient alpha</td>
</tr>
<tr>
<td>Formulation</td>
<td>5</td>
<td>2.63</td>
<td>7.64</td>
<td>0.83</td>
</tr>
<tr>
<td>Search</td>
<td>6</td>
<td>4.64</td>
<td>14.23</td>
<td>0.8</td>
</tr>
<tr>
<td>Review</td>
<td>8</td>
<td>5.54</td>
<td>16.51</td>
<td>0.75</td>
</tr>
<tr>
<td>Transfer</td>
<td>5</td>
<td>12.25</td>
<td>17.72</td>
<td>0.39</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>25.06</td>
<td>81.93</td>
<td>0.72</td>
</tr>
</tbody>
</table>
5.7 Summary of the results of inferential analysis

Table 5.16
Summary of the results of inferential analysis

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>F</th>
<th>Sig.</th>
<th>Decision</th>
<th>Partial $\eta^2$</th>
<th>Internal consistency of scores</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formulation of ideas</td>
<td>485.95</td>
<td>.000</td>
<td>Reject Ho1</td>
<td>0.81</td>
<td>0.83</td>
<td></td>
</tr>
<tr>
<td>Search for new ideas</td>
<td>366.293</td>
<td>.000</td>
<td>Reject Ho2</td>
<td>0.76</td>
<td>0.8</td>
<td>0.85</td>
</tr>
<tr>
<td>Review of meaning</td>
<td>24.206</td>
<td>.000</td>
<td>Reject Ho3</td>
<td>0.86</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>Transfer of knowledge</td>
<td>58.027</td>
<td>.000</td>
<td>Reject Ho4</td>
<td>0.41</td>
<td>0.39</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>722.008</td>
<td>.000</td>
<td>Reject Main Hypothesis</td>
<td>0.86</td>
<td>0.72</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.16 summarises the results of inferential statistical analysis. The evidence on the Table shows that the four null hypotheses of this study were rejected on the grounds that observed P-values is less than 0.05 for each sub dependent variable. The results show that:

- A significant difference was found in the formulation of ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.
• A significant difference was found in the search for new ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

• A significant difference was found in the review of meaning between learners taught with the constructivist method and learners taught with the traditional lecture method.

• A significant difference was found in the transfer of ideas between learners taught with the constructivist method and learners taught with the traditional lecture method.

In addition to the results of hypotheses testing it was found that the size of the effect of the constructivist method (evaluation) on conceptual change was 0.86. Higher effects were observed on formulation of ideas, search for new ideas, and review of meaning, while a low effect was observed on transfer of knowledge. The sensitivity of ANOVA to detecting the variance between the two population means is calculated as 0.85. The reliability coefficient of the constructivist teaching model is 0.72.
5.8 Results of qualitative analysis

The qualitative component of this study is aimed at determining how the paradigm shift from the traditional to the constructivist approach is welcomed by science teachers and independent persons. The data needed to achieve this aim was collected through direct classroom observation by designated experienced science educators, interviews for the science teachers who implemented the constructivist instructional method, analysis of learners’ Achievement Test papers by examiners, and analysis of the video-recorded teaching and learning sessions for TI and CI groups by the researcher.

The results are presented in four sections, each with a summary of the results. Section 1 is the results of observation by independent persons. Section 2 is the results of analysis of achievement test papers. Section 3 presents the results of interviews while Section 4 is the results of filmed teaching and learning sessions. A summary of the results of the qualitative analysis is presented at the end of the section, followed by main findings of the empirical study.
5.8.1 The perceptions of the independent observers

A total of three independent judges were involved in classroom observation. The effect of constructivist instruction in comparison with traditional instruction was judged with reference to the following dependent variables: formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge.

5.8.1.1 Formulation of ideas

The opinions of the judges to a large extent indicate preference for constructivist instruction over traditional instruction although some weakness of the constructivist instruction model as it was implemented on secondary school science teaching were also identified. The judges criticized the traditional method for its teacher-centeredness. Judge 1 observed that teachers of the traditional group merely transferred their own ideas to the learners. Teacher-learner interaction was minimal. In addition, Judge 1 observed that the traditional method was ineffective to link the learners’ prior knowledge with new concepts. Judge 1 remarked:

Learners in the traditional group were unable to relate new concepts to what they had learnt previously. The teaching approach did not draw on their prior knowledge. There was also no demonstration of originality of ideas on the part of the students. Information was flowing from one direction – from the teacher only.
Teacher talk was dominant and few examples from everyday life were used to illustrate new ideas. Most students were unable to provide their own examples (Judge 1).

The view expressed by Judge 1 was also shared by Judge 2, who argued that teaching and learning in the traditional instruction group was such that information was flowing only from the teacher to the learners. This judge criticized traditional instruction for not eliciting learners’ prior ideas and using same in developing the new concepts. The judge remarked:

Most lessons in the traditional instruction group began with a review of the learners’ previous knowledge of the concepts but failed to use such knowledge to drive the other phases of the lesson. This made it difficult for the learners to perceive the link between their prior knowledge and the new concept. Consequently their ability to make predictions is limited (Judge 2).

The judge further observed that although the traditional instruction group teachers made use of sketches and diagrams when clarifying new concepts to the learners, they did not explain the concepts using examples from their locality. The third Judge observed that while teachers in the traditional instruction group drew examples from everyday life when explaining new concepts to the learners, most learners were unable to provide some examples of their own on the concepts. The Judge observed that most of the learners relied on their teachers for information. According to this Judge, “There was
hardly opportunities for the learners to construct their own ideas” (Judge 3).

From the foregoing it is apparent that all the Judges shared a common opinion that traditional instruction of science teaching does not facilitate the learners’ ability to relate new concepts to prior knowledge, predict outcomes of events or processes, generate original ideas, illustrate new concepts with the use of sketches and diagrams, and draw examples from their locality to explain new concepts. This observation is consistent with the Schools Development Plans/Audit Reports for the period 2003-2005, which identified teacher-centeredness and boredom. The reports further argued that traditional methods of science teaching in Seychelles do not draw out the learners’ prior ideas, skills and interest and link them with new (Plaisance Secondary School 2003; Mont Fleuri Secondary School 2006; Anse Boileau Secondary School 2006).

On the other hand, there seems to be a consistency in the opinion of the three Judges on the effect of constructivist method of science teaching on learners’ ability to formulate their own ideas. Judge 1 observed that most constructivist group lessons began by eliciting learners’ prior knowledge followed by a review of previous lesson. This strategy enables the learners to build a link between new concepts and previous lessons, and by doing so construct their own understanding rather than absorbing factual knowledge transmitted by the teacher. The Judge further remarked, “Most learners in the constructivist group could predict outcomes
and draw examples from everyday life to explain new concepts” (Judge 1). The views expressed by Judge 1 are similar to that of Judge 2 who remarked:

The approach to teaching in the constructivist group for the past three weeks is such where new concepts are linked with learners’ prior knowledge to derive new meaning (sic). With this approach the learners could trace conceptual links and their ability to predict the likely consequences of events or processes is enhanced” (Judge 2).

However, Judge 2 criticised one teacher of the constructivist group for failing to ask higher order questions, and use sketches and diagrams when clarifying the learners’ misconceptions in spite of the fact that all teachers in the constructivist group attended the workshop where the principles and application of the constructivist instructional model was explained to them. Judge 2 stressed that for constructivist instruction to facilitate formulation of ideas, learners should be exposed to using diagrams and sketches to clarify concepts. They should also be encouraged to draw examples from their vicinity when clarifying ideas. In addition Judge 2 advised teachers to challenge the learners with higher order questions rather than simple factual recall type questions.

Judge 3 however differed in some ways with Judges 1 and 2 on the effect of constructivist instruction on formulation of ideas. According to Judge 3, there was a problem in the introduction phase of the lessons. The judge observed that
teachers explored concepts and principles that the learners should otherwise investigate themselves. In the views of Judge 3 the constructivist group teacher did not provide the learners with ample opportunities to formulate their own ideas. According to Judge 1, “Learners in the constructivist group made attempts at drawing connections between previous learning and new experience thereby constructing new mental patterns”. The opinion of Judge 2 further illuminated that of Judge 1 on teaching and learning in the constructivist group, noting:

The learners’ prior knowledge was used in directing the instructional process. They were given sufficient opportunities to make their own predictions on the concepts and principles they were learning. Sketches and diagrams were used by the students to illustrate their understanding of the concepts. Most students demonstrated innovative thinking. They were able to use everyday life examples to explain new ideas (Judge 2).

This statement suggests that constructivist group teachers used various strategies to simplify concepts to the learners and offered to them opportunities to develop innovative thinking by using local examples to explain new concepts and using sketches and diagrams to throw additional light on their own ideas. The perceptions of the three Judges on the effect of CI and TI on formulation of ideas indicated that 2 out of the 3 Judges were of the opinion that compared to traditional instruction, constructivist instruction was more effective than traditional instruction in enhancing the learners’ ability to relate new ideas to prior knowledge,
predict outcomes of events or processes, and generate original ideas, although the teachers are inconsistent in the application.

I think the observed inability of the constructivist group teachers to expose the learners to using sketches, diagrams and local examples, and attempting higher order questions suggest that old habits die hard. I am aware that the Ministry of Education has organized several workshops and seminars for secondary school science teachers on meaningful teaching and learning of science including the use of diagrams and sketches in clarifying concepts to the learners. I too participated in some of the workshops. Almost all the science teachers that participated in this study also attended those workshops. In addition, professional development sessions are held at school and department levels where teachers are further exposed to new skills and strategies to improve teaching and learning. In spite of such opportunities most teachers remain stiff to change. They find the traditional method as the ‘soft’ pedagogy and the way to make things easy for them.

5.8.1.2 Search for new ideas

The Seychelles National Curriculum identifies the learning of science as an active and continuous process of exploration of the physical and biological aspects of the universe (Ministry of Education 2001). Although the curriculum advocates that learners should be given opportunities to develop their
observations, use scientific skills and do investigations, the prevailing culture of teaching has not achieved much in this connection. For instance, during the experimental phase of this study, Judges 1 and 2 observed that traditional instruction was ineffective to promote learners’ ability to search for new ideas.

Judge 1 observed that higher order questions were rarely used in the traditional instruction group. This means that the present instructional approach to the teaching of science in Seychelles falls short of promoting one of the essential skills in science – inquiry. The Judges observed that the learners were not given opportunities to exchange ideas; rather their activities were limited to mere listening to teachers’ explanations. Learners in the traditional instruction group were not motivated and exposed to exploring multiple sources in search for new ideas. This lack of motivation usually stems from the construction phase. Since the learners did not see the link between new learning and prior lessons and could not formulate hypothesis because conceptual dissonance was not achieved and no gap to fill. Judge 1 further remarked that although the learners were seated in groups of fours and sometime threes, there was no evidence of dialogic learning. Questions were mainly low order factual recall type ... and tasks given were less challenging. Hence the level of motivation remained low and the development of new insights was decimated. The learners merely absorbed factual knowledge transmitted to them by their teachers.
Judge 2 described traditional instruction as ‘spoon-feeding’. It is spoon-feeding in the sense that learners were not encouraged to search for new ideas on their own; rather the teachers supplied all the information to the learners. According to Judge 2, traditional instruction was ineffective in promoting critical/analytical reasoning. Knowledge was transmitted and absorbed rather than search for and constructed. In addition Judge 3 remarked that traditional instruction did not offer to the learners the opportunities to engage in inquiry and hands-on learning.

Comparing the traditional lecture method groups with the constructivist method group, Judges 1, 2, 3 suggest that learners who received metacognitive instruction demonstrated greater ability to search for new ideas. In addition to searching for ideas from books, they also explored other sources such as internet, resource persons, and their peers in search for ideas. They were meaningfully engaged on tasks and used instructional time judiciously. Collaborative sharing of ideas was apparent and motivation was sustained throughout the duration of the lesson.

Judge 3 described the learning environment in the constructivist instruction group as one that keeps the learners longer on task. When learners remain actively engaged on task they develop critical, reflective and independent thinking. In addition Judge 1 expressed satisfaction with the quality of models, displays and
presentations produced by the learners in the constructivist group, which he argued was not apparent in the traditional group. For the learners to be able to design those models and discuss the principles underlying their constructions, the judge suggested that they must have searched for ideas from multiple sources, a learning approach which Judge 2 described as ‘project-based’. Project-based approach, offers to learners the opportunity to independently explore new concepts, and by doing so their curiosity to accomplish assigned tasks remains high. Judge 3 described learning in the constructivist group as project-based, active, learner-centered, discovery approach.

Judges 2 and 3 however observed that some learners in the constructivist group rarely asked questions. This observation is consistent with previous evaluation of the performance and achievements of secondary school learners on science in Seychelles, which shows that science teachers opt for lower order questions more than making use of higher order questions to challenge the learners’ thinking.

The 2000 National Examinations Report on science also shows that most learners in Seychelles scored higher on questions that demanded mere recalling of information, while questions that demanded analytical thinking were poorly answered. The inability of the learners to attempt mentally challenging questions is basically because they have got so used to lower order questions (Ministry of Education 2001; 2003). The Reports further remarked, “Year after year comments are made
about learners’ poor performance in science, and yet nothing has been done which had redressed this. Continuing with this scenario would lead to resources being wasted and learners disillusioned by their performance” (Ministry of Education 2003a:13).

5.8.1.3 Review of meaning

In the context of this study review of meaning encompasses identifying limitations in other people’s opinions, summarizing main ideas learned during the lesson and organizing them in logical order, using new information that were gathered to extend or modify previous conception. It also consists of analysing and construing new meaning from science concepts, constructing models of reality, and suggesting how new concepts could be applied to solve problems in society.

Judge 1 was of the opinion that traditional instruction offered less opportunity to the learners to evaluate their own ideas since the teaching method did not encourage hypotheses formulation. Consequently the learners were unable to modify the preconceptions they came with into the new lesson. In addition, Judge 2 observed that most traditional instruction learners were unable to summarize the main ideas discussed during the lesson. This implies that they could not prepare their own notes. They rarely use scientific terms when presenting ideas and could not explain how science concepts and principles can be applied to solve problems in
the society. They lacked the vocabulary to present ideas logically. I would say that the problems encountered by the traditional instruction group stemmed from ineffectiveness of the method of teaching in guiding the learners to discover conceptual links. When this link is omitted learners encounter difficulties to extend or modify meaning.

Judge 3 qualified traditional instruction as “the olden days’ style’ of teaching. The notion of ‘olden days’ suggests that traditional instruction is becoming obsolete and ineffective for science teaching in the 21st century. This view has also been expressed by Redner (1987:18) that “science has changed its ends; it is no longer the old science of the last few centuries”. If we welcome this notion that science has actually changed its ends, it is imperative to advocate a paradigm change; otherwise we would be applying a 19th century tactic to solving a 21st century problem.

There was consensus in the views expressed by the Judges on the effects of constructivist method of science teaching review of meaning. In the opinion of Judge 1, “The learners linked new concepts with prior knowledge and were able to formulate new ideas from the link. When their notes were inspected it was observed that most constructivist instruction learners were able to prepare their own notes by putting together the main points that were discussed during the lesson. This attribute was missing in the traditional group.
Judge 2 provided a more vivid account of the effect of constructivist instruction on review of meaning, stating:

The learners did not depend on the teacher’s notes. Although some learners were unable to present their ideas in quite a logical manner, they made fair attempts to construct what represented their own understanding. They could use scientific terms such as ‘inflating, deflating, and responding,’ etc., while explaining how they went about their projects to their teacher and peers.

This statement by Judge 2 suggests that constructivist method of science teaching promotes independent learning. Learners who are independent are capable of searching for ideas from multiple sources. The learners were able to initiate their own project and remain on task longer and are able to share new insights with other people. Judge 3 emphasised that constructivist instruction offered opportunities for learners to modify their misconceptions, adding that to make this learning more effective teachers should plan more activities and opportunities for learners to reflect on their constructions. By reflecting on their own ideas learners construct authentic knowledge.

Judges 2 and 3 share common opinion that most learners in this class could explain how the concepts that were taught could be applied in solving problems in everyday life. They were able to do so because it was their own ideas and not the teacher’s. The self-initiated projects that constructivist group engaged on promoted the development of higher cognitive
skills such as self-direction, problem solving and decision making, which are essential for review of meaning. From the foregoing analysis it is apparent that the judges have preference for the constructivist method over the traditional method in regard to review of meaning. However, they were of the opinion that more emphasis should be placed on activities that facilitate reflective thinking.

5.8.1.4 Transfer of knowledge

Transfer of knowledge in the context of this study refers to applying concepts and principles learned in science to solve problems involving identification of structures, application of formula, interpretation of data, drawing/sketching of concepts, and imaginative thinking. The performance of learners were rated on a continuum ranging from ‘Very Good’ to ‘Very Poor’ in consistency with the marking scheme for the Achievement Test in Table 4.3.

With reference to identification of structures, Judges 1, 2 and 3 remarked that traditional instruction learners performed quite poorly. While Judges 1 and 3 qualified the performance as ‘Poor’, Judge 2 described it as a ‘Fair’ performance. It is apparent that 2 out of the 3 Judges were of the opinion that traditional instruction learners performed poorly on identification of structures. On the other hand, Judges 1 and 2 qualified the performance of constructivist instruction learners as ‘Fair’. Judge 3 on the other hand was not satisfied with the learners’ performance.
on this item; a performance he described as ‘Poor’. The two remarks ‘Fair’ and ‘Poor’ do not convey a message that the performance was good. It is evident from these remarks that the constructivist group did not perform much better than the traditional group in solving problems involving identification of concepts.

With reference to solving problems involving application of formula, the opinions of the Judge varied widely. Judge 1 described the performance of the traditional group as ‘Fair’, while Judges 2 and 3 qualified the same performance as ‘Very Poor’. Similarly the Judges differed in opinion on the performance of the constructivist group on this item. While Judges 2 and 3 qualified the performance of the constructivist group learners as ‘Good’, Judge 1 rated it as ‘Very Poor’. Putting the remarks of the judges together they share the view that the constructivist group performed better than their traditional group counterpart solving problems involving application of formula.

On ability to solve problems involving interpretation of data, Judge 1 and 3 qualified the performance of the traditional group as ‘Poor’ while Judge 2 qualified it as ‘Very Poor’. The comments of the three judges give the impression that traditional instruction learners performed poorly on this item. On the other hand, Judges 1 and 3 perceived the performance of constructivist group as ‘Very Good’ while Judge 2 qualified it as ‘Good. These remarks give the impression that compared to the traditional group the
judges were satisfied with the performance of constructivist group learners on solving problems involving interpretation of data.

The fourth item that was evaluated by the judges is problems involving drawing/sketching. The Judges were of the opinion that performance of the traditional group was satisfactory. Judge 1 rated this performance as ‘Fair’ while Judges 2 and 3 rated it as ‘Good’. These comments convey the notion that traditional instruction learners performed satisfactorily well on problems involving the use of diagrams/sketches to illustrate concepts. On the other hand Judges 1 and 3 remarked the constructivist instruction learners performed fairly well on this item while Judge 2 rated the performance as good. Following these remarks, it is apparent that constructivist group did not perform better than the traditional group on involving drawing/sketching of concepts.

Comparing the performance of the two groups on problems involving imaginative thinking all the judges rated the performance of the traditional instruction group as ‘Very Poor’. On the other hand, 2 out of the 3 Judges rated the performance of constructivist instruction group as ‘Fair’ while one of them described the performance as ‘Poor’. One of the judges remarked in disappointment, “It is surprising to observe that most learners do not know the importance of plants in their everyday life”. This boils down to the fact that teacher do not use examples from everyday life when explaining concepts and principles to the learners. Tallying
the opinions of the Judges on this item, it is not perceptible that the constructivist group outperformed the traditional group.

5.8.1.5 Summary of the opinions of the Judges

The results of analysis of the opinions of the three judges following classroom observation and analysis of test scripts indicate as follows:

1. The Judges were of the opinion that learners who were taught with the constructivist method were able to relate new ideas to prior knowledge, predict outcomes of events or processes, and generate original ideas more than TI. They were more able than their TI counterparts in formulating their own ideas. Hence it was concluded that CI is more effective than TI in facilitating learners’ ability to formulate their own ideas in science.

2. The unanimous opinions of the Judges indicated that learners who received constructivist instruction demonstrated greater ability to search for ideas than their counterparts that received traditional instruction. Hence the judges perceived CI as being more effective than TI in facilitating the ability of learners to search for new ideas in science.
3. It was found by the judges that CI learners performed better than TI learners on ability to review meaning. Consequently, it is the view of the judges that CI is more effective than TI in enhancing the learners’ ability to review meaning in science.

4. The independent judges were of the opinion that CI learners performed better than their TI counterparts on ability to solve problems involving imaginative thinking. Consequently the judges concluded that CI is more effective than TI in facilitating imaginative thinking in science.

5.8.2 Opinions of the class teachers (CI group)

The three teachers who implemented the Constructivist Teaching Model in their respective classes expressed their opinions on the effect of the paradigm change. The opinions of the teachers were expressed in the various phases of this study. At the end of Pretest all the participants, including the teachers were invited for debriefing. The purpose of this debrief was to elicit the opinions of the participants on necessary modifications that could strengthen the constructivist model. During debrief the class teacher who implemented the model reported that the effect of the model will become glaring if more time was given. The teacher pointed out that since the learners were not used to independent learning they need more time to get used to this new approach.
The teachers pointed out that the learners found the constructivist approach quite new as they were not used to it. As such it took sometime for them (the teacher and learners) to shift their minds from the traditional practice they were used to and attune them to the constructivist approach. It was for this reason that the participants suggested that the duration of the Evaluation Phase should be extended to a full Term (13 weeks). The teacher also lamented that the school does not have sufficient resources for this method of teaching. According to the teacher he went all the way to improvising material. He also frowned at the practice where teachers have been caused to shift focus – spending more time in dealing with administrative issues at the detriment of actual teaching and learning that should be the teachers’ primary concern. The issue of class cover was frowned at too during the debriefing. According to the teacher if all these distracting elements were controlled teachers will have more time to prepare and deliver more effective lessons.

In the 12th week of the evaluation phase the two science teachers in the experimental groups were interviewed to educe their perception of the paradigm change. The items of the interviews are as follows: 1) What impact did the constructivist teaching have on learners’ attitudes toward science, and how? 2) What problems did you and the learners encounter while implementing the constructivist teaching method? 3) Would you recommend implementation of the constructivist teaching for science teaching in other classes and schools in Seychelles? Why?
5.8.2.1 Effect of constructivist teaching on the learners’ attitudes towards science

The two teachers of the constructivist group were of the opinion that constructivist instruction was effective in motivating the learners in taking ownership of their own learning. One of the teachers remarked that one of the benefits of the constructivist method of science teaching is that ownership of the lesson shifted from the teacher to the learners. The teacher remarked:

Unlike previously when the learners depended on the teacher for notes and other information, they are now more motivated to take initiative. They are now much eager to search for ideas and discuss their views with others. Through these activities they were able to generate their own ideas rather than depend on teachers ideas” (Teacher 1).

The comments of Teacher 1 suggest that there was improvement in the attitudes of the learners during science lessons. The learners were more eager to learn and do things on their own compared to their attitudes in the past.

Elaborating on the effect of constructivist method of science teaching on learners’ attitude towards science, Teacher 2 mentioned that there was an improvement on learners’ attitudes during lessons. Teacher 2 remarked:
Prior to this time most students were unable to gather ideas on their own. This was a big problem. It took effort on my own part to check their notes regularly. It was not quite easy at the beginning anyway especially for the low ability students and girls in the class, but gradually they improved. Keeping diaries enables the student to write down ideas in the way they made sense to him. In addition, the students are now more able than they were to search for ideas on their own. It is also easier for me now to identify where and when the student encounters difficulties.

The above comment gives the impression that even though the teacher has preference for constructivist instruction, she perceived the implementation quite challenging.

5.8.2.2 Problems encountered by the teachers and learners while implementing the constructivist method

Teacher 1 identified crowded curriculum, time, and class cover as the major problems he and the learners encountered while implementing the method. Teacher 1 remarked:

While implementing the MI we moved slowly, not too slow anyway to ensure that no student is left behind and each has the opportunity to construct his or her own ideas or restructure what needed to be reconstructed. This takes some time. But the way the curriculum is planned is such that teachers are always rushing through the content to cover the curriculum. This does not afford the learners time to construct their own ideas.
Teacher 1 further remarked that it is difficult to guide the learners to construct new understanding when teachers themselves do not have sufficient time to plan and prepare their lessons. On the other hand, Teacher 2 observed that the problem is lack of resources. The teacher remarked:

At the beginning the learners were not used to doing certain things on their own but now they wanted to do more. They are now more demanding and to satisfy their demands we need more books, magazines, journals and computers etc. The school does not permit learners to take books from the library home. With this practice the learner could not search for more information after school. I borrowed books on my name and gave to the learners to take home. Apart from books, the next problem we encountered was time. The syllabus is too loaded. Teachers and learners are under pressure to cover the content before the end of the year. For learning to be effective learners need more time to search and review ideas. There is great need for a decongestion of the syllabus.

The perception of Teacher 2 validates the opinion of Teacher 1 that the constructivist method they implemented in their respective classes shifted ownership of learning to the learners. However, both teachers lamented that the secondary science curriculum is too overcrowd and does not give the teachers and learners time to reflect or evaluate their learning. The teachers recommended that more resources should be supplied to schools and more time required for learners to reflect on their own learning, if we are to implement the constructivist approach on secondary school science in Seychelles as its principles suggest.
5.8.2.3 Recommendations by the science teachers

On whether the constructivist method should be recommended for science teaching in Secondary schools in Seychelles, Teacher 1 responded ‘Yes’. He went further to elaborate:

I was using the same method to teach in other classes and I noticed remarkable improvement especially in terms of learners’ motivation to learn. They now want to learn. They were more focused on tasks; they were able to search for new information on their own and determined to complete assigned tasks on stipulated time.

Similarly, Teacher 2 mentioned that the implementation of the constructivist approach to science teaching has changed the learners’ attitude towards science. According to this teacher the learners are now intrinsically motivated. If this attitude is sustained for a longer time most learners would excel not only in science but on other subjects taught at school as well as on everyday life endeavors. Looking closely at the opinions of the two science teachers who implemented the constructivist method in their respective classes, it is apparent that both showed preference for constructivist approach over the traditional approach.
5.8.2.4 Summary of the results of interviews

Provided below are the results of interviews with the two science teachers that implemented CI:

1. Both teachers observed improvement on the attitudes of the learners toward science learning. They observed that the learners are now motivated and have taken ownership of the lesson. Consequently, their ability to formulate, search and review meaning has improved remarkably.

2. Both teachers lamented on what they described as ‘overcrowded curriculum’. Their view is that effective implementation of constructivist instruction on secondary school science in Seychelles will require more resources and time for the teachers as well as the learners.

3. Both teachers were of the view that the constructivist approach to science teaching should be introduced in other classes and schools in Seychelles following to its effects on learners’ attitudes.
5.8.3 My own observation

5.8.3.1 Observation during Pretest

My observations are based on two main sources – evidence from field observation during pretest and analysis of video-filmed learning sessions of the constructivist and traditional groups by the staff of the National Audio-Visual Centre of the Ministry of Education Seychelles. A total of four session were recorded; two sessions per group.

During Pretest, which was aimed at identifying the weaknesses of the model and making necessary modifications with a view to strengthen it, I observed that the teacher and learners found the first two weeks of the implementation very challenging. They were quite reluctant to drop the conventional approach to teaching and learning. Rather than allowing the learners to construct their own ideas, the teacher was transmitting her own thought to the learners. There was hardly any perceptible difference between the constructivist group and the traditional group in spite of the workshop held and draft of the constructivist instructional model provided to each teacher participant with a view to familiarize them with the principles and application of the constructivist method of teaching. The conservative attitude of the teacher and the learners explained to a large extent how dominant the traditional method of teaching is rooted in schools in Seychelles.
National Examinations Reports on performance and achievements in science (Ministry of Education 2001e, 2003c) had condemned the traditional method for being ineffective to facilitate higher order cognitive skills, and urged science teachers to adopt teaching approaches that promote critical thinking, autonomy, and sound judgment rather than mere regurgitation of factual information. In a study of ‘Mixed Ability Teaching: Issues and Concerns of Primary School Managers in Seychelles’, Antat (2006) found that teachers in Seychelles are conservative and reluctant to shift from the traditional methods of teaching to new and more effective methods. This drabness to welcoming change has a lot of implications on learners’ performance and achievements on science.

However I observed that teaching began to improve in the third week following closer monitoring of the teacher. Gradually the teachers began the practice of giving the learners autonomy on their own learning. Through questioning the learners were encouraged to discover for themselves the link between prior lessons and new concepts. Learners began to make tentative propositions on their own. I must not fail to point out that questioning was not adequately used to stimulate the learners to critical thinking. Prompts such as ‘Why, How, Give reason, etc, were rarely used, while questions involving such actions as Mention, State, List were commonly asked. To a large extent the teacher used local examples to clarify new concepts and their principles to the learners. Cooperative learning was apparent. Prior to the third week of the pretest the learners invested almost half
of the instructional time on copying notes. In most cases the teacher gave the learners notes to copy prior to explanation of concepts. The learners were merely noting down and absorbing the teacher’s thoughts rather than theirs.

5.8.3.2 Analysis of the video-recorded sessions

Analysis of the filmed sessions for the evaluation phase of the experiment showed improvement on the application of the constructivist method. For instance the filmed sessions showed that most CI lesson began with review of previous lesson followed by introduction of new concept. This is extremely important as a review of learners’ prior knowledge provides them the opportunity to see the link between new and prior learning. Tracing this link is crucial to formulation of ideas. Learners perceive this link differently and by so doing formulate alternative conceptions. Although the traditional group also began their lessons with a review of prior lessons, there were little emphasis on the link between new lesson and previous lesson. Consequently the ideas remained isolated from one another. With this practice learners in the traditional group were unable to formulate tentative hypotheses but were good at memorizing factual information.

The filmed sessions also showed that locally available resources were used in teaching new science concepts in the two constructivist groups, while their counterparts in the traditional groups depended on textbooks as the only source
of information. CI learners were seen conducting experiments, observing, searching for new ideas from different sources, making comparisons, illustrating their own ideas with sketches and diagrams, preparing summaries of their own ideas, sharing new insights with their peers and teachers, and using the concepts and principles they have learned to construct models of reality. Learners took ownership of the lessons, their level of motivation quite high and sustained throughout the lesson duration. Although some constructivist group learners could not present ideas in quite a coherent manner, they were able to extend their responses to a reasonable extent when prompts and probes were applied by the teacher. Instruction was more of deductive learning than inductive.

On the other hand the traditional group depicted a learning environment where the teacher rather than learners dominated the instructional process. Evidence from the filmed session indicated that flow of information during lessons was one directional – from the teacher to the learners. Instruction was more of induction than deductive. Teachers presented facts, explained concepts, and clarified principles with the use of diagrams or sketches, and demanded silence in the class all in an attempt to convey their own thoughts to the learners. Much of what the learners did was seatwork and listening rather than applying other inquiry learning techniques such as conducting experiments and searching for new meaning to verify concepts.
It was apparent from the video-taped sessions that although TI learners may have absorbed large amount of new information transmitted to them by the teacher, the instructions did not sufficiently arouse them to identify the limitations of the preconceptions that they came with into new lessons and reconstruct them too. This observation is consistent with the opinions of the independent judges who also described teaching and learning sessions in the traditional as ineffective to bring about conceptual change.

5.8.3.3 Summary of the results of qualitative analysis

The results of analysis of qualitative data showed that the constructivist instructional method of science teaching is more effective than the traditional method in promoting the learners’ ability to formulate ideas, search for new ideas, review meaning and transfer knowledge. The paradigm change from traditional to the constructivist approach was also welcomed. However, science educators in Seychelles blamed teachers for being conservative. This means that science teachers are reluctant to drop the old culture of learning where knowledge is absorbed rather than formulated; transmitted rather than searched for; committed to memory rather than reviewed, and regurgitated rather than applied to solve problems. The science teachers welcomed the paradigm change but remarked that their inability to implement the constructivist method in the most effective way was due to problems such as heavy workload, overcrowded curriculum and dearth of teaching and learning resources in schools. This
observation also validates Antat’s (2006) study of issues and concerns of mixed ability teaching in Seychelles. The study found that whole class teaching is a common practice in schools in Seychelles. It further observed that the inability of teachers to implement new and more effective methods of teaching were traced to inadequate materials for teaching and learning, and lack of commitment on the part of the teachers.
6.1 Introduction

In Chapter 1 the research problem, purpose/aims, and hypotheses of my study are stated. Research has shown that the misconceptions the learners come with into the science lessons are resistant to change. This study investigates the effect of constructivist method of teaching of science on the learner’s ability to reconstruct ideas, and the extent to which science educationists in Seychelles welcome the paradigm shift from the traditional approach to the constructivist approach. This chapter discusses the results presented in Chapter 5 by relating my findings to previous studies, justifications of this study, and my model of the process of conceptual change. The implications of my findings and suggestions for further research are also discussed. The chapter concludes with the closing remarks.

6.2 Discussion

Evidence from cognitive research indicate that learners come into new science lessons with some ideas that are resistant to change in spite of teachers’ efforts to modify them (Peterson 2002; Stromdahl 2002; Vosniadou 2002; Beeth 1998). Traditional teaching methods are becoming less tenable to stimulate conceptual change as they have ignored the fact
that the knowledge which the learners discover by themselves is more enduring than the knowledge transmitted to them by the teacher or someone else.

Constructivism on the other hand recognizes that learning is a cognitive process involving construction and reconstruction of ideas. As a learning theory, constructivism recognizes the learner as a meaning maker rather than a passive recipient of factual knowledge. It conceived learning as a hypothesis formulation-testing process where meaning is modified on the grounds of evidence. Fundamentally, the constructivist approach to teaching recognizes that the conditions that inspire conceptual change are internally (cognitively) induced. Inducing this change necessitates a shift of ownership from the teacher to the learners.

Empirical studies conducted by Baser (2006); Zohar and Aharon-Kravetsky (2005); Erylimaz’s (2004); Kishfe and Abd-Khalick (2002); and Zarotiadou and Tasparlis (2000) reviewed in ‘section 1.4’ indicate that constructivist teaching methods have more positive effect on learners’ performance and achievement in science than traditional teaching methods. Looking closely at the findings of previous empirical studies side by side with the summary of my findings in ‘sections 5.4.3, 5.7, 5.8.3.3’ gives credible evidence that learners’ misconceptions of science concepts can be modified using effective methods of teaching. Although each of the empirical studies reviewed in ‘section 1.4’ implemented a different method of constructivist teaching in comparison with
traditional method, their results indicate that the learners who received constructivist instruction showed significant gain on attitudes and academic achievements than those that received traditional instruction. It was also found that in situations where no significant difference was found between the performance/achievement of the constructivist group and traditional group, it was discernible from qualitative evidence that the learners and teachers who applied the constructivist methods showed preference to the constructivist approach over the traditional approach. Evidently these findings suggest that science educationists welcomed the paradigm shift from the traditional methods to the constructivist methods.

In the justification of my study presented in ‘section 1.5’, it was observed that most previous studies were confined to exploring conceptual change using a single variable, usually academic achievement. Those researches did not take into account the cognitive, social, affective, or metacognitive variables that stimulate and sustain learning. My Conceptual Change Model in “Figure 2.1” identifies four cognitive elements that are essential for conceptual change to occur. These elements include formulation of ideas, search for new ideas, review of meaning, and transfer of knowledge. The results of the test of the null hypotheses indicate that there is a significant difference between the learners who received constructivist instruction and the learners who received traditional instruction in favor of the constructivist group on the four sub variables of my study.
The values of the effect of the CTM on each of the sub variables in ‘section 5.6.2’ are as follows: Formulation of ideas (0.81), search for new ideas (0.76), review of meaning (0.86), and transfer of knowledge (0.41). Although a significant difference is found between the two groups in terms of transfer of knowledge, the effect size of the Constructivist Teaching Model (CTM) is minimal on this variable compared to its effect size on formulation of ideas, search for ideas, and review of meaning.

The partial eta squared values of the CTM also varied in terms of the phases of this study as presented on Table 5.14. The figures show that the effect sizes of the CTM on pretest and evaluation are 0.46 and 0.86 respectively. These figures indicate a gain in the size of the effect of the CTM on evaluation compared to pretest. It is important to highlight that the duration of pretest was five weeks while evaluation lasted for 13 weeks or one academic term. It is logical to argue that observed gain on the effect size of the CTM over the two phases could be a function of time. This suggests that time is a critical factor of conceptual change. Although cognitive research has shown that misconception once formed is rigid to change, my study shows that the learners’ ability to identify and modify their misconceptions is enhanced when they regulate their own learning.

My study is guided by two assumptions. The first is the assumption of normality, and the second is the assumption of equality of variances. The results of the test of these
assumptions presented on Tables 5.5 and 5.6 show that the assumption of normality in the distribution of TI and CI scores is fulfilled while the assumption of equality of the variances of TI and CI groups is violated. This observation is indeed worrying as it raises doubts whether the observed difference in the performance and achievement of TI group and CI group is due to the effect of the Constructivist Teaching Model or whether it is due to the effect of the extraneous variables that I could not control. In my view the design (pseudo-experimental) chosen and used in conducting this study is the appropriate where randomisation of the subjects is not possible due to ethical reasons and other reasons beyond the control of the researcher. It is equally important to note that the results of the test of statistical power, effect size, and internal consistency of CI scores in ‘Tables 5.13, 5.14, and 5.15’ respectively signal high the validity of my study. However, the implicit extraneous variables that impelled the violation of the assumption of equality of variances need to be further explored.

As I mentioned in the justifications of my study, previous research has evaluated the effect of the constructivist approach on the teaching of science using samples of learners from other parts of the world, however, none of such studies has been conducted using learners in Seychelles. Conducting my study using secondary school learners and teachers, and science educationists in Seychelles has bridged some empirical gaps. Although the learners used in my study are selected from the Lower secondary, the conclusions I have
drawn can be suffused to learners in the Upper secondary in Seychelles. In addition to bridging empirical gap, my Constructivist Teaching Model inspires reform in the approach to science teaching in Seychelles – the paradigm shift from the traditional approach to the constructivist approach. The model also serves as a resource to science teachers, teacher trainers, and trainees who aspire to improve their methods of teaching and those who intend to undertake further research on improving the teaching and learning of science.

6.3 Implications of the findings

Although the results of my study corroborates the findings of previous studies in stating that constructivist teaching methods are more effective than traditional teaching methods in facilitating learners’ performance and achievement in science as I have mentioned in 6.2, I must caution that science educationists in Seychelles should not cling to the assumption that the constructivist approach is a panacea for all science learning ills.

To guarantee the efficacy of my model of constructivist teaching necessitates commitment on the part of the learners, teachers, and educational managers and administrators. Effective learning is inspired by good pedagogy. Good pedagogy demands that teachers play the role of facilitators while the learners take autonomy of their own learning. It entails giving to the learners the opportunity to identify the limitations of their own conceptions, search for new
ideas to illuminate and evaluate their own ideas, and applying the new knowledge in finding solution to problems in everyday life. Against this backdrop I draw the following inferences:

1. Science teachers should provide to the learners the ample opportunities to formulate their own ideas rather than the learners absorbing the teachers’ own ideas. It is important for teachers to note that all knowledge emanates as a hypothetical construction. No individual constructs knowledge for another. The knowledge that the learner constructs by himself is more meaningful than that transmitted to him by the teacher or someone else.

2. Science teaching should aim at exposing the learners to activities that involve exploring multiple sources in the search for new ideas. Evidence from this study has shown that learning activities that engage the learners in critical search for new ideas enhance critical thinking and self-regulation.

3. Science teaching should recognise that the preconception the learners come with into new lessons are resistant to change. Consequently, teaching should aim at providing the learners with opportunities to identify their misconceptions and modify them in the light of new evidence. Restructuring of ideas is akin to hypothesis testing.
4. The value of knowledge lies on its use. As such, instructions should aim at enhancing the learners’ ability to apply the science concepts and principles they have learned to solve given problems.

5. Knowledge construction is a complex cognitive process involving four distinctive cognitive events, namely formulation of ideas, inquiry, review of meaning, and transfer of knowledge. Time plays a crucial role in this process. Therefore, science teaching should be designed and implemented in such a way that allows the learners sufficient time to search for and reflect on their own ideas. Given time, learners will be able to identify by themselves inherent limitation in their own thoughts and actions.

6. Science educationists should organise sensitisation programs for science teachers to create in them the awareness that traditional instruction is becoming less and less relevant to achieving the goal of science education in the New Millennium, thereby necessitating a paradigm change. Teachers should be encouraged to implement the constructivist methods in science teaching.

7. School managers/administrators should equip schools with adequate resources for science learning. This is crucial in promoting inquiry-based hands-on learning of science.
6.4 Suggestions for further research

Based on the limitations of my study, I suggest that further research should:

- Re-evaluate the effect of my model of constructivist teaching of science in ‘Figure 3.1’ on conceptual change with sample from the Lower secondary, judging that the results of my study give the impression that the model has least effect on the transfer of knowledge and large effect on the formulation of ideas, the search for new ideas, and the review of meaning.

- Investigate the effect of my model of constructivist teaching of science on conceptual change using learners in the Upper Secondary in Seychelles since my study was conducted with learners in the Lower Secondary.

- Investigate the effect of my model of constructivist teaching of science on conceptual change with learners in the Independent schools in Seychelles since my conclusions are limited to public secondary schools in Seychelles.
6.5 Closing remarks

This study observed that since the mid 1980s there has been a growing interest on cognitive research in effort to better understand the process of learning, the factors influencing learning, the consequence of learning, and intervention aimed at facilitating learning. Traditional theories and models of learning spin on the assumption that teachers are precursors of knowledge and learners are empty vessels waiting to be filled with knowledge. This assumption is widely refuted and is becoming less and less tenable. Evidence from recent studies indicates that learners do enter new lessons with empty brains rather than they come with some preconceptions. These preconceptions are at variance with the aim of the curriculum and negate effort by teachers to modify them. This circumstance has led to extensive research on the design, implementation, and evaluating models of teaching aimed at modifying the alternative frameworks that the learners come with into new lessons. Although the teaching models draw from constructivism, each defines a distinctive route to learning.

Underpinning the constructivist approach to teaching is the perception that learners’ preconceptions can be modified if the learners rather than the teacher take ownership of learning. Shifting ownership from the teacher to the learners entails giving the learners autonomy to think, direct and manage their own learning. This implies a paradigm change, a change of the culture of the learning, which most teachers are unwilling to compromise.
Most teachers cling so tenaciously to tradition and are ignorant of contemporary models of teaching that have been designed to improve the teaching of science. In my opinion these teachers need to be sensitized so that they will come to awareness that the New Millennium opens unlimited opportunities and challenges to mankind. They (teachers who cling to traditional approach) need to appreciate the fact that the economic prospects of a society depends fundamentally on the ability of its members to construct and apply new knowledge. It is therefore irrational and unproductive to keep applying a 20th century approach in solving a 21st century problems.

Seychelles is one of the smallest island states in the world. It is made up of 115 islands scattered over an area of about 750000 square kilometers on the Indian Ocean, and a fragile ecosystem (Republic of Seychelles 2000d). Its population as at the time of this research was about 83,000 with 25 state primary schools, 10 State secondary schools, and 3 private schools. With a system of comprehensive education in place, the National Science Curriculum adopts the approach where basic science concepts and principles are taught at the Lower secondary using the integrated approach. At the Upper Secondary the specialized subjects which include Biology, Chemistry, Physics, and Combined Science are taught in greater depths. Evidence from the National Evaluation Reports and Schools’ Audit Reports that were analysed in the course of this study show that learners’ performance and achievement in science has consistently declined since 1998. Teaching is monotonous and lessons are dominated by teachers. Instruction
rarely draws out the prior knowledge, skills and interest of the learners. The learners are not actively involved in their own learning. Each year’s report deplores the methods of teaching and the achievement of the learners in science, and recommends a change of the approach. My model of constructivist teaching of science (Figure 3.1) marks the starting-point. However, I must emphasise that this model is not the solutions to low performance and achievements in science but rather an attempt to bridge a didactic gap that had been ignored by previous research. I am optimistic that if science teachers in Seychelles implement the model consistently as prescribed in ‘section 3.4’ it will go a long way to improve the learners’ attitudes and achievements in science.

I must not fail to emphasise that conducting this study has inspired me to develop my own perspective of learning. Through this study I have been able to learn how learners think, and how and what they think of their own thinking. The array of cognitive theories of learning, constructivist experiences, models of constructivist teaching that I have had the opportunity to analyse, and the pedagogical gap I identified in the context of this research collectively have inspired my thinking about learning and the conditions that induce conceptual change. Enthused by my theorising crystallized in my model of the process of conceptual change in ‘figure 2.1’, I deduced my definition of learning as ‘the formulation, review, and restructuring of ideas’. 
Through this study my understanding of education in Seychelles has broadened remarkably. The government has provided the basic infrastructure and facilities for the teaching and learning of science. Over 60 per cent of science teachers currently in secondary schools are expatriates from countries such as India, Sri Lanka, Nigeria, South Africa, and Kenya, and Mauritius on the contract employment of the Ministry of Education. There are also qualified teachers trained locally and other trained in colleges and universities in the United Kingdom, Australia, India, South Africa, New Zealand, China, and Canada. There are ongoing professional development opportunities in the form of conferences, seminars, workshops, networking, and mentoring that are available for teachers in all the state schools. Amid all of these provisions, there is still a lack of a sense of purpose on the part of the learners. Teachers have no control of the learners. There are catalogues of rights prescribed for learners and no mention their responsibility. Family structure is a concern. Most homes are unstable. Drugs abuse, sexual abuse and assault, and alcoholism pervade social life. The situation is precarious as it affects the learners and their schooling, and portends a bleak future for the country as a whole.

Living and working in Seychelles as a lecturer/teacher trainers at the National Institute of Education for a period of six years (from 2002 to 2008) provided me with the opportunity to visit the schools, observe teaching and learning, attend workshops and seminars, and interactions
with the members of the society at both formal and informal levels. Through these lived experiences I could infer that there are some implicit adversative factors influencing the performance and achievements learners in Seychelles that need to be explored far from those identified in the National Examinations Reports and Schools Audit Reports. Concerned with the future of education on this island, I recommend a sponsored research to investigate the factors influencing the attitudes and achievements of learners in Seychelles. The investigation will aim at ascertaining why learners in Seychelles lack a sense of purpose and what should be done to reverse the trend. The outcome of the study will inform the long-yelled-for reform on education on the island. In my view, any reform prior to identifying why the learners in Seychelles lack a sense of purpose and what should be done to reverse the trend may not achieve the purpose for which it was designed.
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ACKNOWLEDGEMENT SLIP

| To: Mr. Anyanwu R. Ndubisi |
| Faculty of Educational Studies |
| NIE |
| Date: 22\textsuperscript{nd} February 2005 |

We acknowledge with thanks your letter dated 14\textsuperscript{th} February 2005 regarding Field Experimentation.

Comments: Approval has been conveyed to carry out field experimentation as per your request.

Kindly contact schools concerned for further organisation.

We wish you success in your study.

Jeanne Simeon (Mrs)
Director General
Schools Division
Appendix 2

Letter refusing my request to publish the results of this study in the original names of the schools selected

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Enquiries To:
Telephone Ext: 3131

Date: 23rd August 2005

Mr. Raymond N. Anjanywu
Faculty of Educational Studies
National Institute of Education

Dear Mr. Anjanywu,

Re: Doctoral Research: Permission to use original names of schools

We acknowledge receipt of your letter dated 8th August 2005 addressed to the PS (EHRD).

Further to our meeting on 18th August 2005, your request has been discussed with senior officials in the Education and Human Resources Department.

I regret to inform you that approval has not been granted as per your request. I would like, however, to wish you success with your study and appreciate the fact that you have chosen to conduct it in secondary schools in the Seychelles.

Thanking you for your understanding,

Yours sincerely,

Jeanne Simeon (Mrs)
Director General - Schools Division
For: Principal Secretary (EHRD)
Appendix 3

Request to use venue for workshop

MEMO

From: Raymond Anyanwu (EDST)

To: Director (NIE)

Date: 14th February 2005

Subject: REQUEST TO USE THE CONFERENCE ROOM FOR A WORKSHOP

Theme of workshop
Validating a constructivist intervention aimed at improving learning effectiveness of secondary level science in Seychelles

Participants
Science teachers from selected secondary schools

Date
26th February 2005 (Saturday)

Time
9.00am to 2.00 pm

Thanks for your cooperation

Anyanwu Raymond (Mr)
(Organizer)
Appendix 4

Approval to involve some NIE lecturers in classroom observation

National Institute of Education

MEMO

From: D NIE

To: Mr. R. Anyanwu

Date: 1st April 2005

Subject: Mr. Raymond Anyanwu

NIE is pleased to inform you that approval has been granted for Dr. Nonis and Mr. Kirubananthan to be involved in monitoring of field experimentation as per your request of 3rd March 2005, provided it does not adversely affect their duties at NIE.

Should their involvement in this project has negative effects on their NIE duties, NIE will be left with no alternatives but to cancel this approval.

Thanking you for your understanding and best wishes in your research.

Alex Souffe (Mr)
Appendix 5

Lesson Plan Format

School:  
Class:  
Date:  
Time:  
Topic:  
Teacher’s Intention (Aim):  

Learning Objectives: On completing this lesson the students should be able to:

a.  
b.  
c.  

Students’ Prior Knowledge  

Media/Materials/Resources  

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Homework

Post Lesson Evaluation
Appendix 6

Teaching Effectiveness Scale (TES)
(For Class Teacher’s use only)

Name of Sch ............................................. Name of Student ..............................................
Class .......................................................... No in Class ................................. Date ..............

Scoring Key: Very Good (5); Good (4); Fair (3); Poor (2); Very Poor (1).

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<td>Share new insights with other people</td>
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<td>Identify the incoherence in other people’s views</td>
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<td>Extend existing ideas using new information</td>
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<td>Perform tasks independently</td>
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<td>Use sketches to illustrate new concepts</td>
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<td>Show curiosity to complete given task</td>
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<td>Propose plausible solutions to problems</td>
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<td>Construct representations or models of reality</td>
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<td>Summarize main ideas learned during lessons</td>
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<td>Relate new concepts to everyday life</td>
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Appendix 7

Anecdotal Sheet
(For independent observers only)

Name of School ........................................ Class Observed
Date of observation....................... Duration of observation...

Section A: Formulation of ideas

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<td>Predict the outcomes of events</td>
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<td>Make sketches to show conceptual links</td>
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General Remarks
## Section B: Critical search for new ideas

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**General Remarks**
### Section C: Review of meaning

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<td>Use newly generated information to elaborate existing ideas</td>
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<td>4</td>
<td>Deduce meaning of science terms/terminologies</td>
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<td>Use scientific terms when expressing ideas to others</td>
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<td>Suggest new ways to apply the concepts to solve problems in society</td>
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**General Remarks**
Appendix 8

Pretest Scores
(Traditional Approach)

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## Appendix 9

**Pretest Scores**

*(Constructivist Approach)*

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## Appendix 10

**Evaluation score**  
*(Traditional Approach)*

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