EFFECT OF MODEL-BASED INQUIRY INSTRUCTIONAL TECHNIQUE ON ACHIEVEMENT, SKILLS ACQUISITION AND INTEREST OF PRE-SERVICE CHEMISTRY TEACHERS

BY

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TITLE PAGE

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DANLADI, SAôIDU, a postgraduate student of the Department of Science Education, with Registration Number PG/Ph.D/09/50771 has satisfactorily completed the requirements for the award of Doctor of Philosophy in Science Education. The work embodied in this thesis is original and has not been submitted in part or whole for any other diploma or degree of this or any other university.

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DEDICATION

This research work is dedicated to the entire clans of Mallam Adamu, Mallam Shuʻaibu and Mallam Usman Maitsamiya for their support and encouragement.

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Abstract

This study investigated the effect of Model Based Inquiry (MBI) instructional strategy on achievement, skills acquisition (creative and critical thinking) and interest of male and female pre-service chemistry teachers. Eight research questions and twelve null hypotheses tested at 0.05 level of significance guided the study. A quasi experimental (non-equivalent control group) design was adopted for the study. 174 (151 males and 23 females) pre-service chemistry teachers (NCE II) from two State Colleges of Education (SCOEs) in North West geo-political zone were involved in the study. Simple random sampling by balloting was used to select the two SCOE out of the seven SCOEs in the geo-political zone. The two randomly selected SCOEs were randomly assigned to experimental and control groups. In each of the two selected colleges, all the NCE II chemistry students were used in their intact classes. The regular chemistry lecturers in each of the colleges who were earlier trained in the details of instructional sequences of MBI and Conventional Inquiry (CI) were involved in teaching the subjects. The experimental group was taught CHEM 221 using MBI instructional technique while the control group (CI) was taught the same course with CI approach. The collegesô regular time tables were used for the period of 10 weeks. Four instruments were used for the study, these are: Chemistry Achievement Test (CAT), Creative Thinking Test (CTT), Test of Critical Thinking (TOCT) and Chemistry Interest Inventory (CII).The four instruments were subjected to face and content validation. The instruments were also trial tested and from the data collected, the reliability coefficients of the instruments were obtained. CAT had 0.81 using Kudder-Richardson (K-R20) while CTT had 0.79 using Kendalôs coefficient of concordance (W). TOCT had 0.85 using Pearson Product Moment correlation and CII had 0.87 using Cronbachôs Alpha. The validated instruments were administered as both pre and post tests while the data obtained were analyzed using mean and standard deviation for the research questions and the Analysis of Covarience (ANCOVA) for the hypotheses. The findings among others showed that teaching chemistry with MBI instructional technique enhanced pre-service teachersô achievement, skills acquisition (creative and critical thinking) and interest better than CI approach. This will avail pre-service teachers the opportunity for the acquisition of sustainability related competencies required for the 21st century. Based on the findings, among others, it was recommended that the National Commission for Colleges of Education (NCCE) should incorporate MBI instructional technique in the National Certificate of Education (NCE) minimum standards.

CHAPTER ONE

INTRODUCTION

Background of the Study

Science and technology education are critical to sustainable national development. The duo has been transforming human life in one way or another for thousands of years. It is glaring that the pace of science and technological transformation has been very rapid in recent times precipitating numerous challenges on daily basis. Inherently, issues challenging the sustainable existence of humankind and general wellbeing such as automation, globalization, workplace change and policies increasing personal responsibility are evolving (Jerald, 2009). This has necessitated a need to equip current and future citizens in general and Chemistry students in particular, with the skills to address the rapidly evolving technology needs/challenges of the 21st century (Ezema, 2011). These skills go beyond the science process skills, but the broader skills such as critical thinking skill and creativity (Silva, 2008; Nwosu, 2015). Chemistry education has the potential to provide for the needed solutions to the challenges of the millennium (Ezeudu & Okeke, 2013).

The potentials of Chemistry education in providing the desired national sustainability is mirrored in the intents of its inclusion in the nationôs curricular packages at different educational levels. At the basic education and secondary school levels, the learning experience is aimed at the acquisition of appropriate level of literacy, numeracy, manipulation and life skills such as the critical thinking and creativity for useful living within the society (FRN, 2004). At the Nigeria Certificate in Education (NCE) level, chemistry education is designed to produce competent chemistry teachers with the capacity to further encourage the spirit of inquiry and creativity in the learners and to apply the skills and knowledge to solve day-to-day problems (National Commission for Colleges of Education, 2008). However, these objectives are yet to be achieved in our schools and colleges as a result, poor academic achievement of students in chemistry have been recorded in recent times. This view is supported by Aina and Akintunde (2013) at college level, the West African Examination Council (WAEC) Chief Examinerôs report (2013) and by extension, Ozaji (2008) the analysis of integrated science for five consecutive years. Science educators have identified some factors militating against the attainment of the objectives to include teachersô methodology and strategies.

Methods and instructional techniques are ways by which teachers present course materials to learners and engage them in the task of learning the curriculum content. They are the tools used by the teacher for actualizing the set aims and objectives (Bello, 2012). If the tools are faulty or inappropriate, the aims and objectives of the teaching and learning will not be achieved. It is clear from the foregoing that the possibility of Chemistry education to provide for the needed solutions to the challenges of the millennium depends on the ability of Chemistry teachers to select and maximally utilize appropriate instructional techniques in their lesson delivery. Chemistry teaching methods should therefore reflect a modern society mandating the need for functioning, thinking-oriented, decision-making students. To be successful, teachers should select and use a wide variety of innovative instructional strategies, because excellent and effective teaching demands high quality techniques and a host of other devices to achieve cross critical outcomes.

The ability of Chemistry teachers in particular to select and utilize the appropriate instructional techniques in their delivery is a function of the pre-service and in-service training they received from the teacher producing institutions and departments. The quality of teachers is dependent on preparation for professional role as distinct practitioners (Aina & Akintunde, 2013). In Nigeria however, low level of performance of pre-service teachers, especially their poverty of knowledge and skills has been a recurrent problem in science education (Agoro, 2013). This underscores the need for the current study. The identified weakness raises the concern about pre-service Chemistry teachersô ability in particular to prepare students for the 21st century knowledge society. Quality of teacher education programs and the ability /willingness of the Colleges of Education (COEs) and universities to provide for innovative programs that will produce better prepared teachers are being questioned (Agoro, 2013). There is an overall lack of political and public confidence in teacher training systems and a profound mismatch between the radically new key competencies demanded from students in the knowledge society and the teaching skills that pre-service teachers are equipped with, in teacher training institutions (Moreno, 2006).

Nevertheless, the need for exposing the prospective science teachers at higher education levels to quality knowledge and skills, both practical and cognitive, remains a necessity. Science educators maintain that the task cannot be accomplished without a radical change from the use of teacher centered traditional practices in teacher preparation programs to the use of student centered approaches such as the inquiry (Nwosu, 2015).

Inquiry signifies search for knowledge or information which involves a systematic process of investigation. Promoted by American educator and philosopher, John Dewy, Inquiry falls under ñinductiveò approaches to teaching and learning. The term inquiry refers ñto a process of seeking knowledge, raising questions, searching answers, evaluating information and asking new questionsò (Virginia & Whitney, 2011). Regardless of the type of inquiry, the processes aim at the improvement of the active involvement of science students in the instructional processes towards attaining the goal of inquiry which according to Oral (2012) is to develop better and richer experiences, hence the authentic knowledge growth. In this study, conventional inquiry entail students explore the academic content through investigation, asking questions and raising answers under the support of the teachers, However, research findings indicate the continuous abuse of the Conventional Inquiry (CI) as verification activities where students closely follow directions dictated by lecturersô laboratory manuals and memorizing what science lecturers and text books have indicated as truth about the natural world. Windschitl, Thompson & Braaten, (2008) and Witt & Ulmer (2010) support further, that students tend to regurgitate with minor variations, the steps of the inquiry without understanding how and why of the procedures. The conception of knowledge mind and learning no longer serve in the 21st century where what we know is less important than what we are able to do with knowledge in different contexts and where our capacity for learning far outweighs the importance of our ability to follow rules (Glibert, 2005). This lead to the proposition by science educators for a more reformed innovative inquiry based instructional technique such as the Model-Based Inquiry (MBI), to align the Conventional Inquiry (CI) with the skill requirements of the millennium.

Model-Based Inquiry is an instructional technique in which science students utilize models as representations of physical properties such as characteristics, entities, and conceptual relationships blended in inquiry process. De Jong and van Joolingen (2008) state that in MBI, students try to grasp the properties of an existing models (learning from models), learn from creating models (learning by modeling) and a way of learning in which these two forms are combined. In MBI, unlike the conventional inquiry, there is always a provision for students to develop an initial platform of understanding (a model) to inform their previous knowledge, questions and hypotheses and data generated are not only used to characterize how outcome are related to conditions but also why the conclusion is reached in particular way (Windschitl, et al, 2008). In sum, conventional inquiry focused on testing hypothesis while MBI is grounded in content, goes beyond how something happens (testing hypothesis) to why something happens i.e. testing idea (Louca, Zacharia, & Constantinou, 2011). Example, in an activity involving the determination of dissolution of different sizes of sugar crystals, the smaller sugar crystals will dissolve faster than the larger sugar crystals (CI) but in MBI, the underlying explanations based on the analyses of how molecular motion helps break the chemical bonds between molecules of sugar will be addressed. In this study, MBI is an instructional technique which engages students in chemical inquiry through physical and conceptual modeling of characteristics and the underlying cause and relationships that exist among organic chemistry concepts. These aspects of the MBI having the potential of wider applicability need to be imbibed by pre-service chemistry teachers during training at the colleges to become competent teachers with the capacity to further encourage the spirit of inquiry and creativity in the learners at the secondary school and basic education levels and to apply the skills and knowledge to solve day-to-day problems. However, studies relating to investigative approaches at pre-service teacher programs indicate the paucity of empirical studies on the effects of MBI in Chemistry instructional practices at colleges of education level.

Chemistry is that aspect of sciences that deals with the nature of matter, its properties and its changes in conditions. Organic chemistry constitutes one of the major branches in chemistry. It is the study of the structure, properties, composition, reactions, and preparation of carbon-containing compounds, which include not only hydrocarbons but also compounds with any number of other elements, including hydrogen (Rice, 2014). The range of application of organic compounds is enormous and also includes, but is not limited to, pharmaceuticals, petrochemicals, food, explosives, paints, plastics and cosmetics. This provides a justification that its study improves the standard of living. Chemistry education in general has a crucial role to play in helping to find answers to various human and socio-economic problems as well as making the society scientifically literate (Ezeliora, 2009; Hua-Jun, 2014). However, Chemistry education can only address these globalization challenges if pre-service chemistry teachers are provided the opportunity to explore and develop their innate potentials. The pre-service chemistry teachers in this study are the level II students of Colleges of Education (COEs). The study did not consider NCE I & III because of newness and standardization issues respectively. NCE II however, is the intermediate and the rate determining stage of the program. From the researcherôs experience, majority of these pre-service chemistry students score low grades with a lot of failures in CHEM 221. Such failures have been recorded at the COE level throughout Nigeria (Aina and Akintunde, 2013). The major reason for this problem advanced by some educators is that teaching and learning in COEs especially in northwest geopolitical zone, are still based predominantly on traditional practices such as lecture, expository, demonstration (Education Sector Support Program in Nigeria [ESSPIN], 2009; Ijaiya, Alabi & Faasasi, 2011). Such practice militates against the realization of the objectives of pre-service chemistry teachersô training (Adeyemi & Adeyemi, 2014). Moreover, the Northwest geopolitical block leads in the country on the shortage of NCE teachers both in quality and quantity (Egwu, 2009).These circumstances vis-à-vis the knowledge and skill requirement (especially critical and creative thinking) of the millennium underscore the need for the shift in emphasis to the use of more studentsô (activity) centered instructional techniques such as the Conventional inquiry. However, the continuous abuse of this type of inquiry has been established in the literature. Thus, science educators proposed reformed innovative inquiry approaches such as the MBI (Windschitl, et. al., 2008). Yet, the MBI has not been satisfactorily explored in determining studentsô learning outcomes especially at pre-service teacher level.

Studentsô achievement connotes academic performance in school subject as symbolized by a score or mark on achievement test. According to Anene (2005), studentsô academic achievement is quantified by a measure of the studentsô academic standing in relation to those of other students of his age. Ogunsaju (2004) states that, the academic standard in all Nigeria educational institutions have fallen considerably below societal expectations. One of the reasons for the low standard could be associated with the quality of teachers trained in the colleges of education (Adeyemi & Adeyemi, 2014). However, studentsô achievement is determined by certain factors such as teachersô attitude, enthusiasm, and learning environment as well as studentsô attitude and background (Adeyemi, 2014). A strong relationship exists between high-quality instruction, teacher professional development and studentsô achievement (Araoye, 2013). So effective teaching demands quality techniques and host of other devices to achieve cross critical outcomes (Van Wyk, 2010). However, despite the importance of chemistry to mankind and the efforts of researchers to improve on its teaching and learning, the achievement of students in the subject remains low in Nigeria (Adesoji & Olatunbosun, 2008). This is a manifestation of a negative ripple effect throughout the education system which stems from the teacher preparation programs. Since improved teacher preparation will lead to greater teacher effectiveness and ultimately improved studentsô achievement (Okeke-Oti & Adaka, 2012) and there is paucity of research on studentsô learning outcomes at the pre-service level employing MBI, the need for this study becomes crucial.

Learning outcomes in terms of cognitive and intellectual skills that are relevant with wider applicability which pre-service students should imbibe during training is the acquisitions of skills to enable them become useful members of the society (FRN, 2004). The type of curriculum designed, its quality, and the instructional delivery which accommodates the acquisition of skills is germane for manpower development. This implies that pre-service teacher programs must provide training in the acquisition of skills which in this study are the critical thinking and creativity among other 21st century skills. These skills, though implied in the NCE science curriculum as higher order thinking skills, problem solving skills, scientific skill/attitudes or analytical thinking, they are not well developed/addressed, hence the need to do so because of the millennium skill requirement.

Critical thinking is a rational thinking in the pursuit of relevant and reliable knowledge about the material world. It is a purposeful, self-regulatory judgment which result in interpretation, analysis, evaluation and inference as well as explanation of the evidential, conceptual, methodological or contextual considerations upon which judgment was based (James, 2007). Critical thinking in this study is a reflective thinking which enables pre-service teachers to draw conclusions, make tacit assumptions, deduce, interpret and evaluate arguments. The goal of critical thinking, which concurs with the goals of science teaching, according to Kalman (2008) is to enable students to become the maximally rational human beings that they are capable of being. The rationality involves the use of those skills or strategies that increase the probability of a desirable outcome. Angeli and Valanides (2008) state that critical-thinking skills are necessary for active citizenship in any pluralistic and democratic society, where citizens are daily confronted with tremendous amounts of information and ill defined problems with real uncertainty as to how they can be best solved. Research findings, though inconclusive, relate critical thinking with a number of instructional approaches such as between constructivist and traditional approach (Tynjalas, 1998), Digital Game-Based Learning (DGBL) integrating High Order Thinking Skills (HOTS) (Yan, 2014) and between dialogical and non-dialogical approach (Frijters, 2008). Other studies such as Myer and Dyer (2006), Heong, Yunos and Hassan (2011) and Ramos, Dolipas and Villamor (2013) discovered that achievement relates positively to CT skill acquisition at different education levels including higher education. These researches were based on foreign countries however the need for developing critical thinking and creativity more than ever before, less have been reported on the Nigerian environment with MBI.

Creativity on the other hand involves not only the generation of ideas but also the evaluation of them and deciding which one is the most adequate. Creativity is a meta-cognitive process of generating novel or useful associations that better solve a problem, produce a plan or result in pattern, structure, or product not clearly present before (Hargrove, 2012). Creativity in the context of this study entails pre-service teachers utilizing the instructional experiences to come up with something original, generate new and different classes of ideas and products. While a conclusive definition of creativity is elusive, researches on creativity have outlined the components of creative thinking (e.g. Karpova, et al, 2011) to include fluency (ability to generate ideas), originality (the degree to which the produced ideas are unique or novel), elaboration (ability to build on existing ideas), and flexibility (ability to generate different classes of ideas). There are inconclusive results on how creativity correlates with achievement. Naderi, Abdullahi, Aizan, Sharir and Kumar (2010), Abayomi (2014) found a positive correlation between the two construct while Olatoye, Akintunde and Yakassai (2010) and Adeola (2011) found no significant correlation between creativity and students achievement. Karpova, et al. (2011) on the aspect of instructional delivery found out that incorporating creativity exercise promote the development of creative thinking in students. Creativity and Critical thinking can be integrated to allow students develop original ideas supported by well reasoned, logical argument linked to dispositions such as the need to evaluate information and a tendency to approach problems uniquely.

There is a glaring citizen outcry against below average quality manpower production characterized by poverty of knowledge and skills from nationĝs educational system (Pollyn, 2014), substantiating the paucity of innovative instructional strategies in our traditional classrooms at all education levels (Colman, 2014; Giginna and Nweze, 2014; Aniodoh and Ezeh, 2014). As a result, pre-service teachers produced from such COEs in particular are seriously limited in intellectual skills especially those of the critical thinking and creativity (Nwosu, 2015). This has produced ripple effect throughout the educational system and contributing to a perpetual state of underdevelopment (Ijaiya, et al, 2011). Several methods like cooperative learning, concept mapping, learning styles etc were employed by science teachers at different educational levels including the COEs, in various attempts to ameliorate the problems but yet the outcome is inconclusive. It is also clear that there is paucity in such attempts as to exploit the curriculum at this level to develop and utilize the combined skills especially employing the MBI in our trainee chemistry teachers in attempts to propel their curiosity and interest in chemistry for success in their classrooms and personal lives

Interest involves a sense of commitment with and curiosity about something, for instance, students having interest in science subjects. The term interest usually refers to preference to engage in some types of activities rather than others (Hagey, Baram-Tsabari, Ametler, Cakmakci, Lopes, Moreira & Pedrosa-de-jesus, 2012). Interest is fundamental in any individualôs choice of task. Interest-driven actions involve personally valued objects or activities; they are accompanied by positive emotions and are self-intentional (Krapp and Prenzel 2011). Hagey et al., posit that an interest may be regarded as highly specific types of attitude, when we are interested in a particular phenomenon or activity; we are favorably inclined to attend to it and give time to it. By implication, studentsô positive attitude towards science leads to a positive commitment to science that influences lifelong interest and learning in science.

The concept of interest strongly affects an individualôs affective functioning with respect to learning (Kim as cited in Lamb, Annetta, Meldrum & Vallett, 2011). The generalized characteristics of interest according to Lamb, et al., (2011) include state of focused attention, flow, increased cognitive functioning, and increased affective functioning. Researchers have shown that studentsô general interest in science was positively related to performance (Bybee and McCrae, 2011) and specifically in chemistry (Agogo, Odoh & Simon, 2014). However a mixed outcome was reported on gender and interest. Hagey et al., (2012) reported that boys in general are more interested in science than girls but in developing countries girls have the same (Alao & Abubakar, 2010) or even more positive attitude and interest in science than boys (Bello & Aliyu, 2013) in electrical electronics and physic respectively. Nworgu (2004) further discovered that girls developed higher interest because they developed greater enthusiasm and enjoyed the biology lesson much more than the boys. Hagey et al. further state that while Biology is of great interest to girls, Physics and Technology prove significantly less interesting to girls than to boys although Chemistry is liked to a similar extent by both genders. A major contradiction in this regard was reported by Fenshman (2007) that females were found to be high achievers than their male counterparts in physics but had very low interest in physics. However, beside the gender issues and interest, Agogo, Odoh and Simon (2014), Blunuz and Jerrett (2007) found out that methods/ instructional techniques are also a function of interest. It is evident that there have been continued inconsistencies in the research findings in the area of interest in science which serves a meditational role for academic achievement of both male and female students especially at the pre-service science teacher preparation level. Hence, there is therefore the need to investigate the effect of the MBI on the identified variables on pre-service chemistry teachers.

Gender according to Santrock (2001) involves the biological dimension of being a female or male. This has been a crucial matter to the educationists. Issues that are multidimensional in outlook as they relate to the teaching and learning of science in this regard have been very contentious. Providing quality education ensures sustainable development. Adapting an approach that takes into account the relationship and interaction between males and females, according to the United State Agency for International Development (USAID, 2008) will address four dimensions: equality of access; equality in the learning process; equality of educational outcomes and equality of external results. Science educators such as Adigwe, 2012 and Nwosu, 2015 conducted researches on gender differences and achievement. The results though inconclusive, showed measurable differences in between male and female students in achievement, and interest in science related subjects (Keziah, 2011).

Most of the studies conducted on gender differences found out boys have better performance than girls. A wide range of factors are responsible for the observed disparity. According to Nwosu (2015) and Eze (2007) sex-role stereotyping or gender stereotyping appears to be the most predominant and perhaps the source of all other causes of gender difference in science, technology and mathematics education. Also related is the cognitive sex differences resulting from a complex phenomenon known as stereotype threat (Miller & Halpern, 2014), composition of classroom peers (Legewie & DiPrete, 2012) and socio-cultural factors (Njoku, 2000). This is opposed to the fact that sustainable development is participatory and needs the involvement of both males and females (Nwosu, 2015) as enshrined in the United Nationsô Millennium Development Goals (MDG) initiatives and United Nations Education Scientific and Cultural Organization (UNESCO) Education for All (EFA) objective of achieving gender equality. Similarly, it contradicts the intent of the National policy on Education (FRN, 2004) that every Nigerian child shall have a right to equal education opportunities, irrespective of any real or imagined disabilities, each according to his or her ability. However, literature abound with statistics that gender parity could be established in science classes that emphasize hands-on/activity based instructional strategies. In view of the fact that inquiry methods such as the conventional inquiry have been used as well as other activity based strategies such as cooperative learning on gender issues in science, the result is still inconclusive. Hence, there is the need to try the MBI and ascertain its impact on achievement, skill acquisition and interest of both male and female pre-service chemistry teachers.

Statement of the Problem

Science and technology have been critical to sustainable national development and positive transformation of human life. Issues that challenge the sustainable existence of human kind such as globalization, automation and workplace change are evolving. This necessitates the need to equip all students including pre-service chemistry teachers with knowledge and skills especially those of critical thinking and creativity to thrive in a rapidly evolving technology driven world.

There is no automatic connection between education and such needed sustainable development except through a good pre-service teacher preparation programs. However, Colleges of Education (COEs) as one of the production pipelines for teachers both in quantity and quality, often fail to satisfactorily equip pre-service teachers for this 21st century environment. The major reason for this problem advanced by some educators is that teaching and learning in COEs especially in northwest geopolitical zone, are still based predominantly on traditional practices such as lecture, expository, demonstration. These practices promote gender disparity in learning, impede studentsô interest and the acquisition of requisite knowledge and skills. These circumstances vis-à-vis the knowledge and skill requirement (especially critical and creative thinking) of the millennium underscore the need for the shift in emphasis to the use of more studentsô (activity) centered instructional techniques such as the Conventional inquiry. But research findings indicate the continuous abuse of inquiry as verification activities, where students closely follow directions and memorizing what science teachers and text books have indicated as truth about the natural world. This lead to the proposition by science educators for a more reformed innovative inquiry approaches such as Model-Based Inquiry (MBI). Moreover, the paucity of the use of MBI in science teaching and learning at all levels of education system has been established. Since the quality of teacher education determines, to a great extent, the quality of instructions and learning outcomes, there is the need to explore the efficacy of MBI at pre-service teacher level. Hence the problem of the study posed as question is: What is the effect of MBI instructional technique on achievement, skill acquisition and interest of pre-service Chemistry teachers?

Purpose of the Study

The purpose of the study is to determine the effects of MBI instructional technique on achievement, skills acquisition and interest of pre-service chemistry teachers. Specifically, the study hopes to determine the:

1. Relative effectiveness of MBI instructional technique and the Conventional Inquiry (CI) approach on pre-service teachersô achievement in chemistry.
2. Relative effectiveness of MBI instructional technique and the CI approach on pre-service teachersô creative thinking skills acquisition in Chemistry.
3. Relative effectiveness of MBI instructional technique and the CI approach on pre-service teachersô critical thinking skills acquisition in Chemistry.
4. Relative effectiveness of MBI instructional technique and the CI approach on pre-service teachersô interest in chemistry.
5. Influence of gender on pre-service teachersô achievement in Chemistry.
6. Influence of gender on pre-service teachersô creative skills acquisition in Chemistry.
7. Influence of gender on pre-service teachersô critical skills acquisition in Chemistry
8. Influence of gender on pre-service teachersô interest in Chemistry.
9. Interaction effect of treatment and gender on pre-service teachersô means achievement scores in Chemistry.
10. Interaction effect of treatment and gender on pre-service teachersô mean creative thinking skills acquisition score in chemistry.
11. Interaction effect of treatment and gender on pre-service teachersô mean critical thinking skills acquisition score in chemistry.

12. Interaction effect of treatment and gender on pre-service teachersô mean interest score in chemistry.

Significance of the Study

The study has both theoretical and practical significance. On the theoretical perspective, this study is anchored on the psychological theories of learning with particular reference to cognitive and constructivist learning theories. Cognitive theorists such as Piaget and Dewey maintain that students begin by developing operation to act on the material world and eventually by the stage of formal operation they acquired abstract logico-mathematical reasoning capacities that allow them to detach themselves from the object world so that they can reason about it in strictly logical perspectives. The constructivists such as Vygotsky however hold the view that knowledge is constructed by the individual learner and is embodied in human experiences, perceptions, imaginations and mental and social constructions. They also hold the view that construction of knowledge includes both physical and intellectual activities in which students interact with objects, people or events and eventually construct a reality of them. In MBI, students are exposed to group problem solving activities in a social supportive environment where they can freely and collaboratively express themselves, ask questions and resolve conflicts of opinions. The conversations in MBI will create an authentic learning opportunity for students through the manipulation of resources as advocated by the socio-cognitive theories of learning. This is supported by provision for students to develop an initial platform of understanding, i.e. a model (to be subsequently validated), which informs their previous knowledge, questions and hypotheses and data generated are not only used to characterize how outcome are related to conditions but also why the conclusion is reached in a particular way.

Practically, the findings of this could be of benefit to students, teachers and curriculum planners. Students exposed to MBI were provided with the opportunities to collaborate with one another, share information, seek solution and explore alternatives in a social supportive environment in the process of authentic knowledge construction. It is anticipated that the use of MBI will help students develop and justify explanations. It will also give them the opportunity to develop meta-knowledge in scientific practices and the understanding of both content and processes of science through model generation. The finding of this study will therefore help to establish the extent such model generation practices affected the development of 21st century skills, such as critical thinking and creativity needed for success in their classrooms and personal lives.

The finding of the study could help science teachers particularly chemistry teachers, to be aware of the effect of MBI as a modified inquiry on studentsô learning through sensitization programs, workshops, conferences and seminars. These activities will demonstrate the need to adopt it as an alternative instructional strategy for teaching chemistry for easier understanding and effective learning by students (pre-service teachers) in the acquisition of skills, especially those of critical thinking and creativity as well in engendering interest among all students irrespective of gender.

The finding of this study when published could provide empirical evidence, which could serve as a guide for organizing conferences, seminars and workshops for professional science teachers, administrators, curriculum planners as well as textbook writers in their effort to help improve acquisition of 21st century skills and interest among science students in general.

The findings of the study when published may also create awareness for curriculum planners especially the National Commission for Colleges of Education (NCCE) to review the Nigeria Certificate in Education (NCE) minimum standard in the aspect of pedagogy to incorporate MBI in the teaching and learning of sciences. Curriculum planners could also benefit from the findings by providing them with information like the indices of achievement, skill acquisition and interest of both male and female students.

Scope of the Study

The study was restricted to the determination of the effect Model-based Inquiry instructional technique on achievement, skills acquisition and interest of NCE 11 chemistry students from the state colleges of education in north-western geo-political zone of Nigeria. The area of study forms a block of educationally disadvantaged section of the country with attendant negative consequences. The key indicator of the scenario was reflected in the Road Map for Nigerian Education sector (Egwu, 2009) that out of the 38.75% of teachers with certificates below the NCE, the North-East and North-West regions constitute about 70% of the said percentage. The course selected for the study is Chem 221 (organic chemistry 2) in which mechanisms of the various reactions throughout the contents are necessary. This accounts for most of the failures recorded in this course because it requires high degree of logical reasoning from students. The major topics in the course include Alkanes, Alkenes, Alkynes, Markovnikoffôs rule, Polymerization, di-enes. (See Appendix A, p. 180).

Research Questions

The following research questions guided the study:

1. What is the effect of MBI instructional technique and CI on pre-service teachersô achievement in Chemistry?
2. What is the effect of MBI instructional technique and CI on pre-service teachersô acquisition of creative thinking skill in Chemistry?
3. What is the effect of MBI instructional technique and CI on pre-service teachersô acquisition of Critical thinking skill in Chemistry?
4. What is the effect of MBI instructional technique and CI on pre-service teachersô interest in Chemistry?

5. What is the influence of gender on pre-service teachersô achievement in Chemistry?
6. What is the influence of gender on pre-service teachersô Creative thinking skill acquisition in Chemistry?
7. What is the influence of gender on pre-service teachersô Critical thinking skill acquisition in Chemistry?
8. What is the influence of gender on pre-service teachersô interest in Chemistry?

Hypotheses

The following null hypotheses tested at 0.05 level of significance guided the study:

1. There is no significant difference in mean achievement scores of pre-service teachers taught Chemistry with MBI and those taught using CI.
2. There is no significant difference in mean creative thinking skills acquisition scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with CI.
3. There is no significant difference in the mean critical thinking skills acquisition scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry methods.
4. There is no significant difference in the mean interest scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry method.
5. There is no significant difference in mean achievement scores of male and female Pre-service chemistry teachers when exposed to MBI.
6. There is no significant difference in the mean creative thinking skills scores of male and female pre-service chemistry teachers when exposed to MBI.
7. There is no significant difference in the mean critical thinking skills scores of male and female pre-service Chemistry teachers when exposed to MBI.

8. There is no significant difference in the mean interest scores of male and female Pre-service chemistry teachers when exposed to MBI.
9. There is no significant interaction effect of treatment and gender on pre-service teachersô means achievement scores in Chemistry.
10. There is no significant interaction effect of treatment and gender on pre-service teachersô mean creative thinking skills score in chemistry.
11. There is no significant interaction effect of treatment and gender on pre-service teachersô mean critical thinking skills score in chemistry.
12. There is no significant interaction effect of treatment and gender on pre-service teachersô mean interest score in chemistry.

CHAPTER TWO

REVIEW OF LITERATURE

Relevant literature to this study was reviewed under the following sub-headings.

Conceptual Framework

- Chemistry Education Delivery
- Concept of Conventional Inquiry
- Concept of Models
- Model-Based Inquiry (MBI)
- NCE Chemistry Education
- Concept of Organic Chemistry
- Concept of achievement
- Skills acquisition (creativity and critical thinking)
- Concept of interest
- Concept of Gender

Theoretical Framework

- Constructivist learning theory
- Cognitive learning theory

Review of Related Empirical Researches

- ♦ Inquiry Learning Techniques and Achievement in Science
- Critical Thinking / Creativity in Science Education
- Interest in Science Education
- Gender Issues in Science Education

Summary of the Reviewed Literature

Conceptual Framework

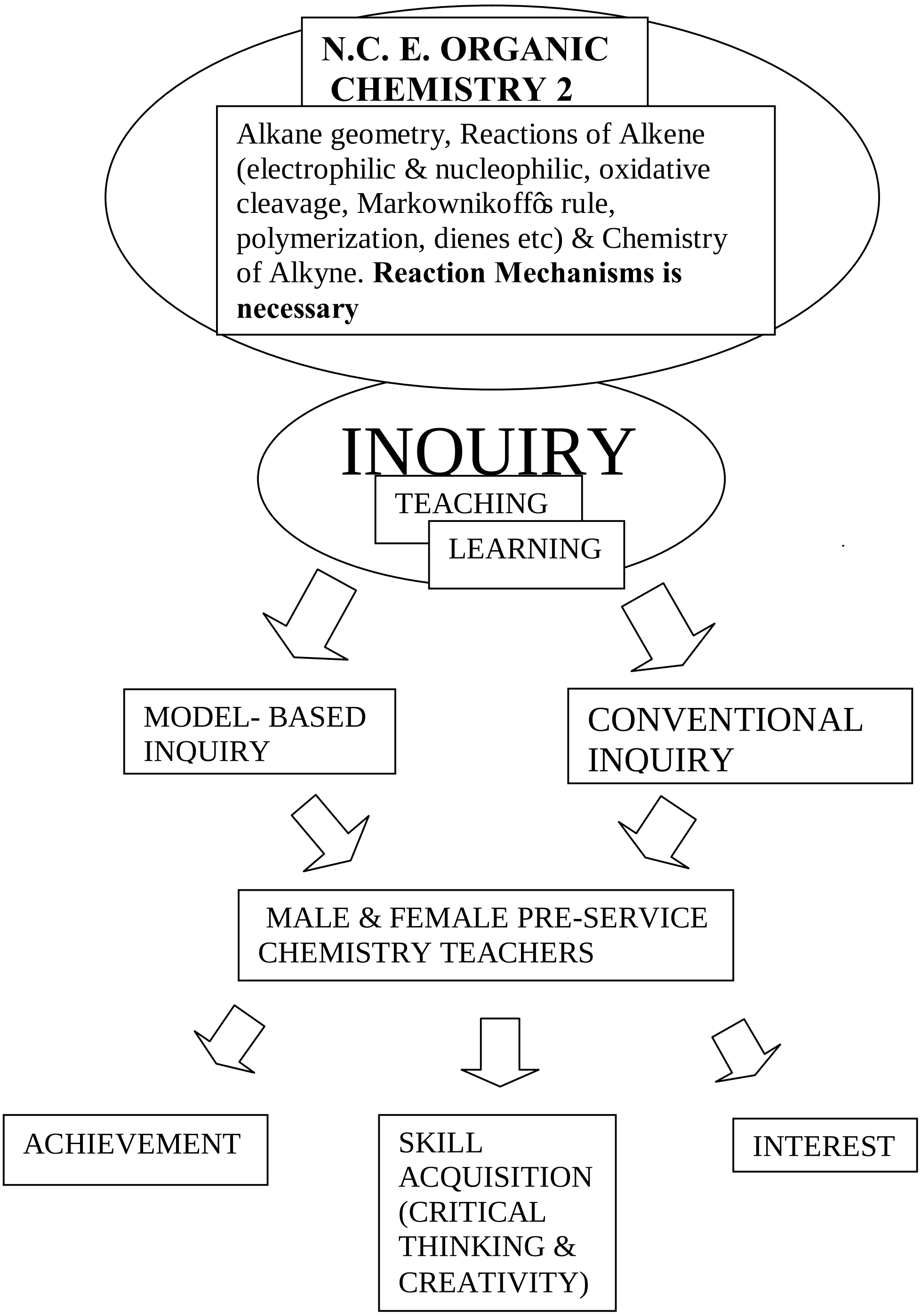


Figure 1: Schema for the study of the effect of MBI on Achievement, Skills Acquisition and Interest of Pre-service Chemistry Teachers.

Explanation of the schema

The schema presents aspects of chemistry (concepts in organic chemistry) and suggested that these concepts should be presented to pre-service teachers using Inquiry based teaching ï learning process. Inquiry approach is an instructional technique that shapes how teachers and learners think about scientific practice. Chemistry and its branches such as the organic chemistry at all education levels especially at the pre-service teacher stage should therefore be effectively taught through the inquiry based approaches. This will unveil the crucial role chemistry plays in helping to find answers to human and socio-economic problems of the contemporary world. However, the inquiry approach was not satisfactorily used to bring about the desired outcome in chemistry students including pre-service teacher level, especially as it relates to the skill requirements of the 21st century. This underscores the need for a reformed innovative inquiry based approaches such as the Argument-Based inquiry, Model-Based inquiry etc. MBI instructional technique focuses learners on the generation of physical and conceptual models through inquiry processes. The schema of the conceptual framework shows the independent variable (MBI) and the dependent variables (academic achievement, skills acquisition and interest). The male and female pre-service chemistry teachers (gender as the moderating variable) will be exposed to the two types of inquiry (conventional and MBI) for the purpose of determining their relative efficacy on academic achievement, skills acquisition and interests. The need for appropriate and adequate learning outcomes at all education levels is crucial in this contemporary world more than ever before. Hence the need to fast tract the requisite learning outcome through exposing male and female pre-service chemistry teachers to such activity based approaches especially on the aspects of achievement, skills acquisition (creative and critical thinking) and interest. This is necessary for quality education defined by the level of knowledge and skills for success in workplaces, personal lives and equitable sustainable development in the 21st Century.

Chemistry Education Delivery

The national policy on Education statement that education is an instrument of national development holds true when the mechanisms for attaining the designed goals are relevant to the citizenฯs needs and national aspirations, and provided they are realizable (Danladi and

Abdullahi, 2013). The major task of education system therefore lies in the process of how to ignite the latent talents in the nationôs citizenry with the aim of preparing and equipping them with relevant knowledge and skills. This is in a bid to make them function effectively, most especially in the globalized world. In line with the Nigerian National Policy on Education (FRN, 2004), the study of chemistry should prepare individuals for useful living within the society and for higher learning. It is expected that those exposed to chemistry education will at least develop a ñsurvival kitò even if further education is not possible or inaccessible to enable students be self-reliant. This is why chemistry is one of the core science subjects that students are required to pass in order to qualify for admission into tertiary institutions to pursue science-based programs like Medicines, Engineering, Pharmacy among others (Njoku, 2007, Muhammad, 2014). It is therefore glaring that Chemistry education has a crucial role to play in helping to find answers to various human and socio-economic problems as well as making the society more scientifically literate (Ezeliora, 2009). Lending credence to this assertion, the Royal Society of Chemistry, RSC (2009) contend that Chemistry has unique and great capacity to solve many of the 21st century global challenges.

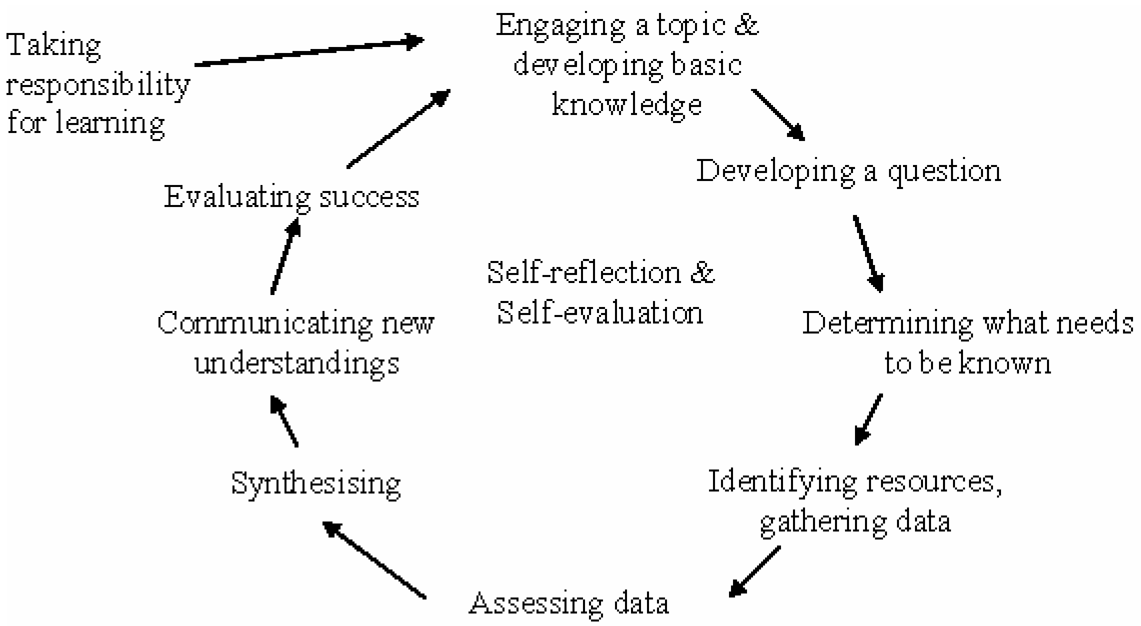
However, it was reported that over the last two decades there are reflections across nations that teaching and learning of chemistry is problematic (Samba, Achor and Ogbeba, 2010). The situation is not different in Nigeria. Consequently, the aims of chemistry education and the opportunities it affords are not fully harnessed and utilized. This has produced a ripple effect throughout the education system and contributing to a perpetual state of underdevelopment. The submission is justified by the prevalence of marked perennial youth unemployment problem. This is testified by the number of graduates roaming the streets of the nation seeking employment into an ñover stretchedò labor force. The peculiar characteristics of these teaming youth is that they are relatively unskilled (Olorukooba, Usman & Yero, 2009), and they lack practical skills (Adeyemo, 2009). It is indeed pathetic that the study of chemistry in Nigerian secondary schools fails to equip the graduates with necessary skills, knowledge and attitude that will enable them to function effectively in the society (Danladi & Abdullahi, 2013).The approaches adopted in its teaching depict difficult picture and a body of isolated facts and lacking relevance (Ezeliora, 2009). To majority of Nigerian students, study of chemistry is mainly a classroom affair.

Science is presented dogmatically in most chemistry instructions as series of disjointed facts and concepts which students find difficult to relate to the real world. Aniodoh and Eze (2014), Giginna and Nweze (2014) lamented in this regard that teaching techniques and instructional strategies used in chemistry classrooms are inappropriate and uninspiring. This stemmed from the fact that chemistry teaching in Nigerian schools is characterized by non involvement of the learners in the teaching and learning process (Ezeliora 2009). In other words it is more teacher centered (ESSPIN, 2009). Undoubtedly, the deficiency has to do with the common use of traditional and related conventional methods by chemistry teachers (Ibe and Nwosu, 2003; Nwosu, 2015). The methods reduce the learner to a passive listener and do not allow them to participate actively in the learning situation. Lecturing minimizes feedback from students, assumes an unrealistic level of student understanding and comprehension, and often disengages students from the learning process causing information to be quickly forgotten. Traditional (lecture and other teacher centered) methods encourage rote learning, students are unable to retain their learning and apply it to new situation and do not produce maximum result for the acquisition of science skills (Ibe & Nwosu, 2003; Kim, 2005; Nwachukwu & Nwosu, 2007; Chukwumeka & Nwosu, 2008; Okwo, Okoye, Ugwu & Onyeka, 2008). The predicament of the traditional teaching methods becomes more acute as the knowledge base continues to expand rapidly and traditional jobs demands shrink while new jobs demands greater sophistication and preparation (Maigida, 2013). The traditional approach of knowledge delivery and skill acquisition in chemistry through lecture and demonstration methods must be improved or even replaced with methodologies which allow students to acquire the needed skills. Students in this millennium need time to explore, make observations, test ideas, learn concepts, wrestle with unfamiliar and counter intuitive ideas, explore alternative perspectives etc (Jerald, 2009). One of such learning in science education literature which creates such opportunity to learners, anchored in cognitive/constructivist learning theories is the inquiry.

Concept of Conventional Inquiry

Inquiry, in different guises and with different terms, has been cited as one of and often the principal goal of science education for decades. In the 1930ôs and 40ôs, it was common to find articles that spoke of developing ñthe habit of scientific thinking and methodò Blair and Goodson (as cited in Quigley, Cynthia, Deaton, Cook & Padilla, 2011). Still others according to Quigley et al. (2011) focused on developing scientific attitudes like objectivity, replicability, and the value of controlled experiments. In the 1960ôs the lines of research coalesced, even though the notion of breaking the whole into minute pieces remained. Inquiry was called science process skills, a set of discrete characteristics of the scientific process. Scientists observed, described, inferred, measured, and hypothesized. They identified and controlled variables, designed experiments, and drew conclusions. The belief was that if students practiced and mastered the distinct skills, they would naturally put them together to solve problems (Colburn, 2000 & Quigley et al., 2011). We have come a long way since that time. We no longer try to break the whole into distinct parts. Instead, the National Science Education Standards described inquiry as ñthe diverse ways in which scientists study the natural world and propose explanations based upon evidenceé ò (NSF, 2000).

Conventional Inquiry signifies search for knowledge or information which involve a systematic process of investigation. Promoted by American educator and philosopher, John Dewey, Inquiry falls under ñinductiveò approaches to teaching and learning. It begins with a set of observations or data to interpret, or a complex real-world problem, and as students studies the data or problem they generate a need for facts, procedures and guiding principles (Spronken-Smith, Bullard, Ray & Roberts, 2008). In science education and other related fields, the term conventional inquiry refers ñto a process of seeking knowledge, raising questions, searching answers, evaluating information and asking new questionsò (Virginia & Whitney, 2011, p. 21). This process is characterized in the following inquiry model developed by a group of McMaster teachers



Source; Justice et al., 2002:19

Figure 2: **The conventional Inquiry Process**

Conventional Inquiry is more than just learning facts. It is knowledge of how to get those facts and how they can be used. Inquiry suggests a need to know and it goes beyond just seeking the right answers but implies seeking resolution to questions and issues (Exline, 2004). This is actualized by an interactive process that actively engages students in learning in a more meaningful ways. Conventional Inquiry is a complex but realistic process in which students use their prior knowledge and scientific theories to generate new understandings of science (Yoshina and Harada, 2007). The learning outcomes of inquiry include critical thinking, the ability for independent inquiry, responsibility for own learning and intellectual growth and maturity (Lee, Hart, Cuevas & Enders, 2004). A publication, devoted entirely to the conceptualization of inquiry, set out its essential featuresð basically a description of how you would know inquiry when you see it (NRC, 2000). These essential features describe what the learner will do when inquiring, including:

- engaging with a scientific question,
- participating in design of procedures,
- giving priority to evidence,
- formulating explanations,
- Connecting explanations to scientific knowledge,
- Communicating and justifying explanation.

Dimensions of Conventional Inquiry

Conventional Inquiry (CI) can take multiple dimensions, but according to NRC (1996) and Inoue and Buczynski (2011), the approach can be seen as a continuum from teacher-led to student-led processes and the common approach can be classified into three;

The first of the type is structured CI. In this strategy, the teacher provides students with a question and the process students use to find the answer. Certain topics can only be explored through structured CI, in particular those that involve answering standard-based questions using a method which is not intuitive or which involves the use of specialized instruments (Gejda and LaRocco, 2006). The obvious advantage to this approach is that these lessons are sure to familiarize students with inquiry methods and allow them to develop process skills. In addition, teachers may be able to anticipate the types of questions that students may pose and easily prepare points of discussion. Structured CI is the most teacher-centered of the three types of inquiry (Inoue and Buczynski, 2011). The teacher provides fairly structured procedures for the inquiry activity and students carry out the investigations. This could be described as the most traditional approach to inquiry.

The second type is the guided CI. In this strategy, the teacher poses a question and provides the students only with materials to be used in their investigations. The students must design the experiment themselves. Many standard-based topics work well with guided inquiry. This approach requires that students are familiar with the main steps of scientific inquiry. Teachers are responsible for preparing inquiry-based assessment to monitor students. Guided CI falls in the middle of the inquiry instructional spectrum (Werner and Myer, 2011). The approach is commonly used when students are asked to make tools or develop a process that result in a desired outcome (National Academy Press, 2000).

The third type is the open CI. In this approach, teachers furnish students with materials to investigate but students must come up with questions and methods for investigation. Because students follow their own path of questioning, it is more difficult to tie this approach to standard-based topics (Inoue and Buczynski, 2011). The key is to choose a topic that intuitively arises from an examination of the materials. To ensure the success of this strategy, Colburn (2000) suggests that teachers can;

- provide carefully planned inquiry-based assessment;
- create well established classroom rules for interaction and the handling of materials;
- offer guidance to students who exhibit frustration;
- prepare guide questions following the activity that tie into standards.

Teachers feel less comfortable with this approach than structured CI, yet given an appropriate topic and lesson preparation; the approach can excite both students and teachers and provide great opportunity for students to develop inquiry skills and articulate scientific reasoning (National Academy Press, 2000).

These CI processes may involve individual student or isolated activity (traditional inquiry), or in a situation in which students collaborate in carrying out the scientific processes (project based inquiry) and in some instances engaging students in argumentation in the course of the inquiry processes (argument based inquiry), which may involve both oral and written form (Choi, Klein & Hershberg, 2014). In this type of inquiry, the moral, ethical, and political influences on decision making in scientific contexts are used to engage students in argumentation (Cavagnetto, 2010). However, the socio-scientific approaches in the argument based inquiry tend to occur in culminating activities such as class debates or role-plays. So despite the emphasis on the importance of verbal and written argumentation, the active involvement of students in the process is rarely found in the current science classrooms and students may continue to do verification activities closely following directions and memorizing what science teachers have indicated as truth about the natural world (Choi, et al., 2014). In the context of the current study, open CI integrating aspects of the argument based inquiry (ABI) were used. Introducing modeling (physical and mental) into the argument-based (modeling argumentation) may probably upgrade the inquiry processes to align with the skill requirements of 21st century. This may perhaps bring about improvement in the active involvement of science students in the instructional processes towards attaining the goal of inquiry which according to Oral (2012) is to develop better and richer experiences, hence growth.

Steps in 5E model of Conventional Inquiry

Bybee (1997) classified the process of inquiry (which falls within the confine of constructivist instruction) into five stages referred to as the 5Es. These are: engagement, exploration, explanation, elaboration and evaluation.

Engage. In the Engage, the students first encounter and identify the instructional task. Here they make connections between past and present learning experiences, lay the organizational ground work for the activities ahead and stimulate their involvement in the anticipation of these activities (NRC, 2000; Werner and Myer, 2011). Asking a question, defining a problem, showing a surprising event and acting out a problematic situation are all ways to engage the students and focus them on the instructional tasks.

Explore. According to Connecticut State Department of Education [CSDE] (2001), in the exploration stage, the students have the opportunity to get directly involved with phenomena and materials. Involving themselves in these activities they develop a grounding of experience with the phenomenon. As they work together in teams, students build a base of common experience, which assists them in the process of sharing and communicating (Werner and Myer, 2011). The teacher acts as a facilitator, providing materials and guiding the students' focus. The students' inquiry process drives the instruction during an exploration.

Explain. This is the point at which the learner begins to put the abstract experience through which she/he has gone /into a communicable form. Language provides motivation for sequencing events into a logical format. Communication occurs between peers, the facilitator, or within the learner himself. Working in groups, learners support each other's understanding as they articulate their observations, ideas, questions and hypotheses (NRC, 2000; Werner and Myer, 2011). Language provides a tool of communicable labels. These labels, applied to elements of abstract exploration, give the learner a means of sharing these explorations. Explanations from the facilitator can provide names that correspond to historical and standard language, for student findings and events. Created works such as writing, drawing, video, or tape recordings are communications that provide recorded evidence of the learner's development, progress and growth.

Elaborate. In this stage students expand on the concepts they have learned, make connections to other related concepts, and apply their understandings to the world around them (Werner and Myer, 2011).

Evaluate This is an on-going diagnostic process that allows the teacher to determine if the learner has attained understanding of concepts and knowledge. Evaluation and assessment can occur at all points along the continuum of the instructional process. Some of the tools that assist in this diagnostic process are: rubrics (quantified and prioritized outcome expectations) determined hand-in-hand with the lesson design, teacher observation structured by checklists, student interviews, portfolios designed with specific purposes, project and problem-based learning products, and embedded assessments (NRC, 2000; Werner and Myer, 2011). Concrete evidence of the learning proceed is most valuable in communications between students, teachers, parents and administrators. Displays of attainment and progress enhance understanding for all parties involved in the educational process, and can become jumping off points for further enrichment of the students' education. These evidences of learning serve to guide the teacher in further lesson planning and may signal the need for modification and change of direction. For example, if a teacher perceives clear evidence of misconception, then he/she can revisit the concept to enhance clearer understanding (CSDE, 2001). If the students show profound interest in a branching direction of inquiry, the teacher can consider refocusing the investigation to take advantage of this high level of interest.

The idea of teaching science by inquiry method which allows students to explore, and experiment with their own concepts about science is often referred to as inquiry-based learning. In inquiry-based instruction, the goal of the instructor is to assist with information processing, to facilitate group discussion, to guide student action, and to increase student thinking. The use of inquiry-based instruction involves creating a classroom or learning environment where the students are self-directed and engaged in open ended, student centered, hands-on activities (Colburn, 2000). Inquiry is more than just learning facts; it is knowledge of how to get those facts and how they can be used (Exline, 2004). The core ingredients of an inquiry-based learning approach according to Spronken-Smith, Bullard, Ray & Roberts (2008) that most researchers are in agreement with include, (a) learning is stimulated by inquiry, i.e. driven by questions or problems, (b) learning is based on a process of constructing knowledge and new understanding (c) it is an 'active' approach to learning, involving learning by doing, (d) a student-centered approach to teaching in which the role of the teacher is to act as a facilitator, (e) a move to self-directed learning with students taking increasing responsibility for their learning and (f) the development of skills in self-reflection.

The foregone interpretation of what ought to be inquiry in all its ramifications typified the science processes, through which the science process skills are developed in the learner. However, it is pertinent to note that developing in the learners the requisite knowledge, interest and skills that are relevant in this millennium requires a learning environment that mirrors the inquiry setting. But research findings indicate the continuous abuse of inquiry as verification activities, where students closely follow directions and memorizing what science teachers and text books have indicated as truth about the natural world. Windschitl, Thompson & Braaten, (2008) and Witt & Ulmer (2010) support further, that students tend to regurgitate with only minor variations the steps of inquiry: observe, develop a question, develop a hypothesis, conduct an experiment, analyze data, state conclusions and generate new questions. Moreover, students carry out these procedures without understanding the how and why of the procedures. The conception of knowledge mind and learning no longer serve in the 21st century where what we know is less important than what we are able to do with knowledge in different contexts and where our capacity for learning far outweighs the importance of our ability to follow rules (Glibert, 2005). Hence, the proposal for a shift to a more innovative form of inquiry, grounded in reasoning with and about models, which in this study is the Model-Based Inquiry (MBI).

Concept of Models

Models are physical, computational, or mental representations that are intended to stand in for some other thing, set of things, or phenomena. Scientific models in particular are tools for expressing scientific theories in a form that can be directly manipulated, allowing for description, prediction, and explanation (Sengufta & Rapp, 2011). Models are representations of an event and/or things that are real or contrived, which depicts a system at some point of abstraction or at multiple levels of abstractions with the goal of representing the system in a mathematically reliable fashion (Catherin, 2009). Generally, models are representation between a source and target, the target being an unknown object or phenomena to be explained, and the source being a familiar object or phenomena that help scientist understand the target (Clement, 2008). While some theorists distinguished between models as part of natural process used to construct an explanation of a phenomena, and models as representational tools for communicating a conceptual referent (Romberg, Carpenter & Kwako, 2005), Windschitl, Thompson and Braaten (2007), Lehrer & Schauble (2003) share a synthesis view that models are representations constructed as conventions within a community. In their view, Romberg et al (2005) state that regardless of how models are conceptualized, they generally emerge from some phenomenological context (event, question, problem), they involve identifying the key features or attributes of the phenomena, and they specify how they are related.

Models play a central role in expert scientistsô reasoning and problem solving and they are instrumental in summarizing data, making predictions, justifying outcomes and facilitating communication in science (Clement, 2008). For example, a biology teacher might show students a plastic replica of a human heart, identifying the ventricles and their relative locations. The replica is not an actual heart, but rather a sculpted reproduction that is intended as an educational tool. This type of model can be handled by students, perhaps taken apart and reassembled, as a means for becoming familiar with the structural features of the heart. The types of educational supports and activities used in everyday science classrooms often rely on such physical models (e.g., ball and-stick chemical molecules; a globe of the Earth; mechanical models of engines built with Lego bricks and gears).

Ornek (2008) categorized models generally into two; the Mental models and conceptual models. Mental models are psychological representations of real or imaginary situations. They occur in a person's mind as that person perceives and conceptualizes the situations happening in the world (Franco & Colinvaux, 2000). Norman (cited in Ornek, 2008) indicates that mental models are related to what people have in their heads and what guides them using these things in their minds (internal cognitive representations). Mental models are mental representations for objects and concepts we learn and know about. When we run mental simulations in our minds for how and why things might happen, we are employing mental models. Mental models, then, are crucial memory representations that can exemplify adequate comprehension. They are the mental products that hopefully result from the use of scientific models (Sengufta and Rapp, 2011). The characteristics of mental models according to Franco & Colinvaux (2000) include:

- They are generative; this means that people or students can produce new information and make predictions while they are using mental models.
- They involve tacit knowledge. The person who uses a mental model is not completely aware of some aspects of his or her mental models. In general, students have some presuppositions about physical or any other phenomena. These are really implicit. They are not conscious and people do not think about them, but rather they use them for reasoning.
- They are synthetic; mental models are simplified representations of the target system which can be a phenomenon or event. That is, they cannot represent the complete phenomenon or event. A representation is never a complete reproduction of what is being represented but, requires conscious or unconscious selection of what aspects will be represented and what other aspects will be left out of the representation. In order to develop a representation of a target, some aspects are isolated to make some kind of simplifications.

DžThey are restricted by world-view; People develop and use mental models according to their beliefs. In other words, a set of limitations forms the possible mental models which people use.

Conceptual models on the other hand are external representation created by teachers, or scientists that facilitates the comprehension or the teaching of systems or states of affairs in the world (Greca & Moreire, 2000). According to Norman (cited in Ornek, 2008), conceptual models are external representations that are shared by a given community, and have their coherence with the scientific knowledge of that community. These external representations can be mathematical formulations, analogies, graphs, or material objects. An example of an object could be a water pump which is sometimes used to model a battery in an electric circuit. An analogy can be established between an atom and the solar system. The ideal gas model is a mathematical formulation (Greca & Moreire, 2000). To come to the point, we can say that conceptual models are simplified and idealized representations of real objects, phenomena, or situations. Conceptual models are mathematical models, computer models, and physical models. There are conceptual models according to Sengufta and Rapp (2011) that have proven valuable as educational tools. Virtual models are computer reproductions of actual objects (e.g., a 3dimensional image of a brain; a program that can explode the Earth to display the interior structure) or interactions between those objects, and which are manipulated through a software interface. Notably, virtual models are useful for exploring concepts or processes, but do not necessarily allow a learner to modify or iterate the underlying computer program or architecture. In contrast, computational models are glass-box simulations of scientific phenomena which can be modified, extended, and rebuilt by learners through direct manipulation of their underlying programs. Computational models have been designed for research domains including physics (e.g., electrical conduction), biology (e.g., natural selection), chemistry (e.g., gas laws), and materials science (e.g., crystallization). Sengufta and Rapp (2011) also noted that these various models are also employed by scientists in actual research laboratories, and thus are not restricted in terms of who might benefit from their usage. The externalized physical, virtual, and computational models that are employed in science classrooms and laboratories are intended as supports for helping individuals to build internalized mental models for scientific concepts (Passmore, Stewart & Cartier, 2010). This present study however utilized aspects of the conceptual and mental model in which students were able to come up with physical models where possible and representational/symbolic models of conceptual relationships existing amongst some organic chemistry concepts.

Models are constructed through modeling (Fretz, Wu, Zhang, Davis, Krajcik & Soloway 2002), a process of developing representations of the concepts and mechanism(s) that are involved in a physical phenomenon (Windschitl et al., 2008). In the context of science education, modeling refers to the process of constructing, extending, verifying, or testing scientific models (Sengufta and Rapp, 2011). In this study, students designed physical models where possible, generate sketchy and diagrammatic models based on their levels. As Schwarz and White (2005) clarify, the term scientific modeling identifies the process used in much of modern science that involves (a) embodying key aspects of theory and data into a modelð frequently a computer model, (b) evaluating that model using criteria such as accuracy and consistency, and (c) revising that model to accommodate new theoretical ideas or empirical findings as necessary. Consider that one of the central pedagogical goals of modeling is to scaffold studentsô development of mechanistic explanations of scientific phenomena. In pursuit of this goal, scientific modeling requires that individuals define and identify important variables and their characteristics as pertaining to the object, system, or phenomenon being modeled. Based on these definitions, individuals can think about how the identified variables interact, and as such, how measurement of those variables and the overall model might be constructed. The success or failures of the resulting models as adequate tools for generating hypotheses and testing data-driven outcomes can be utilized in an iterative way to consider their effective redesign. Scientific modeling, then, is an iterative design process that encourages conceptual understanding and careful testing of model-relevant topics. It is worth noting that the activities described here are directly in line with the activities associated with the scientific method in general; as such, it might be argued that models are themselves the actual language of science (Sengufta and Rapp, 2011).

There is considerable evidence that scientific models and the process of scientific modeling are effective tools for learning. For example, researchers have contended that engaging in the modeling process can help individuals develop sophisticated mental models of scientific phenomenon as well as deep domain knowledge (Sengufta and Rapp, 2011). Thus, students who engaged in modeling are involved in scientific activities that necessitate causal reasoning, hypothesis testing, the generation and evaluation of ideas, and the representation, recording, and analysis of data through scientific inscriptions. These activities encourage encoding into memory, deeper processing, and the types of cognitive experiences that foster learning and transfer. In this study, students (in groups) come up with a physical models and model of relationships (symbolic, physical or sketch) that existed between organic concepts in Chem 221 after an in depth background studies/readings of a particular course content area under the guidance of teacher. The teacher scaffolds students to identify what their respective models fail to predict or consider if any, identify whether their respective models could change in the light of any reason/evidence from other group(s), and what makes their model different from other groups and why to finally arrive at a tentative model. It is by undertaking such critique that students can begin to understand that the function of models is not verisimilitude but rather that they are a tool to assist in the construction of explanations (Osborne, 2013). In this context the researcher utilized both physical and the mental model types in which pre-service chemistry teachers developed mental representations (internal cognitive representations) and physical models where possible through MBI for concepts in chemistry through modeling of the relationships existing between them. Example; at the end of one of the lessons, students model the relationship between synthetic and natural rubber. The relationship goes beyond how the concepts are linked but why the linkage. Modeling plays a central role in the justification and formation of (new) knowledge (Kopenen, 2007), hence, models and the process of modeling have been indicated as core components of scientific endeavors. There is considerable evidence that scientific models and the process of scientific modeling are effective tools for learning and researchers have contended that engaging students in the modeling process can help individuals develop sophisticated mental models of scientific phenomenon as well as deep domain knowledge. Since researches suggest that pedagogies that involve various types of models and modeling are most effective when students are able to construct and critique their own models (Coll, Franc & Taylor, 2012) and the paucity literature on such practices in chemistry at the pre-service teacher preparation level, this study becomes relevant. Hence, pre-service chemistry teachers were exposed to construction of both physical and mental models involved in a more innovative inquiry based approach called Model-Based Inquiry (MBI).

Model-Based Inquiry (MBI)

Authentic forms of Inquiry for school science according to Windschitl et al. (2008) can be grounded in reasoning with and about models, which is the Model-Based Inquiry (MBI). This instructional technique is a pedagogical triumph of teaching and learning of science in which students utilize models as representations of physical properties such as characteristics, entities, and process of a phenomenon. Related to this, Knorr-Cetina (1999) defines MBI as knowledge-building pursuit through the development of coherent and comprehensive explanations through the testing of models. This expression reflects the view of De Jong and van Joolingen (2008) that in MBI, students try to grasp the properties of an existing models (learning from models), learn from creating models (learning by modeling) and a way of learning in which these two forms are combinedò. Elaborating further, Mislevy (2009) states that MBI signifies ñworking interactively between phenomena and models using all of the aspects of models (formation, elaboration, use, evaluation, revision)é with emphasis on monitoring and taking actions with regard to model-based inferences vis-à-vis real-world feedbackò. From the epistemic and model perspective, Windschitl et al. (2007) viewed MBI as a system of activity and discourse that engages learners more deeply with contents and embodies the following five epistemic characteristics of scientific knowledge in which ideas represented in the form of models are;

Dž*testable*: scientific knowledge in the form of models or theories is advanced by proposing new hypotheses that express possible relationships between events, processes, or properties within these models or theories, and by using various domain-specific methods for gathering data aimed at evaluating these hypotheses.

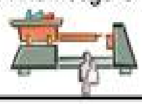
Dž*revisable*: scientific ideas can change in response to new evidence or because a phenomenon is conceptualized in an entirely different way (e.g., kinetic vs. caloric models of heat transfer).

Dž*explanatory*: the goal of science is to provide causal accounts of events and processes, as opposed to accumulating descriptive detail about phenomena or merely seeking patterns.

Dž*conjectural*: causal accounts often involve theoretical or unobservable processes that can only be inferred from empirical observation (data) and that scientific argument aims to persuade others that explanations based on these inferences account most adequately for the observations.

Dž*generative*: scientific knowledge in the forms of models and theories, are the prime catalysts for new predictions, insights about phenomena, and hypotheses for testing; they are not simply ñend-productsò of inquiry.

Unlike the Conventional Inquiry commonly practiced in the classrooms in which there is little possibility of connection between empirical data and unobservable processes, no process for explanation of connections, MBI is grounded in content, connects empirical data with underlying causes, goes beyond how something happens to why something happens (Windschitl, Thompson & Braaten, 2007) i.e. from testing hypothesis to testing idea (Louca et al. 2011). This is depicted in the following figure;

Inquiry as commonly practiced (based on TSM) Goal: *To find patterns in natural phenomena*	Five Epistemic Features of Scientific Knowledge	Model-based Inquiry Goal: *To develop defensible explanations of the way the natural world works*
• Hypotheses, often stated as predictions, are tested. • Predictions are not part of larger sense-making theory, so there is nothing to revise.	Scientific Knowledge is Testable  Scientific Knowledge is Revisable 	• Ideas in the form of models are tested and revised. • Accomplished by evaluating hypotheses that make sense within context of a potentially explanatory model.
• Testing culminates in "conclusions" which summarize trends and patterns in the data, but do not include explanations.	Scientific Knowledge is Explanatory 	• Uses patterns in data, other sources of evidence to explain why focal phenomenon happens. • Models talked about as tools for explanation.
• Going "beyond the data" to the theoretical not often a part of classroom inquiries.	Scientific Knowledge is Conjectural 	• Explanations account for observations with underlying, often unobservable causal processes, or structures.
• Models/theories considered to be only an end-product of inquiry, but more often, are not talked about at all.	Scientific Knowledge is Generative 	• Models/theories used to generate plausible hypotheses, new conceptions, new predictions at any point in the inquiry.

Source; Windschitl et al. (2007, p. 8)

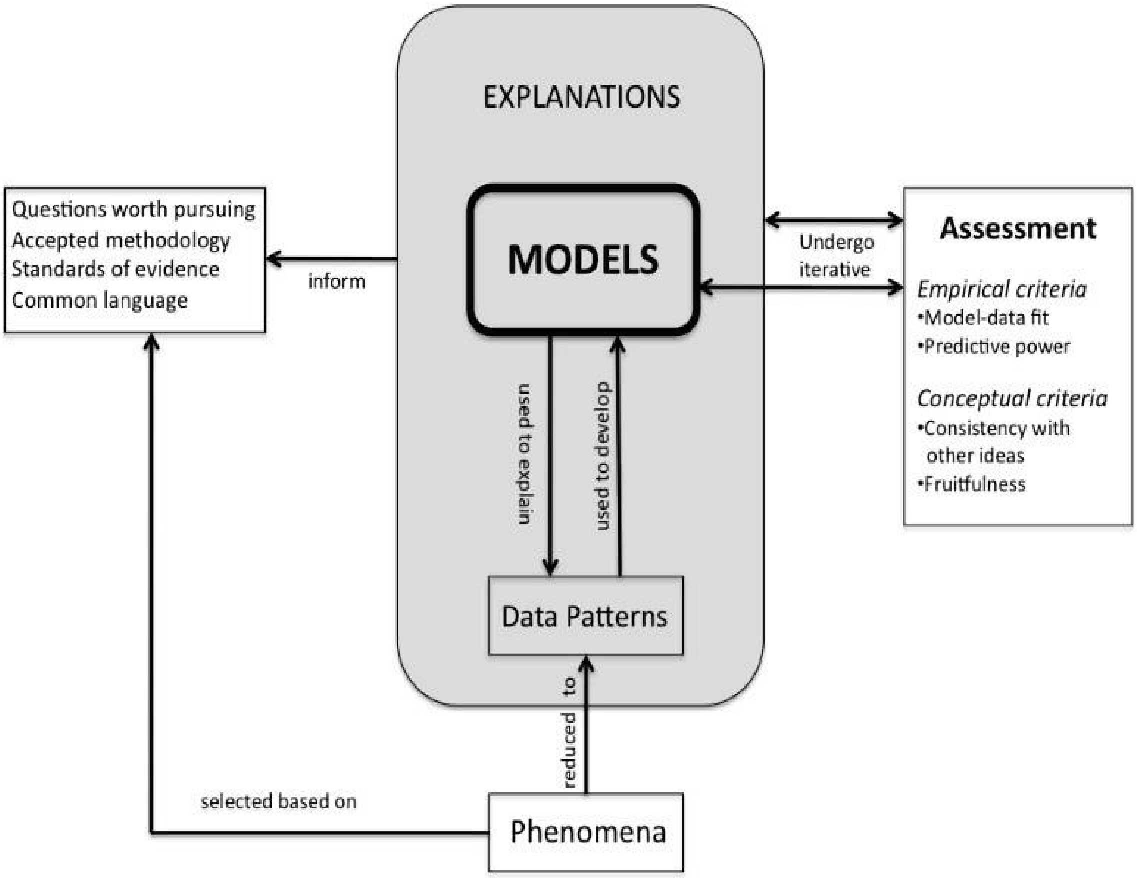
Figure 3: Epistemic comparison of classroom inquiry as commonly practiced and MBI

A vivid example which unveils the striking differences between the inquiry commonly practiced and MBI was provided by Windschitl et al. (2007) in their attempt to investigate on scaffolding pre-service teachers involving Kyle and Jeanne;

In a study where participants were not given scaffolding, one of pre-service teachers, Kyle, conducted an experiment in which he compared the water retention capabilities of different brands of diapers. His hypothesis was simply a guess about which brand would hold the most water based on perceived thicknesses of the samples. His conclusion was about which sample held more water, but Kyle made no suggestions about how or why water might be retained differently by one diaper versus another. This investigation was entirely devoid of conceptual content that could explain the outcomes. Jeanne in a later study investigated how fabrics absorb liquids. Members of her pre-service cohort, however, were required to ñcreate an initial representation of the phenomenonò they were interested in, to ñtest a piece of that modelò and to culminate their investigations by ñconnecting empirical findings with an underlying cause.ò These requirements prompted her to do background reading in both material sciences and the chemistry of liquidï fiber interactions. She found supporting evidence for a hypothesis that various fabrics, based on their molecular structure, would absorb different amounts of neutral, acidic, and basic solutions. She then used her findings to support her theory about unseen molecular-level interactions that explained the empirical outcomes (referred to as theory-directed argument). These two cases illustrate what is meant by testing a hypothesis (Kyle) versus testing an idea (Jeanne). (p. 10).

In this context the researcher adopted the Jeanne option (testing of idea) commensurate with the level of Pre-service chemistry teachers. In addition to this, students were involved in physical modeling at a suitable/appropriate instructional level. The researcher adopted the proposal of Windschitl et al (2007) as the lesson plan. In this proposal, students in groups were given scaffolding to come up with working model (hypothetical) depicting the interaction and relationships between chemical concepts or the construction of physical model were possible. The respective groups carry out an intensive/in-depth background reading/investigation of the conceptual contents that are central to the idea of a particular model in question. This exercise covers two weeks (weekends inclusive). At the end of the each exercise (lesson) students conclude their findings and critique their respective group models (physical and conceptual), explain why and how concepts interact or related to each other in their respective group models. Students presented/displayed their group models (both conceptual and physical) and model authentication follows. These activities avail students the opportunity to identify what their respective group model fail to predict/consider if any. The teacher finally scaffolds the students in developing a whole class model. At the end of the course, students were able to come with a model of all the conceptual relationships in the course outline ï serving as a summary for all other models.

Studying how ideas underlie everyday experiences will provide students with powerful conceptual tools for understanding much of what they see around them. This is possible because in MBI, students are presented with an authentic context that require them to make connections and use one set of ideas to lead them in their investigation of new ideas (Passmore, et al., 2010). Through this process, students are engaged in a process of combining isolated knowledge about poorly understood concepts and relationships into larger, more clearly understood constructs in a way that allows them to represent, reconstruct and explore knowledge of a phenomenon (Mariou, Constantinou & Zacharia, 2007). This subsequently promotes inquiry and conceptual understanding, problem solving, developing hypothesis and determines tests to test relationship (Khan, 2007). It also enables students to develop and justify explanations and give them the opportunity to develop meta-knowledge in scientific practices and understanding of both content and process of science which lead to critical thinking (Passmore et al.., 2010). According to Khan (2007) MBI is in contrasts with most of the approaches to instruction in science education, in that, it provides content and problem scenario, identify given information and the solution goals for the problem, model how to solve a sample problem and to use the same or similar heuristics to solve similar problem. Passmore et al. (2010) corroborate further that not all hypotheses are followed with control experiment as a step to inquiry but other forms which are subject specific, i.e. other legitimate modes of inquiry within science in a bid to test ideas by developing explanations and creating arguments in support of model(s). To this effect, Passmore et. al (2010) provided the following figure reflecting the MBI view of science, which acknowledges discipline-specificity of inquiry and depicts model as a cornerstone of every science discipline. The incorporation of models in the process of inquiry ensures the versatility of the MBI.



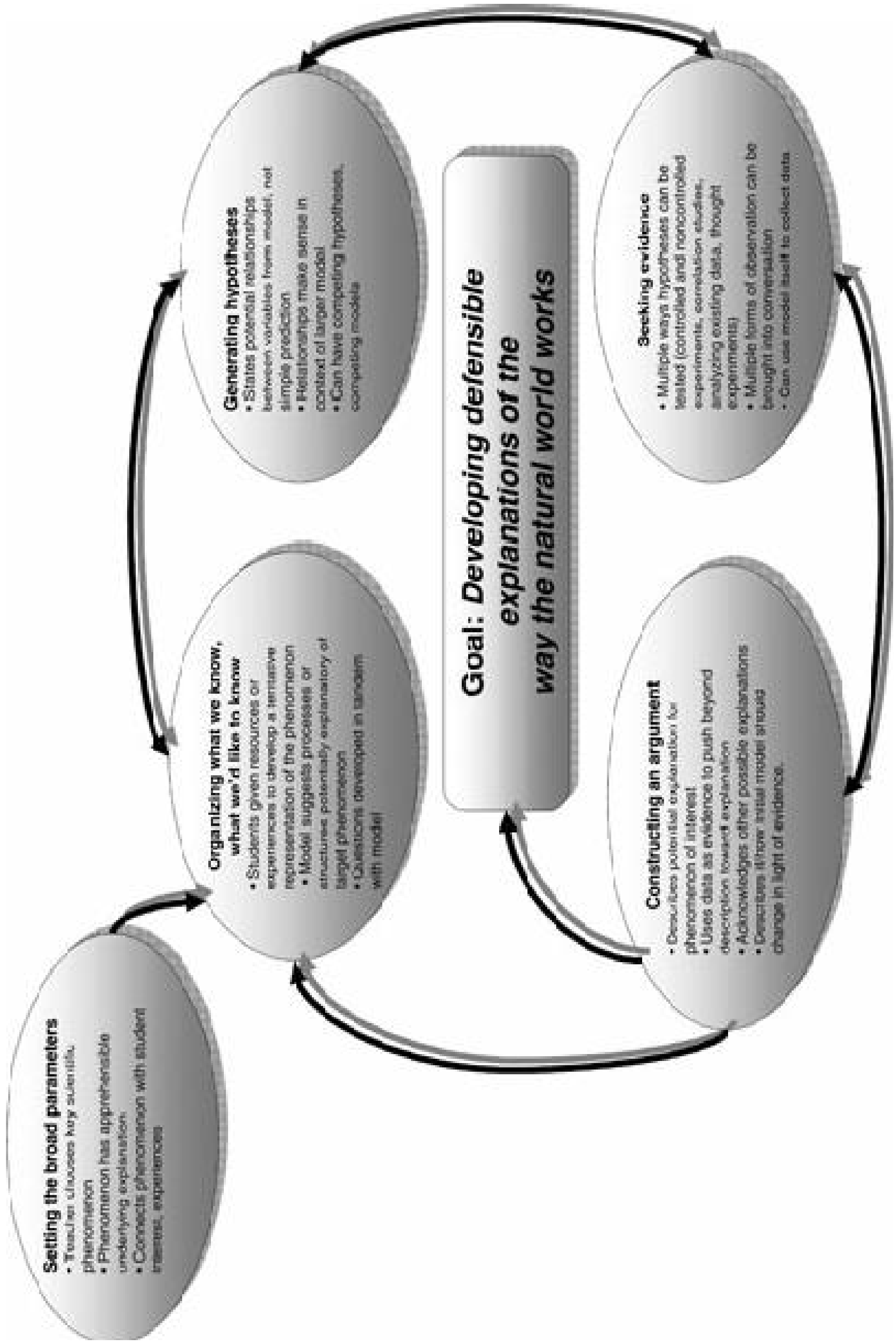
Source: Passmore, Stewart and Cartier (2010, p. 394)

Figure 4: Central position of Model in a discipline-specific practice

According to Passmore et al. (2010) models are placed at the center of this depiction of discipline-specific practice. The words models and data-patterns are nested within the larger construct of explanation in order to illustrate that explanations are distinct from models, but are structures that bring models to bear on particular data patterns that have been abstracted from phenomena. The right side of the diagram shows that both models and explanations undergo assessment based on conceptual and/or empirical criteria. That is, sometimes the model may be critiqued in isolation, but more often it is an explanation arising from the model that is evaluated leading to an assessment of some aspect of the underlying model (or a re-evaluation of what was considered the relevant data pattern). The left side of the framework is meant to convey that key models and accepted explanations within disciplines are important inputs into the norms of the practice and those norms then are important filters through which practitioners view the world and the phenomena that may need exploration.

The goal of MBI according to Windschitl et al. (2007) is to develop defensible explanations of the way the natural world works. These words were carefully chosen. In using ñexplanations,ò they emphasize that the end product should be a statement that helps us understand some aspect of the world at the level of causation. This explanation is embodied in the testable, modifiable representations of scientific ideas, i.e., models. ñDefensibleò alludes to the use of evidence in creating such an explanation. The ñnatural worldò focuses learners on processes, events, or structures in the general domains of biology, physics, earth science, or chemistry.

The version of MBI proposed by Windschitl et al. (2007) begins with the teacher setting the general parameters of what will be studied. This is followed by four kinds of intellectual activity/conversation engaged in by students. These activities/conversations are ñorganizing what we know and what we want to know,ò ñgenerating a testable hypothesis,ò ñseeking evidence,ò and ñconstructing a scientific argument.ò Some of this activity/conversation is procedural, but the emphasis is on purposefully articulating relationships between ideas, evidence, and explanation. The four interrelated conversations supporting MBI are presented in the figure below;



Source: Windschitl et al. (2007, p. 15)

Figure 5: Four interrelated conversations supporting MBI

In MBI, teachers direct their planning efforts primarily to the intellectual work students will do, rather than focusing on material manipulations. The intellectual discourse of the classroom, in turn, is shaped by the epistemic context of how knowledge evolves within the scientific community. As with other forms of inquiry, MBI can be more or less guided depending on the circumstances. For learners below the tertiary level of educational system, they would not be expected to incorporate highly abstract theoretical ideas into models or explanations (Windschitl et al. 2007). In this study, considering the ability of the subjects and by virtue of their status ï prospective science teachers at secondary and basic levels- less abstract theoretical ideas in model (whether physical or otherwise) development were employed. This is in a bid to make the training impact significantly on trainee teachers i.e. benefit commensurate with their societal role of training younger generation and by implication actualizing the objectives of the NCE program. The use of MBI is an attempt to re-orientate the common science inquiry practices in order to bridge the world of science and science education systems in an intellectually honest way and for pre-service teachers, to have a clear conception of inquiry and the practices of authentic science (Windschitl et al. 2007). These aspects of the MBI having the potential of wider applicability should be imbibed by pre-service chemistry teachers during training at the colleges and universities to cascade same to their students at the secondary school and basic education levels. Moreover, while literature is replete with studies relating to investigative approaches at pre-service teacher programs, there is paucity of empirical studies on the effects of MBI in Chemistry at college of education level.

NCE Chemistry Education

The intrinsic values as well as the utility values of Chemistry in all spheres of human activity have necessitated its inclusion in the school curriculum ranging from the ordinary level of our education system to the tertiary level, with major fields such as analytical, biomolecular, environmental, industrial, polymer, electrochemistry, polymer etc. Colleges of education falls under the tertiary level saddled with the responsibility of providing teacher education program embodied in the Nigeria Certificate in Education (NCE) which according to FRN (2004) is the minimum qualification for entry into the teaching profession. Colleges of education should prepare pre-service teachers with right attitudes, values, skills, and personalities needed for effective delivery in the teaching profession (Ezeudu, Chiaha & Eze, 2013). The college should also encourage in pre-service teachers, a spirit of improving critical thinking, creativity, nationalism and belongingness and adaptable to the changing roles of education in society. The pre-service chemistry teachers in this study refer to the students admitted into the chemistry program in colleges of education with particular reference to NCE II. The study did not consider NCE I & III because of newness and standardization issues respectively. NCE II however, is the intermediate and the rate determining stage of the program. Moreover, students in this level are expected to go for a complete semester practical teaching come NCE III first semester, at secondary and basic education. The level according to FRN (2004) is expected to among other things;

Džproduce highly motivated, conscientious and efficient classroom teachers for all levels of our education system;

Džencourage further the spirit of inquiry and creativity in teachers

The federal government in a giant stride towards the realization of these objectives established the National Commission for Colleges of Education (NCCE) through an act (1983 No.3). The commission was established to among other things co-ordinate all aspects of teacher education programs below degree level, lay down minimum standards for all programs of teacher education and continually review such standards. The NCCE (2012) as a guiding principle categorically states that the teaching and learning of Chemistry at the Nigeria Certificate in Education (NCE) level should be such as to produce competent, effective and efficient pre-service teachers, who having acquired the requisite skills should be able to impart same to their pupils. In a bid for the commission to provide effective pre-service teacher program, the chemistry program at this level is structured to produce highly qualified middle ï level manpower knowledgeable in the processes of Chemistry and capable of inculcating these in the student (NCCE, 2012). The commission further states that students should have competencies in chemistry teaching including ability to:

Dž develop functional knowledge of Chemistry concepts and principles;

Dž observe and explore the chemical environment;

Dž apply the skills and knowledge gained through the study of chemistry to solve day-to-day problems;

Dž explain simple natural phenomena;

Dž develop scientific attitudes such as curiosity etc.

Dž manipulate simple apparatus for purposes of demonstration and use; and

Dž improvise simple equipment from available junk in the chemical environment.

Further still, one of the mandates of the teacher training program at the NCE level is to produce specialized quality pre-service teachers for the basic education subsector which encompasses the following categories of education (NCCE, 2012);

Dž Early Childhood Care and Education

Dž Primary Education

Dž Junior Secondary Education

Dž Adult and Non-formal Education and

Dž Special (Needs) Education

Each of these categories of education is distinctive and extensive in addition to those of the senior secondary education (which remain content specific), thus, the program remain relevant to the subsector if the system prepares teachers with requisite knowledge and skills to teach effectively at the different levels and areas of the basic education program, without being oblivious of the needs for higher education of the beneficiaries (NCCE, 2012). The NCCE further emphasized that apart from the required content knowledge, pre-service teachers will also be provided with opportunities to acquire skills and attitudes of an effective teacher. By implication, the new teacher education program will use learning of content (professional knowledge) in such a way that it also relates to and supports the development of professional skills and professional engagement or attitude. The development of appropriate teaching skills will require the provision of adequate opportunities to ópractice teaching. The NCE program is re-focused toward the attainment of Education For All (EFA) demands and the Millennium Development Goals [MDGs]. Some of the goals include the attainment of universal primary education, gender equality, eradication of extreme poverty and hunger and environmental sustainability.

The chemistry curriculum was drawn based on courses in chemistry that cut across NCE 1 to NCE 3. The program at each level is subdivided into first and second semester comprising mostly of core (compulsory) chemistry and science education courses with very few electives. In NCE 1 first semester, students will be exposed to four core chemistry courses of 5 credits (introductory organic chemistry, general chemistry, and practical and chemistry methodology). Students are expected to be exposed to six core chemistry courses of 6 credits which comprised of 3 introductory physical, inorganic and practical; laboratory Techniques; application of mathematics to chemistry. The credit load increases at the studentsô second year (NCE II), in the first semester of this level, chemistry students are expected to cover 5 core chemistry courses of 1 credit each. These include environmental and industrial chemistry, nuclear chemistry, practical, and chemistry of non metals, properties of ionic compounds liquid states and colloids with chemistry of gaseous state as the only 1 credit elective. In the second semester, students will cover 5 core courses of 7 credits which comprised of organic chemistry 2, metal alloys and transition elements, practical, basic analytical chemistry and research techniques and chemistry methodology. The first semester of third year is dedicated for teaching practice. The second semester of NCE III consists of 4 core courses of 7 credits besides other related education and general studies in education (GSE) courses that form crucial part of the program. These include; chemical kinetics, chemistry of alcohols, chemical equilibrium and thermodynamics and practical with natural products and amines as 1 credit elective. In all, the minimum credit required for graduation in this program (chemistry courses) is 32. The courses are arranged in a complementary format. The particular organic chemistry course to be used for this study was preceded by general chemistry, introductory organic chemistry 1 (first semester, level 1), introductory organic chemistry II (second semester, level 1).

Concept of Organic Chemistry

Organic chemistry is a chemistry sub discipline involving the scientific study of the structure, property (physical & chemical) and reactions of matter in its various forms that contain carbon atoms. It constitutes one of the major branches in chemistry dealing with the study of the structure, properties, composition, reactions, and preparation of carbon-containing compounds, which include not only hydrocarbons but also compounds with any number of other elements, including hydrogen (Ababio, 2004; Rice, 2014). The range of application of organic compounds is enormous and also includes, but is not limited to, pharmaceuticals, petrochemicals, food, explosives, paints, plastics and cosmetics. This provides a justification that its study improves the standard of living.

Among the NCE II chemistry courses, CHEM 221 (second semester organic chemistry II) was used for the study. From the researcherǿs experience, CHEM 221 is one of the most difficult courses in NCE chemistry program as majority of students score low grades with a lot of failures. This is relatedwith the nature of the course content and emphasis on reaction mechanisms(actual sequence of events by which the reactants become converted to the products)in each of the reactions. Such information of extraordinary value needed in defining and understanding the range of applicability of given reactions require high level of logico-mathematical reasoning. The course content of Chem. 221 include chemistry and molecular geometry which cover aspect of orientation of atoms in alkane molecules, a function of their physical and chemical properties. Electrophilic and nucleophilic additions, free radical addition, oxidative cleavage (ozonolysis), carbonium ions and Markownikoffôs rule as reactions of organic compounds (their mechanisms and application) are also contained in chem. 221. Moreover, polymerization (types), conjugated dienes and their 1, 4, electrophilic addition and resornance orbital interaction and the alkyne chemistry formed the remaining course content with an emphasis on the reaction mechanisms.

The commission however, identified the following four objectives expected to be attained at the end of the course (Chem 221):

1. describe the geometry of saturated hydrocarbons
2. identify electrophiles and nucleophiles in a chemical reaction
3. state Markonikuffôs rules and its application on unsymmetrical olefins
4. describe the reactions of unsaturated hydrocarbons including dienes

However, literature indicates that the aims and objectives of pre-service chemistry teachersô training in particular are yet to be fully realized (Adeyemi & Adeyemi, 2014; Aina, 2014; Aina & Akintunde, 2013; Okon, 2008). Reason for this problem advanced by some educators is that pre-service teachersô preparation programs in Colleges of education are still based predominantly on traditional practice (Agoro, 2013; Babalola & Jaiyeoba, 2008; Ijaiya et al, 2011; Odu, 2011). It is pertinent to note however, that no education system can rise above the level of its teachers (FRN, 2004). By implication, the quality of teacher education in chemistry determines, to a great extent, the quality of chemistry learning outcomes. There is paucity of researches in determining the learning outcomes for pre-service chemistry teachers using innovative inquiry approaches such as the MBI. This study will attempt to determine the effect of MBI on the achievement of pre-service chemistry teachers.

Concept of Achievement

Achievement connotes academic performance in school subject as symbolized by a score or mark on achievement test. According to Anene (2005), studentsô academic achievement is quantified by a measure of the studentsô academic standing in relation to those of other students of his age. It is the level of knowledge, skills or accomplishment in area of endeavors. Internationally, it is the comparison of the relative standing of countries in terms of their learning outcomes. For example, OECD (2010) in a study conducted by the program for international studentôs assessment (PISA) in 40 OECD countries (2006-2009) discovered a relatively static student achievement in science. Keeves (2009) in a related study reported that, in the second International Study of Science Achievement (1983 ï 1984), out of the twenty-three countries that participated, Nigeria came last and second to the last in mean science achievement for the 10 and 14 year old levels, respectively. In the same vein, Olatoye (2009) conducted a study that assessed the level of secondary school studentsô achievement in science in Lagos State, Nigeria. The findings revealed that studentsô achievement was generally poor. The overall percentage means score was 31.3%.Presently, the condition of science teaching and learning is very discouraging (Olatoye, 2009). This portends a gloomy future for the graduates under these studies. The situation gives rise to the consistent poor studentsô performance in science in public examination.

Similarly, Ogunsaju (2004) states that academic standard in all Nigerian higher education institutions (COEs inclusive) has fallen considerably below societal expectations. One of the cogent reasons responsible for this failure is mirrored in the fact that the quality of output of any operation is a function of the input that is processed. Consequently, the quality of output of primary and secondary school leavers depends, to a large extent, on the quality of teachers trained in the colleges of education (Adeyemi & Adeyemi, 2014). Besides the training factor, other causes have been identified and regarded as being responsible for the dwindling trend in studentsô achievement in science. In colleges of education and other institutions of higher learning, Antherson (2003), Araoye (2013), Bello and Aliyu (2013), Adeyemi and Adeyemi (2014), contend that studentsô achievement in teaching and learning is determined by teachersô attitude and enthusiasm, learning environment as well as studentsô attitude and background. In the same vein, Klentschy (2006), Akinsolu (2010), Avilla & Orleans (2013), Araoye (2013) and Okeke-Oti & Adaka (2012), found out that a strong relationship exists among high-quality instruction, teacher professional development and studentsô achievement. Excellent and effective teaching demands high-quality techniques/strategies and a host of other devices, not only to achieve cross critical outcomes, but because variety, itself is a desideratum (Van Wyk, 2010). Therefore, there is the need to focus on teachersô competency in respect to their pedagogical practices and mastery of subject content matter during pre-service training.

Despite the fact that efforts have been made by science educators to provide for varieties of instructional techniques that will ensure optimum achievement among students, studies have shown that science teachers have consistently stuck to lecture/expository methods of teaching as major strategy in their classrooms (Ibe and Nwosu, 2003; Ezeliora, 2009; Samba, et al., 2010). Consequently, students become passive listeners i.e. not given the opportunities to participate in learning activities. They contend that traditional methods encourage rote learning; students are unable to achieve much or retain their learning. It has been shown that traditional methods do not encourage learners to apply what they learn to new situation nor produce maximum result for the acquisition of skills. This they do, instead of adopting innovative activity-based techniques that engage students in hands-on and minds-on activities particularly those that employs the methods of inquiry (FRN, 2004). By implication, the teaching and learning of science in an ideal science classroom is expected to be carried out following the processes proposed and used by scientists (Isuogo-Abanihe et al. 2010). Though literature is replete with studies relating investigative teaching strategies with studentsô academic performance, there is paucity of studies on relative effectiveness of MBI in enhancing studentsô achievement in college chemistry. However, despite the importance of chemistry to mankind and the efforts of researchers to improve on its teaching and learning, the achievement of students in the subject remains low in Nigeria (Adesoji & Olatunbosun, 2008). This is a manifestation of a negative ripple effect throughout the education system which stems from the teacher preparation programs. Since improved teacher preparation will lead to greater teacher effectiveness and ultimately improved studentsô achievement (Okeke-Oti & Adaka, 2012) and there is paucity of research on studentsô learning outcomes at the pre-service level employing MBI, the need for this study becomes crucial.

Skills Acquisition

Learning outcomes in terms of cognitive and intellectual skills that are relevant with wider applicability which pre-service students should imbibe during training is the acquisitions of skills to enable them become useful members of the society (FRN, 2004). The type of curriculum designed, its quality, and the instructional delivery which accommodates the acquisition of skills is germane for manpower development. This implies that pre-service teacher programs must provide training in the acquisition of skills which in this study are the critical thinking and creativity among other 21st century skills. These skills, though implied in the NCE science curriculum as higher order thinking skills, problem solving skills, scientific skill/attitudes or analytical thinking, they are not well developed/addressed, hence the need to do so because of the millennium skill requirement.

We are living in a rapidly evolving, technology-saturated world precipitating numerous challenges on daily basis. Inherently, issues challenging the existence of humankind and general wellbeing such as automation, globalization, workplace change, policies increasing personal responsibility are evolving (Jerald, 2009). The statement poses a daunting task for school system to prepare students to deal with more rapid changes than ever before, for jobs that have not yet been created, to use technologies that have not yet been invented and to solve economic and social challenges that we do not yet know will arise (Organization for Economic Co-operation and Development, 2010). The greatest of these challenges is the increase of non-routine cognitive and non-routine manual jobs with corresponding disappearance of routine jobs (Baartman and Gravemeijer, 2011). This has necessitated a need to equip current and future Chemistry students (in particular) through an effective pre-service training, with the skills to address these needs/challenges of the 21st century (Ezema, 2011). These skills and competencies can best be taught in the context of the academic curriculum, not as a replacement for it or ñadd onò to it; in fact, cognitive research suggests that competencies like creativity, critical thinking and problem solving are highly dependent on deep content knowledge and cannot be taught in isolation (Silva, 2008). The circumstance situate rightly in the national educational goal statement which emphasizes ñthe acquisition of appropriate skills and the development of mental, physical and social abilities and competencies as equipment for the individual to live in and contribute to the development of the societyò (FRN, 2004, p. 3).

Skills represent a particular way of using innate fundamental capacity in relation to environmental demands, with human being and external situations together forming functional system (Adeyemo, 2009), the development of which essentially depends on instructional processes (Adeyemo, 2010). The 21st century is a world in which comfort with ideas and abstractions is the passport to good job, in which creativity and innovation are the key to good life (New Commission on the Skills of the American Workforce, 2006). It follows therefore, that the intellectual demand of the century requires more advanced skills. According to Silva (2008) and Jerald (2009) students in this millennium must have a mastery of broader and more sophisticated cognitive skills like critical thinking, creativity (innovation). Silva and Jerald further submit that for success both on the job and in their personal lives, students must also better learn how to *apply* what they learn in those subjects to deal with real world challenges, rather than simply ñreproduceò the information on tests. Critical thinking and creativity skills are tools for this application. This study intends to investigate the effect of MBI on the acquisition of the two skills.

Critical thinking skill

The American Philosophical Association according to James (2007) defined critical thinking as a purposeful, self-regulatory judgment which results in interpretation, analysis, evaluation and inference as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which judgment was based.. It employs a process of reflecting upon the meaning of statements, examining evidence and reasoning, and forming judgments about the facts. Information is gathered from observation, experience, reasoning, and/or communication and requires the thinker to use clarity, accuracy, precision, evidence, thoroughness and fairness (Hmelo-Silver & Barrows, 2006). James (2007) further submits that critical thinking involves the individualôs ability to identify central issues and assumptions in an argument, recognize important relationships, make correct inferences from data, deduce conclusions from information or data provided, interpret whether conclusions are warranted on the basis of the data given, and evaluate evidence or authority. The goal of critical thinking- which is in tandem with the goals of science teaching- according to Kalman (2008) is to enable students to become the maximally rational human beings that they are capable of being. The rationality involves the use of those skills or strategies that increase the probability of a desirable outcome. It describes thinking which is purposeful, reasoned and goal directed.

Critical thinking can be seen as having two components: 1) a set of information, belief generating and processing skills, and 2) the habit, based on intellectual commitment of using those skills to guide behavior (Critical thinking skills are important because they enable students to deal effectively with social, scientific, and practical problems (Shakirova, 2007). In a nutshell, students who are able to think critically are able to solve problems effectively. Merely having knowledge or information is not enough to be effective in the workplace (and in their personal lives), students must be able to solve problems to make effective decisions, they must be able to think critically (Peter, 2012; Weissberg, 2013). Although definitions differ, many researchers have defined or characterized critical thinking in terms of cognitive skills. Cognitive skills of analysis, interpretation, inference, explanation, evaluation and self regulation are at the heart of critical thinking (Facion, 2000).

Source: Insight Assessment (2013)

Figure 6: Components of Critical Thinking

A set of cognitive skills identified by Burris (2005) as necessary for effective critical thinking were the ability to:

DŽDistinguish between verifiable facts and value claims.

DŽDistinguish relevant from irrelevant information, claims, and reasons.

DŽDetermine factual accuracy of a statement.

DŽDetermine credibility of a source.

DŽIdentify ambiguous claims or arguments.

DŽIdentify unstated assumptions.

DŽDetect bias.

DŽIdentify logical inconsistencies in a line of reasoning.

DŽDetermine the strength of an argument or claim.

Researchers have linked critical thinking with higher-order thinking skills (HOTS) and used Bloomôs taxonomy of educational objectives as basis for this analysis (James, 2007; Peter, 2012). The first two levels of knowledge and comprehension form the lower-order thinking skills while the other four levels (application, analysis, synthesis and evaluation) form the elements of critical thinking skills. The same apply to the 2001 revised Bloom taxonomy in which remembering and understanding form the lower-order thinking skills while application, analysis, evaluation and creating form the higher-order thinking skills (Silva, 2008).These enable students develop an even broader set of in-demand competencies the ability to think critically about information, solve novel problems, communicate and collaborate, create new products and processes, and adapt to changeð will be at an even greater advantage in work and life (Baartman and Gravemeijer, 2011). According to Silva (2008), Jerald (2009) and Lay & Khoo (2013) students in this millennium must have a mastery of broader and more sophisticated skills like critical thinking and creativity. Although researchers agree with the cultivating of CT and creativity as one of the main purposes of higher education as it is necessary for students to become competent citizens in modern society (Haghparast, Nasaruddin & Abdullah, 2013), these skills are not well developed/addressed in school sciences, hence the need to do so because of the 21st century demand.

Critical thinking is a reflective and reasonable thinking ability which enable students to objectively analyze information, evaluate evidences and draw conclusions. It improves in students the quality of their thinking by skillfully analyzing, assessing and reconstruction of their thinking. The goal of critical thinking- which is in tandem with the goals of science teaching- according to Kalman (2008) is to enable students to become the maximally rational human beings that they are capable of being. The rationality involves the use of those skills or strategies that increase the probability of a desirable outcome. It describes thinking which is purposeful, reasoned and goal directed. Angeli and Valanides (2008) state that critical-thinking skills are necessary for active citizenship in any pluralistic and democratic society, where citizens are daily confronted with tremendous amounts of information and ill defined problems with real uncertainty as to how they can be best solved. Critical thinking enable students develop an even broader set of in-demand competenciesð the ability to think critically about information, solve novel problems, communicate and collaborate, create new products and processes and adapt to change ج which will be at an even greater advantage in work and life in the 21st century. (Baartman & Gravemeijer, 2011). Halpern (cited in Kalman, 2008) states that when we think critically, we are evaluating the outcomes of our thought processes i. e. how good a decision is or how well a problem has to be solved. Critical thinking also involves evaluating the thinking processï the reasoning that went into the conclusion weôve arrived at or the kinds of factors considered in making a decision. Research findings, though inconclusive, relate critical thinking with a number of instructional approaches. There was significant difference in Critical Thinking acquisition (CT) between traditional and group discussion (Garside, 1998) and constructivist learning environment enhances CT more than traditional learning environment (Tynjalas, 1998). Related studies revealed a significant difference on CT higher scores between dialogical and non-dialogical in Biology but the gain was at the expense of subject matter knowledge (Frijters, 2008). Also, a significant difference was reported between 3 approaches (general, infusion and immersion). Students in general approach out performed those in other two approaches on CT (Angeli and Valanides, 2008). Furthermore, it was established that students in Digital Game-Based Learning (DGBL) integrating High Order Thinking Skills (HOTS) outperformed those exposed to Technology enhanced learning (TEL) in terms of problem solving, academic achievement critical thinking and creativity (Yan, 2014). Other studies such as Myer and Dyer (2006), Heong, Yunos and Hassan (2011) discovered that achievement relates positively to CT skill acquisition at higher education and does not differ among male and female students. Ramos, Dolipas and Villamor (2013) further established how some levels of critical thinking (evaluation, analysis, inference and comparison) influenced studentsô performance across genders. However, most of the researches were foreign based but there is paucity of such researches employing the effect of MBI on acquisition of critical thinking and creativity skills in Nigerian environment.

Creative thinking (creativity)

Creativity as the power to use imagination in developing new and original ideas or products is a skill in need and indeed. It can be equated to a driving force that drives human behavior to shape their lives (Onu, 2006). With each generation, it is important for students to be skillfully prepared and professionally competent than their predecessors. However, coming into the twenty-first Century it is even more important for them to be creatively prepared to be able to go beyond the ideas of the present and deal with the complex social and environmental issues facing this world (Karpova, Marchetti & Barker, 2011; Hargrove, 2012).

Definitions of creativity have developed and evolved over several decades and have encompassed (a) concepts of the creative process or the mental routines that are operative in creating ideas, (b) the creative person when he or she demonstrates certain creative characteristics in personality, traits, attitudes, or behaviors, (c) the creative product or tangible object, and (d) the creative environment that fosters the creative person (Warr & Oô Neill as cited in Karpova, et al., 2011). Heinla (2006) posits that - divergent thinking as an ability to offer various unusual and original ideas- is a component of creative thinking and further defines it as a cognitive process providing new ideas, products, tools, or works of art. Hargrove (2012) in a related submission describes creative thinking as a meta-cognitive process of generating novel or useful associations that better solve a problem, produce a plan or result in pattern, structure, or product not clearly present before. In science, Koestler (cited in Taber, 2012) gave a more elaborate interpretation of creativity as the art of putting two and two together to make five. In other words, it consists in combining previously unrelated mental structures in such a way that you get more out of the emergent whole than you have put in. This derives from the fact that the whole is not merely the sum of its parts, but an expression of the relationship between its parts; and that each new synthesis leads to the emergence of new pattern of relations on higher levels of the mental hierarchy. While a conclusive definition of creativity is elusive, researches on creativity have outlined the components of creative thinking (e.g. Karpova, et al., 2011) to include fluency (ability to generate ideas), originality (the degree to which the produced ideas are unique or novel), elaboration (ability to build on existing ideas), and flexibility (ability to generate different classes of ideas). There are inconclusive results on how creativity correlates with achievement. Naderi, Abdullahi, Aizan, Sharir and Kumar (2010) and Abayomi (2014) found a positive correlation between the two construct while Olatoye, Akintunde and Yakassai (2010) and Adeola (2011) found no significant correlation between creativity and students achievement. The development of creativity in chemistry education in this millennium cannot be overemphasized. For obvious reason that, it will help in dealing with the complex social and environmental issues inherent with the rapid science and technological sophistications. This can only be possible through the creative application of chemistry principles Asiyi (cited in Giginna and Nweze, 2014). In teaching chemistry creatively, the teacher should allow students time to use their imagination and originality so as to develop divergent, convergent, associative and analytical thinking skills and attitudes needed to solve real life problems (Giginna and Nweze, 2014 and Colman, 2014).

Creative thinking has been linked to well-being and successful adaptation to the demands of daily life. Creative ideas - the ultimate source of all intellectual property are invaluable contributions one can make to an organization, society or humanity at large. In their meta-analysis of 70 studies, Scott, Leritz, and Mumford (2004) found that the most effective creativity training programs utilized a cognitive framework for developing creativity rather than a social, personality, or motivational framework. A social framework described the environment of the training; personality variables described the perception of freedom to explore inherent creative ability within the training. Its importance demands that further research should be carried out on its acquisition and factors influencing the acquisition. This study will contribute in finding out the extent of creative thinking acquisition.

Creativity and Critical thinking can be integrated to allow students develop original ideas supported by well reasoned, logical argument linked to dispositions such as the need to evaluate information, a tendency to approach problems uniquely appear to link the two types of thinking. Although a body of knowledge does not exist that states what instructional method is most effective in developing these skills, research suggests that these skills can be influenced by the instructional strategies utilized in the educational process (James, 2007). Example; Clyde (2010) states that instructional techniques that include high-level questioning, authentic investigation and small group learning are the most valuable for improving critical thinking skill. Scolt et al., (2004) submit that the most successful approach to developing creativity focused training content on the core practices of idea recognition and idea evaluation. Karpova et al., (2011) further submit that creativity and creativity training literature suggest that the ability to observe and see things from different perspectives, idea generation and idea evaluation are essential elements of successful creativity training. The chemistry curriculum at the NCE level has the potential to develop and utilize these skills. However, it is glaring that there is paucity in such attempts as to exploit the curriculum at this level to develop and utilize the combined skills.

However, there is a glaring citizen outcry against below average quality manpower production characterized by poverty of knowledge and skills from nationȏs educational system (Pollyn, 2014), substantiating the paucity of innovative instructional strategies in our traditional classrooms (Colman, 2014, 2014; Giginna & Nweze, 2014; Aniodoh and Eze, 2014). At the pre-service training level, student teachers are reduced to mere passive recipients of information and the lecturers have become one sided and teacher centered (Babalola & Jaiyeoba, 2008). As a result, pre-service teachers produced from such institutions in recent times are seriously limited in intellectual skills especially those of the critical thinking and creativity. This has produced ripple effect throughout the educational system and contributing to a perpetual state of underdevelopment (Ijaiya, et al, 2011). Several methods like cooperative learning, concept mapping, learning styles etc were employed by science teachers at different education levels, in various attempts to ameliorate the problems but yet the outcome is inconclusive and hence the need to try the MBI. Moreover, there is very little focused research in terms of what actually characterizes creative teaching in higher education (Craft, Hall & Costello, 2014). It is also clear that there is paucity in such attempts as to exploit the curriculum at this level to develop and utilize the combined skills especially employing the MBI in educating our trainee chemistry teachers to propel their curiosity and interest in chemistry for effective instructional delivery.

Moreover, the development of critical and creative thinking is valued as a broad educational goal, yet little appears to be done in tertiary courses to specifically develop critical and creative thought patterns in our trainee teachers. The study in effect, is an attempt in this regard to ignite studentsô interest and curiosity which according to Kuppuswammy (2007) serve as a pre-requisite for skills acquisition.

Concept of Interest

Interest involves a sense of commitment with and curiosity about something, for instance, students having interest in science subjects. Interest is content specific (Hagey, Baram-Tsabari, Ametler, Cakmakci, Lopes, Moreira and Pedrosa-de-jesus, 2012), i.e. it is always directed towards an object, activity, field of knowledge, or goal (Krapp and Prenzel 2011), hence the preference or will to engage in some types of activities rather than others (Hagey et al., 2012). It is the differential likelihood of investing energy in one set of stimuli rather than another and so fundamental in any individualôs choice of task (Csikszentmihalyi and Hermanson cited in Hagey et al., 2012). Interest-driven actions involve personally valued objects or activities; they are accompanied by positive emotions and are self-intentional (Krapp and Prenzel 2011). Interest is the motive which serves as important influence in producing both activities and attitudes that are favorable to learning. It was also identified as the intention used by individuals to approach success and avoid failure (Oh. Jia, Lorentson & LaBanca, 2012). Nworgu (2004) sees interest as the cause of certain actions, acting as a drive or motivation that propels people to act in certain ways either externally or internally. It is external when motivation addresses the act of a deed in order to achieve a separate result, such as receiving materialistic or social benefits or avoiding punishment, and internal when motivation addresses an act that has no aspiring result other than the enjoyment of performing this act. Hagey et al., posit that an interest may be regarded as highly specific types of attitude, when we are interested in a particular phenomenon or activity; we are favorably inclined to attend to it and give time to it. By implication, studentsô positive attitude towards science leads to a positive commitment to science that influences lifelong interest and learning in science. Interest plays a major role in any undertaking as it influences devotion to duties, fairness, firmness, honesty, endurance, and discipline.

Researches have shown that studentsô general interest in science was positively related to performance (Bybee and McCrae, 2011; Oh, et al., 2012; Oh and Dembo, 2010; Holstermann, Grube & Bogeholz, 2010), skills acquisition (Tyler-Wood, Knezek & Christiensen, 2010) and specifically in chemistry (Agogo, Odoh & Simon, 2014). However a mixed outcome was reported on gender and interest (Njoku, 2005, Nwachuku, 2008; Hagey et al., 2012,). In this regard, Hagey et al reported that boys in general are more interested in science than girls but in developing countries girls have the same (Alao & Abubakar, 2010) or even more positive attitude and interest in science than boys (Bello & Aliyu, 2013) in electrical electronics and physics respectively. Nworgu (2004) further discovered that girls developed higher interest because they developed greater enthusiasm and enjoyed the science lesson much more than the boys. Hagey et al. further state that while Biology is of great interest to girls, Physics and Technology prove significantly less interesting to girls than to boys; Chemistry is liked to a similar extent by both genders. But Anaekwe (1997) posits that sex has no influence on studentsô interest in chemistry. A major contradiction in this regard was reported by Fenshman (2007) that females were found to be high achievers than their male counterparts in physics but had very low interest in physics. However, beside the gender issues, Blunuz and Jerrett (2007) found out that method is also a function of interest development.

Developing interest in science is central to the main goals of the science literacy for support of scientific inquiry as well as to acquire and subsequently apply scientific and technological knowledge for personal, social and global benefit (Njoku, 2005, Nwachukwu, 2008; Bybee and McCrae, 2011). The vision for scientific literacy includes citizens who voluntarily study sciences guided by an internal motivation. Interest in sciences is not only a goal, but also a means to achieve science literacy, through its contribution to the learning experience and the learning process in formal and non-formal environments (OECD 2008). Adults and children alike (male and female) invest more in studying content that interests them. Interest connects students to content for a longer period of time. Thus, raising the level of studentsô interest is likely to affect their engagement and involvement, satisfaction, concentration, internal motivation, resulting memory and accomplishments (Nisan, 2006). It is therefore paramount that for a student to be competitive in the 21st century; the place of interest cannot be overemphasized (Tyler-Wood, et al., 2010). It is critical that students be provided with educational settings to nurture and optimize their interest such that gender equity is established. It is evident that there have been continued inconsistencies in the research findings in the area of interest in chemistry which serves a meditational role for academic achievement (Agogo, et al., 2014) and skill acquisition of both male and female students especially at the pre-service science teacher preparation level. Hence, there is therefore the need to investigate the effect of the MBI on the identified variables in NCE 11.

Concept of Gender

The term gender is often used to indicate the distinction between human beings on the basis of masculinity and feminity in relation to their expected roles (Eriba & Ande, 2006). Gender according to Santrock (2001) involves the biological dimension of being a female or male. This has been a crucial matter to the educationists. Varied multidimensional issues as they relate to the teaching and learning of science in this regard have been very contentious.

Providing quality education ensures that boys and girls are fully able to realize the benefits of education. Adapting an approach that takes into account the relationship and interaction between males and females, according to the United State Agency for International Development (USAID, 2008) will address four dimensions: equality of access; equality in the learning process; equality of educational outcomes and equality of external results.

Several researches on gender issues have been conducted in science education. Results of researches conducted by Adigwe (2012), Bybee and McCrae (2011), Eriba & Ande (2006), Hagey et al. (2012), Maigida (2013), Njoku, 2005, Nworgu (2004), Nwosu (2001), Riding, Grimleg, Dahraei, & Banner (2003) and Trumper (2006), showed measurable differences between girls and boys in achievement and interest in science related subjects (Eriba & Ande, 2006; Kezia, 2011). The disparity is even larger among the exceptionally gifted category of students than the average ability group (Preckel, Goetz, Pekrun & Kleine, 2008).Conversely, researches have also shown that females score higher than males in reading comprehension (Mau & Cheng, 2000). However, some studies showed that there is no significant difference in the performance of the boys and girls in the learning of Sciences (Keziah, 2011; Kundu & Totoo, 2007)

A wide range of factors are responsible for the observed disparity. According to Nwosu (2105) and Eze (2007), sex-role stereotyping or gender stereotyping appears to be the most predominant and perhaps the source of all other causes of gender difference in science, technology and mathematics education. Francis (2000) submits that Boys tend to be noisier, more physically active, and more easily distracted than are girls. Studies also find that masculine stereotypes portray boys as appeasing competitive, active, aggressive, and dominating, while girls are viewed as conciliatory and cooperative (Francis 2000). This position was further supported by Yang (2015) that female students perceived more to task orientation and cooperation while male perceived more in investigation and involvement.

Other scholars argue that stereotypical gender identities perpetuate the belief that girls have to work hard to learn in school, whereas boys are naturally gifted and that boys do indeed benefit indirectly from a stronger academic climate (Quenzel & Hurrelmann, 2010). Student too, view sciences as being male domain and success in the sciences as masculine imperative (Velayuthans, Aldrudge & Fraser, 2012). Despite the transformation of gender relations even in modern societies, stereotypical gender identities continue to shape orientations toward studentsô academic success and produce behaviors that reinforce the inherent identities while potentially affecting their achievement, skills acquisition and interest. This is inimical to the fact that sustainable development is participatory and involves equity (Nwosu, 2015) as enshrined in the United Nationsô MDGs initiatives and UNESCO Education for All (EFA) objective of achieving gender equality by 2015. Similarly, it contradicts the intent of the National policy on Education (FRN, 2004) that every Nigerian child shall have a right to equal opportunities, irrespective of any real or imagined disabilities, each according to his or her ability. Nevertheless, literature is replete with statistics that gender parity could be improved in science classes that emphasize hands-on/activity based instructional approaches (e.g. Nwosu, 2015; Gok & Silay, 2010; Nworgu, 2004; Okeke, 2001). Lee (2003) proposed utilizing inquiry methods in this regard. Lee contends that through inquiry, females and males are provided with opportunities to explore and support their own ideas, within the constraints of the curriculum. Males can benefit from interactions with the thought processes of females, while females can benefit from the confidence of the males. While researches such as Okeke (2001), Nworgu (2004) and Gok & Silay (2010) utilized methods such as cooperative learning, inquiry etc, there is the need to try MBI to ascertain its impact on achievement, skill acquisition and interest of both male and female pre-service chemistry teachers.

Theoretical Framework

Learning theories if applied well explain and predict behavior. Accordingly, theory opens our eyes to other possibilities and ways of seeing the world. It is however perceived as simply a postulation requiring explanation in order to make meaning (Olaitan, Ali, Eyo and Sowande, 2000). Chauhan (1989) on the other hand saw theory as a provisional explanatory proposition or set of propositions concerning some natural phenomena and consisting symbolic representation of:

1. The observed relationship among independent variables,
2. The mechanism or structures presumed to underlie such relationship, or
3. Inferred relationships and underlying mechanisms intended to account for observed data in the absence of any direct empirical manifestations of the relationships.

Based on these conditions, the theoretical framework which underlines this study is based on Constructivism rooted from Cognitive learning theories.

Constructivist Theory of Learning

Constructivism is basically a theory based on observation and scientific study about how people learn or how they come about real knowledge of the world. It is rooted from biology, epistemology, philosophy and psychology in a bid to determine the pattern or process of knowledge generation which Piaget (1970) referred to as ñobjectivityò. This conceptualization was premised on Piagetôs notion that the entire purpose of intellectual growth as one of coming to know reality more objectively through developing increasingly decentered - and hence more objective ï perception of reality. Piaget maintained that ñthe structure of the mind is the source of our understanding of the worldò. Piagetôs theory is developmental in orientation, suggesting that we begin by developing operation to act on our world and eventually by the stage of formal operation we have acquired abstract, logico ï mathematical reasoning capacities that allow us to detach ourselves from the object world so that we can reason about it in strictly logical terms. Fosnot (cited in OôLouphlin, 1992) one of the advocate of this theoretical triumph further defined it as a model that emphasizes that learners need to be actively involved, to reflect on their learning and make inferences and to experience cognitive conflict. In essence, it is a model which places educational consumer needs rather than supplier needs far more important (Kim, 2005). In a similar effort, Sigel (cited in OôLouphlin, 1992) views that constructivism is embodied in the mental interpretation of extreme experience: ñto the constructivist, the individualôs behavior is a function of how he organizes experiences and how he places his own imprint on these experiencesò. This interpretation roots from his earlier work on constructivism and offers its definition as which refers to that process of constructing, in effect, creating a concept which serve as a guideline against which objects can be gauged. Constructivists believe that the knowledge is constructed by the individual learners and ñis embodied in human experience, perceptions, imaginations, and mental and social constructionsò (Jonassen, Cernusca, & Ionas, 2007). And to construct knowledge, learners need to solve problems, to be active, and to take actions to accomplish goals (Chan, 2010). During the course of interactions with objects, people or events, the individual constructs a reality of them. This mental construction then guides subsequent actions with the object or events. Humans are perceivers and interpreters who construct their own reality through engaging in those mental activities...thinking is grounded in perception of physical and social experiences, which can only be comprehended by the mind. What the mind produces are mental models that explain to the knower what he or she has perceived. We all conceive of the external reality somewhat differently, based on our unique set of experiences with the world and our beliefs about them.

Constructivism holds that people construct their own understanding and knowledge of the world, through experiencing things and reflecting on those experiences. When we encounter something new, we have to reconcile it with our previous ideas and experience, may be changing what we believe, or may be discarding the new information as irrelevant. As individuals experience something new, they filter this information through mental structures (schemata) that incorporate prior knowledge, beliefs and preconceptions to make sense of the information (Prince & Felder, 2006). In any case, we are active creators of our own knowledge. To do this, we must ask questions, explore, and assess what we know depicting the process of scientific inquiry. This process according to Yager (1991) involves inviting ideas, exploring, proposing explanations and solutions and taking action forming the cornerstone of the MBI. Learners in this circumstance are considered to be active, self-directed, creative and innovative, thus, learning need to be conceived of as something a leaner does, not as something that is done to a learner, ultimately, the learnerȏs ownership of ideas is established (Nworgu, 1997). To summarize, Jonassen et al. (2007) state that, because of the emergence of constructivism, the instructional systems field has been shifted from instructional communication to practice-based learning.

The common thread that runs across the interpretation of what ought to be constructivism within the theoretical assumption as proposed by developmental constructivists such as Jonassen and others are as follows (Kim, 1993);

Dž knowledge is constructed out of sensual and perceptive experiences of the learner in which learning is internalize through the learner's constructive process in nature.

Dž knowledge is the personal understanding of the outside world through personal experience rather than the experiences of others.

Dž this internally represented knowledge becomes the basis of other structures of knowledge and a new cognitive structure of the person.

- Dž learning is an active process of developing meaning based on individual personal experiences. In other words, learning is a developing process by the learner's understanding of the real world.
- Dž it comes from the premise that personal understandings result in various perspectives. The perspectives constructed within the individual cognitive conceptual structure attempt to share all possible various perspectives.
- Dž learning creates knowledge in the context of a situational reality. Knowledge is the understanding of meaning through situational contexts, not objective reality.

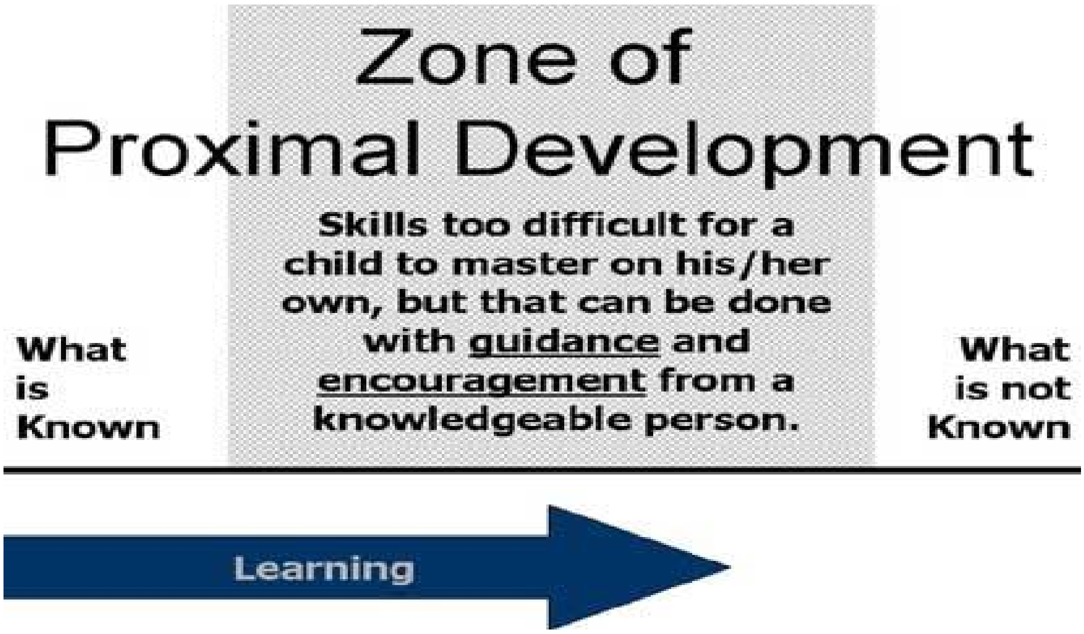
In contrast to cognitive constructivism, social constructivists place more emphasis on the social context of learning. Dewey according to Inman (2011) argued in his Pedagogic Creed that real learning stems from the stimulation of the childȏs powers by the demands of the social situations in which he finds himself. So, Dewey argued that education and learning are social and interactive processes and that the school as a social institution provides an environment in which social reforms can and should take place. He sees classroom as a social context where students can take part in manipulating materials and thus form a community of learners who construct their knowledge together. He also emphasize that students thrive in an environment where they are allowed to interact with the curriculum. Dewey believed that the teacher is a partner in the learning process whose guidance and support help learners to construct their learning and independently create meaning within his/her experience within the subject matter. The obvious implication of to this study is students in MBI must be engaged in meaningful activities in a social and interactive processes/context in which pre-service teachers will be actively involved in manipulating materials that culminate into model generation. The teacherȏs role remains a facilitator in the learning process whose guidance and support help learners to construct their learning and independently create meaning within their modeling experiences.

Moreover, Vygotsky as the main proponent of social constructivism maintains that cultural history, social context and language play an important role in the pattern and rate of development of children. Vygotskyǿs theories present knowledge as a societal product (Johnson and Johnson, 1999). Vygotsky (1978) maintained that human development (e.g. social characteristics, communication styles, personality, cognitive ability, linguistic styles and academic background) originate and develop out of social and cultural interaction. As knowledge is situated in the culture and within a historical context, meaning is the result of participation in social activities. This proposition tandems the MBI context and since skill acquisition is usually a property of a social group (Colman, 2014), it requires interactions among students within their specific groups or cultural settings. In MBI, science students are exposed to group problem solving activities that requires collaborative and cooperative problem solving efforts in a social supportive environment where they can freely express themselves, ask questions and resolve conflicts of opinions. In such environment, students gain conceptual understanding of scientific ideas and generate their ideas (mental models) through interactive engagement with the curricular materials, with each other and their teacher as a facilitator.

Although physical objects can be used as tools for learning (Hill, 1997), Vygotsky argued that social tools such as language and other sign systems play the most important role on development and learning. Erduran (1998) states that philosophers and psychologists recognize that the acquisition and employment of models are close associated with the learning and use of language too. In MBI student are expected to articulate, investigate and brainstorm on certain concepts through with they can verify, generate present and argue out their group model. The power of this argumentation depends squarely on the use of language.

Vygotskyǿs most widely applied idea is that of a Zone of Proximal Development (ZPD). Vygotsky (1978) defines the ZPD as the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance teacher or the collaboration with more capable peers. Invariably, ZPD is between what a child can do unaided by a more knowledgeable person (teacher, adult, more capable peers among others) and what he/she can do under the guidance of a more knowledgeable person. Jacobs, Lee & Ng (1997) in a simplified form state that ZPD indicates what a student can do today only with peer support, they can do tomorrow on their own as a result of having enjoyed that support before previously. Vygotsky (1978) sees the ZPD as the area where the most sensitive instruction or guidance should be given - allowing the children to develop skills they will then use on their own - developing higher mental functions. Bruner (1996) uses scaffolding as an umbrella term to describe a range of actions and strategies that an adult uses to help childrenꞌs learning efforts. The form of these supportive interventions may vary but all aim to help the learners gain goals that would be beyond them without the support provided. With gradual withdrawal of the scaffold, the learner becomes progressively independent. Vygotsky also views interaction with peers as an effective way of developing skills and strategies. He suggests that teachers use collaborative learning exercises where less competent children develop with help from more skilful peers - within the zone of proximal development. In MBI one of the prerequisite for meaningful learning is the acquisition of cognitive tool or prior information called scaffold (De Jong, 2006) used as a platform or support (from the teacher or more capable peers) for the learnersꞌ process of the inquiry (Bolton, Brennan & Terry, 2009). To allow for this in MBI, students of differing learning capabilities are grouped together and collaborate to accomplish given tasks. The more knowledgeable students support their peers in all the steps of modeling. The influence of such collaborative activity as described by Vygotsky on learning is that as functions are first formed in the collective in the form of relations among children it will ultimately become mental functions for the individual

The following figure gives a conceptualization of ZPD. With the MBI in the ZPD, the boundaries of the zone shift to the right.



Source: Saul, M. (2007)

Figure 7: Zone of Proximal Development

Damon (1984) proposed a theoretical model by integrating Piagetǿs and Vygotskyǿs perspectives on peer collaboration. This model suggests that through group activities/discussions that occur during collaborative arrangement, students could achieve the following:

Dž They expose inadequate or inappropriate reasoning, which result in disequilibrium that can lead to better understanding;

Dž They motivate individuals to abandon misconceptions and search for more powerful concepts.

Dž They provide a forum that encourages a critical thinking.

Dž They lead to constructive controversy, which focuses studentǿs thinking and increases the use of higher order cognitive process.

Dž They encourage students to vocalize ideas, which inevitably improve their performance.

Thus, according to the constructivist theory of learning (Sponken-Smith, 2008) which aligns with the tenets of MBI, effective teaching must offer experiences that:

- build on what students already know so they can make connections to their existing knowledge structures
- encourage students to become active, self-directed learners
- provide authentic learning opportunities
- involve students working together in small groups (i.e. in collaborative or cooperative learning).

Rather than being the ñsage on the stageò in a transmission mode of teaching, constructivist teachers should act as a ñguides on the sideò, providing opportunities to test the adequacy of studentsô current understandings (Hoover, 1996). The important role of the teacher is emphasized as follows - in short, in some way or another, I propose that the children solve the problem with my assistance (Vygotsky, 1978). This suggests that although social learning groups provide the medium for students to generate thought and construct understanding, learning is also highly dependent on the teachersô ability to scaffold students during these constructive activities (Raymond, 2000). In this context, the teacher provides support for students to develop internal cognitive representations. In MBI supporting students in form of scaffolding (teacher and the more knowledgeable peer) is central and through the conversations students are given the opportunity to collaboratively develop internal cognitive representations during the physical and mental modeling exercises. Meaningful learning activities built on prior knowledge, motivate students and foster their interest in an effort to use their own cognitive process that could lead to their academic achievement and skills acquisition.

Review of Related Empirical Researches

This section aims at highlighting salient features of some empirical studies whose findings have relevance to this study. The review of related literature on this section is arranged under inquiry learning techniques and achievement in science education, critical and creative thinking in science education, interest and gender issues in science education.

Inquiry learning techniques and achievement in Science education

Adeyemi and Adeyemi (2014) investigated personal factors as predictors of studentsô academic achievement in science in south western Nigeria. The study used ex post facto design using survey design model. The sample of the study consisted of 1100 (level 200 and 300) NCE students in Federal, State and Private Colleges of education in south western Nigeria using stratified random sampling. The study found that a number personal factors like studentsô interest, home environment, parental support and study habit were significant predictors of studentsô academic achievement while other factors like studentsô perception of course and self concept were not found to be significant predictors of studentsô academic achievement. The study though carried out at NCE level did not consider the instructional delivery as a factor in determining studentsô achievement especially as it involves the prospective teachers. However, this study will empirically investigate achievement in relation to MBI.

Araoye (2013) conducted a study on redressing studentsô motivation and academic achievement in Biology education at the Federal College of Education (Special), Oyoin which seventy Biology students were sampled for the research. A structured questionnaire was developed and used to generate needed responses. The data collected were analyzed using chi-square statistical method and results discussed. The findings revealed that factors like good students background in Biology, high teacher-student ratio, positive attitude of the students and good teacher methodology promote high achievement in Biology and vice versa.

The study investigated issues central to studentsô achievement especially the method, but constrained to employ two investigative instructional strategies. The current study will adopt Conventional inquiry and more innovative inquiry (MBI) on studentsô achievement.

Giginna, and Nweze (2014) conducted a study on the effect of e-learning on studentsô achievement in acids, bases and salt. The quasi-experimental design was adopted. Chemistry Achievement Test was used as the instrument for data collection. Mean, standard deviation and ANCOVA were used for data analysis. The findings showed that students taught with e-learning achieved higher than those taught with traditional method. The study centered only on achievement comparing non investigative approaches in an e-learning. This study will use a more activity oriented approaches in which students will physically manipulate resources in model construction to determine achievement at pre-service teacher training level.

Agboola & Oloyede (2007) carried out a research studies on the effect of project, inquiry and lecture-demonstration teaching methods on senior secondary studentôs achievement in separation of mixtures practical test in Osun state. The research instrument used was Chemistry Achievement Test (CAT). The data was analyzed using t-test analysis, one way analysis, analysis of variance (ANOVA) and Scheffe post-hoc analysis. The results of ANOVA showed a significant difference between the groups. Students taught with project methods performed better in the chemistry Achievement Test (CAT) than the students taught with lecture demonstration method, while those students taught with lecture-demonstration method performed better than those taught with inquiry method. Students taught with project method performed better than students taught with inquiry method. The study concluded that the project method enhanced better performance in chemistry practical better than either inquiry or lecture-demonstration method. The study was limited to the use of investigative methods with traditional approach while the current study will employ a more innovative form of inquiry to determine its effect on pre-service chemistry teachersô achievement.

Lona (2000) carried out a study on effects of inquiry based approach instructional method on studentés achievement in learning some selected physics concepts. His primary variable of interest was method while the secondary variables were gender and prior level of achievement and the dependent variable was achievement. The initial samples of subjects were 165 but only 141 were involved in the analysis. Physics achievement test A and B in addition to two teaching schedules A and B constituted the instruments used in the study. The study involved the use of Campbell and Stanleyés (1996) pretest-posttest control group designs. A 2x2x2 analysis of the data was carried. It was concluded that there was a significant difference between the score of the experimental group taught with the traditional method and the control group taught with the inquiry method. The result of the study indicated that the mean scores of the experimental group on the post-test were significantly higher than the means score of the control group. It was also discovered that the method bridge the gap between boys and girls in the achievement test. The study has bearing on present study considering the variables. This study may provide critical outcomes especially in the extent that gender difference may be minimized by the incorporation of modeling in the inquiry process. This present study will therefore; tests the effect of MBI on the academic achievement and interest of NCE 11 students and also find out if the method could bridge the gap between boys and girls.

Arts (2008) carried out a research on the effect of Traditional and Guided Inquiry Instructions on the achievement of students in Physics laboratory. The study focuses on the adaptation of the undergraduate physics laboratory from a traditional cookbook and laboratory report setting to one of a guided-inquiry setting. This research study includes the analysis of data gathered from 38 undergraduate students enrolled in General Physics at Pikeville College. Twenty two (22) of the student participated in a traditional laboratory setting that consisted of cookbook laboratories and at-home write-ups; this group is considered the control group. The remaining sixteen students received guided inquiry instruction adapted from the same laboratories completed by the control group. Quantitative data for the study was obtained by administering Identical Laboratory Practical Examinations (ILPE) to each group. Results indicated that the inquiry group showed significant gains in their understanding of the physics principles studied over the control group. The present study will hopefully produce more positive result when the traditional inquiry incorporates the use of model.

Scallon and Stephen, (2006) carried out a research on comparative study of Authentic research versus Guided Inquiry in factors affecting Middle School students abilities to know and do Genetics. This exploratory mixed methods study addressed the types of gains students made when engaged in one of two forms of inquiry. Gains were measured on three levels: Conceptual understanding, the process of scientific investigation, and use of practical reasoning skills. One hundred-thirty (138) 8^{th} grade students from a rural public school in East Texas participated in this study. Classes of students were randomly assigned to one of the two treatment groups: guided inquiry or authentic student research learning. Non parametric statistical analysis and constant comparative qualitative analysis were used to triangulate pre-tests and post-tests, studentsô journals, and studentsô drawings to address the research questions. Findings support greater gains in conceptual understanding of domain specific content in a highly scaffold guided inquiry. Further authentic scientific research learning was more effective for developing understanding of scientific investigation as a process and application of knowledge through practical reasoning skills. However, the current study compares conventional inquiry and MBI on studentsô achievement through physical and mental modeling for holistic development of meta-cognitive knowledge.

Sadeh and Zion (2009) carried out a research on the development of dynamic inquiry performances within an open inquiry setting and guided inquiry setting on high school biology students in Ramatb Gan, Israel. This study compared the influence of open versus guided inquiry learning approaches on dynamic inquiry performances among high-school biology students. The data sources included interviews, studentsô inquiry summary papers, logbooks, and reflections. A quantitative content analysis of the two groups, using a dynamic inquiry performances index, revealed that open inquiry students used significantly higher levels of performances in the criteria changes during inquiryò and ñprocedural understanding.ò However, the studyĝs results indicated no significant differences in the criteria ñlearning as a processò and ñaffective points of view. The study utilized open versus guided inquiry process to determine studentsô inquiry process performance not academic achievement, while the current study will adopt guided inquiry process in MBI to determine pre-service chemistry teachersô academic achievement.

Critical and Creative thinking skills in Science Education

Nwagbo and Chukelu (2011) investigated the effects of biology practical activities on secondary school studentsô process skill acquisition in Abuja Municipal Area Council. The design of the study was quasi experimental; specifically the Pre-test, Post-test, Non Equivalent Control Group Design. The sample comprise of 111 (SS 1) biology students randomly drawn from two co-educational schools were used for the study. Two research questions and two null hypotheses guided the study. An instrument known as Science Process Skill Acquisition Test (SPSAT) was used for data collection. The data collected were analyzed using mean, standard deviation and Analysis of covariance (ANCOVA) at 0.05 level of significance. The results revealed that practical activity method was more effective in fostering studentsô acquisition of science process skills than the lecture method. There was no interaction between method and gender on studentsô process skill acquisition. Skill acquisition is central to both studies, nevertheless, the current study will determine the effect of MBI on interest, critical and creative thinking skills acquisition on pre-service chemistry teachers.

Yager and Akcay (2008) conducted a study to determine whether Science, Technology, and Society (STS) learning increases student concept mastery, general science achievement, use of concepts in new situations, and attitudes toward science in middle school classrooms. The study involved two teachers and fifty-two (52) students in grades 6 through 8. Two sections of middle school science were taught by two longtime teachers where one used an STS approach and the other retained a typical use of the textbook as a class organizer. Each teacher administered the same pre- and post-assessments. Major findings indicated that middle school students experiencing the STS format with constructivist teaching practices; (1) learned basic concepts as well as students who studied them directly from the textbook, (2) achieved as much general concept mastery as students who studied in a textbook dominated way (4) developed more positive attitudes about science, (3) applied science concepts in new situations better than students who studied science in a more traditional way (5) exhibited creativity skills that were more individual and occurred more often, and (6) learned and used science at home and in the community more than students in the typical textbook dominated section. The STS rooted from constructivism, has been a needed reform in Science Education just like the MBI. However, the current study will determine the efficacy of MBI not only on achievement and skills acquisition, but also prospective teachersô interest.

Myer and Dyer (2006) conducted a study to determine the influence of student learning style on critical thinking skill. The target population for this ex post facto study was 135 students enrolled in a college of agriculture and life sciences leadership development course at the University of Florida. Results showed that no critical thinking skill differences existed between male and female students in the study. Students with deeply embedded

Abstract Sequential learning style preferences exhibited significantly higher critical thinking skill scores. No differences in critical thinking ability existed between students of other learning styles. These findings have implications for faculty with teaching appointments in colleges of agriculture. If Abstract Sequential learners are inherently adept at thinking critically, teachers may not need to focus as intently on teaching strategies that address this learning style. By contrast, however, Concrete Sequential, Abstract Random, and Concrete Random learners may need additional attention through instructional methods and techniques that enhance the critical thinking skills of these learners. The study adopted students learning style on achievement and critical thinking skills, the current will however adopt MBI to determine its effect on not only critical thinking skill but also creativity and interest of college pre-service teachers.

Heong, Yunos and Hassan (2011) conducted a study to identify the perception of the level of Marzano Higher Order Thinking Skills among technical education students in Faculty of Technical Education (FPTek), Universiti Tun Hussein Onn Malaysia. A total of 158 students of FPTek were randomly selected as sample. A set of adapted questionnaire from Marzano Rubrics for Specific Task or Situations (1993) was used as research instrument. The data were analyzed using Statistical Package for Social Science (SPSS) software. The findings indicated that students perceived they have moderate level for investigation, experimental inquiry and invention. However, decision making and problem solving are at low level. The Eta analysis indicates that there is a very low positive relationship between the level of Marzano Higher Order Thinking Skills and gender, academic result as well as socio economic status. Besides that, the findings also show that there is no statistically significant difference in gender, academic result and socio economic status on the level of Marzano Higher Order Thinking Skills. However, there is significant difference in socio economic status on the level of decision making. These results have implication on the current study as it relates to critical thinking. However, this study will consider creativity and interest using MBI.

Ramos, Dolipas and Villamor (2013) conducted a study to determine the relationship between higher order thinking skills (HOTS) of students and the academic performance in physics. The research was conducted at Benguet State University during the school year 2010-2011 and respondents were students enrolled in Physics. Results show that 49.5% of female students have average HOTS level on analysis while 54.4% of male students have below average level. On comparison, almost 50% of both male and female students have below average level while more than half of male and female students have average level on inference. Almost half of male students and female students have average level of HOTS on evaluation. Male and female students have similar level of HOTS on all four areas. Moreover the HOTS level on analysis, comparison and evaluation significantly influence the physics performance of male students while the HOTS level on analysis, inference and evaluation significantly influence the physics performance of female students. The HOTS which signifies critical thinking skill and its levels (inference, evaluation etc) and achievement form part of the scope of the current study but incorporates creativity and interest of chemistry students at college level.

Papaevripidou, Constantinou and Zacharia (2007) conducted a study aimed at fostering scientific modeling skills and enhancing conceptual understanding among fifth graders through the use of Stage cast Creator. The sample comprised of 16 fifth graders (8 boys and 8 girls) who were randomly selected and assigned in groups of four. Paper-and-pencil tests were used both before and after the study to evaluate studentsô modeling skills and understanding of concepts related to ecosystems. The data analysis followed two ways, first, open ended questions were analyzed using phenomenography and responses subsequently coded and transformed for analysis of MANCOVA, repeated measures, to test whether there were significant differences in the responses prior to and after the instruction. The results indicated the importance of the synergy of the studyôs goals: to learn about marine ecosystems and develop modeling skills. They found significant differences between studentsô pre- and posttest scores, suggesting that their approach facilitated the development of both modeling skills and enhanced conceptual understanding of marine ecosystems of fifth graders. Since critical thinking and creativity are essential in understanding of all systems, this study will find out the extent of MBI in such skill acquisition.

Nuangchalerm and Thammasena (2009) conducted a study to (i) investigate effective teaching criterion through inquiry-based teaching at 80/80, (ii) find out effectiveness index of inquiry-based teaching, (iii) compare analytical thinking between before and after students had learned by inquiry-based learning activities, and (iv) study learning satisfaction of second grade students after they had learned through inquiry method. Participants of the study were 10 second grade students, sampled by purposive sampling technique. Research instruments comprised of 8-lesson plan, 20-item achievement test, 20-item analytical thinking test, and 15-item questionnaire on learning satisfaction. Data were gathered and analyzed by Wilcoxon Matched Pairs Singedï Ranks Test. They concluded that inquiry-based learning activities promoted students in terms of both cognitive, analytical thinking, and learning satisfaction. This reflects the intent of the present study in the use of inquiry based approach to determine studentsô achievement and skill development. The current study may probably unveil more opportunities to students when modeling is incorporated in the inquiry processes.

Gyuse, Achor and Chianson (2015) examined how creative secondary schools are. The study surveyed 300 purposively selected junior and senior secondary school students in 10 schools in Makurdi. A 28 items questionnaire built on the version of the measuring questionnaire by Torrance was used as the instrument for data collection. Percentage mean, bar graph, independent t-test and ANCOVA were used to analyze the data. The findings among others unveil no significant mean difference in creativity level among JS1. JS3 and SS3 and there was no significant difference between mean creativity level of male and female students. The implication of these findings to current study, though employed survey, is determination of the level of creativity among students. However this study will modestly attempt to investigate the acquisition of creative skills using MBI among pre-service teachers.

Maigida (2013) conducted a study to determine the effect of cognitive apprenticeship instructional technique (CAITs) on studentsô achievement, skill performance and retention in automobile mechanics. The population of the study was 167 technical college (TC) automobile mechanic students out of which 144 students were sampled through simple random sampling. The instruments for data collection in the study were Automobile Mechanic Achievement Retention Test (AMART) and Automobile Mechanic Skill Performance Test (AMSPT). Mean and standard deviation were used to answer the research questions while ANCOVA was used to answer the research hypotheses at .05 level of probability. Students taught using CAITs obtained a higher mean achievement, retention and skill performance scores than their counterparts taught using the conventional methods and there was significant difference between the effect of gender (male and female) on studentsô achievement in automobile mechanics. These findings have a direct relevance to present study because CAITs and MBI root from constructivism and the variables are almost similar but the current study will focus on cognitive skills (creativity & critical thinking) instead of motor skills.

Abayomi (2014) conducted a study on the effect of learning-by-doing on SSS studentsô achievement in vocational agriculture and level of creativity. The quasi-experimental design used 88 SS 3 students (61 males and 21 females) with 42 students in learning-by-doing group and 46 students in conventional method group. The instruments used were the vocational agriculture achievement test (VAAT) and Nicholas Host Creativity test

(NHCT). The t-test was used to analyze the data. Findings from the study revealed that there is a significant difference in achievement scores between the experimental and control group. The female students showed better improvement in creativity than their male counterpart. The findings of the study have direct implication to the present study, but while the study used conventional method versus learning by doing, the current study will utilize the effects of two investigative approaches (CI & MBI) not only on studentsô creativity but also on their critical thinking skills acquisition.

AngeliandValanides (2008) conducted a study on Instructional effects on critical thinking: Performance on ill-defined issues. In the study, undergraduate students in dyads (N =72) were randomly and equally assigned to four groups, namely three teaching groups (General, Infusion, and Immersion) and the control group. Students were initially administered the California Critical Thinking Skills Test (CCTST). After instruction, each dyadôs critical-thinking performance on an ill-defined problem was tested. A one-way ANCOVA, with the mean CCTST score of each dyad as covariate, indicated that the covariate and the teaching method were significant. Post hoc comparisons showed that the Infusion and the Immersion groups outperformed only the control group. Other quantitative and qualitative analyses revealed that students assigned to the different teaching groups exhibited diverse understandings of critical thinking. The findings of this study have relevance to the current one in the aspect of problem solving situation which requires students to use higher order thinking skills, however MBI will be adopted in the current study to investigate its effect on the acquisition of critical thinking (not the understanding of it) and creativity.

Karpova, Marcketti and Barker (2011) conducted a study to understand how student (N = 114) creative thinking could be increased in a university classroom. Creativity exercises that can be incorporated in various courses were developed. To evaluate effectiveness of the training, figural format of the Torrance Test of Creative Thinking (TTCT) was used to assess student creative thinking before and after completion of the exercises. The study employed repeated measures factorial design which adopt general linear model (GLM) repeated measures, which provided analysis of variance when the same measurement was made twice on each participant. The results of the GLM repeated measures analysis of variance revealed that the creativity exercises had a significant influence on the Creativity index. Creative thinking, which was operationalized as the composite Creativity Index measured by the TTCT, was significantly higher for the total group of participants after completion of the creativity exercises than before the training. Individual class analyses showed that students in four of the five participating classes had significantly higher creative thinking after completion of the exercises. The study demonstrates that by incorporating creativity exercises into existing courses, instructors can help students develop creative thinking ð a critical aspect of oneôs professional development. The relevance of this finding to this study is glaring with regards to the level, the type of skill and the reform intent but differs from the current study by the adoption of MBI in which avails students with limitless exercises not only in creativity but also critical thinking through physical and mental modeling.

Panasam and Nuangchalem (2010) conducted a study to compare learning achievement, science process skills and analytical thinking of fifth grade students who learned by using organization of project-based and inquiry-based learning activities. The sample used in the study consisted of 88 fifth grade students, 2 selected classrooms at Muang Nakhon Ratchasima School, under the Office of Nakhon Ratchasima Educational Service Area Zone 1 in the first semester of the academic year 2008, obtained cluster random sampling technique. The research instruments used in the study were 30-item 4-choice science learning achievement test with discriminating powers ranging 0.28-0.46 and a reliability of 0.86; a 20-item 4-choice science process skill test with difficulties (P) ranging

0.36-0.68, discriminating powers ranging 0.38-0.72 and a reliability of 0.82 and a 20-item 4-choice analytical thinking test with difficulties (P) ranging 0.44-0.67, discriminating powers ranging 0.32-0.81 and a reliability 0.76. Hostelling T2 was employed for testing hypotheses. In conclusion, the plans for organization of project-based and inquiry-based learning activities were appropriately efficient and effective. The students in 2 groups did not show different learning achievement, science process skills and analytical thinking. Therefore, science teachers could implement both of these teaching methods in organization of activities as appropriate for learners to achieve in the future. This study may probably unravel the mystery between the two possibly reflecting the upgrading of the inquiry methods used through MBI not only on science process skills, critical thinking but also creativity.

In a related study, Okoronka (2009) investigated the comparative effect of analogy, problem solving and concept mapping model based instructional strategies on studentsô achievement in Physics. These strategies were crossed with two levels of cognitive styles and three levels of quantitative abilities which served as moderator variables. A 4x2 x3 pretest, post test, control group, quasi-experimental design was employed. Data were collected using Cognitive Style Test (CST), Qualitative Ability Test (QAT) and the Achievement Test in Physics (ATP). A total of 243 SS 11 students from 8 schools in Lagos took part in the study. Data were analyzed using the analysis of variance (ANOVA), multiple classification analysis (MCA) and Scheffe Post Hoc Analysis (SPHA). The result showed significant main effect of treatment on achievement and cognitive style. The most effective treatment condition was the problem solving strategy. Field independent students achieved significantly higher than their field dependent counterparts. These results have implications for improving instructional delivery, the influence of cognitive style on studentsô achievement as well as teaching difficult concepts in Physics and by extension, has relevance to the present study as it involve divergent thinking (creativity). However, the present study will also consider the acquisition of critical thinking using MBI with gender as the moderating variable instead of cognitive styles.

Yang (2014) conducted a study using Blended approach -Digital game-based learning (DGBL). Data from 68 eleventh grade vocational high school students were evaluated after a quasi-experimental, 27 week intervention. Pretest and posttest results were evaluated by MANCOVA and demonstrated that the experimental group (blended DGBL incorporating integrative HOTS activities) outperformed the comparison group (technology enhanced learning) in terms of creative thinking, critical thinking, problem solving, and academic achievement, with significant improvements on all four measures. While technology-enhanced learning was effective in promoting academic achievement and creative thinking, the DGBL condition was deemed most effective in providing an authentic context for developing employment-related skills and knowledge. The results and methodology of the study has implication on the current one. While this blends instructional strategies digitally, the current study blends modeling in authentic inquiry processes (MBI) to determine its effect on critical and creative thinking skills at pre-service teachersô level.

Sandeg and Odabasi (2009) investigated how the online problem based learning (PBL) approach employed in an online learning environment influenced undergraduate studentsô critical thinking skills (CTS) and content knowledge acquisition. The pretestï posttest control group design was used in the study. The subjects included the students who were enrolled at the Department of Primary School Mathematics Teaching in Anadolu University Education Faculty. Subjects attended to Computer II course in 2008 spring. Experiment group attended the online PBL course whereas the control group attended the online instructor-led course. Each group consisted of 20 students. Data collection tools consisted of a multiple choice content knowledge acquisition scale and the Watsonï Glaser critical thinking skills test. The results of two-way mixed design ANOVA indicated that learning in the online PBL group did not have a significant effect on the content knowledge acquisition scores but had a significant effect on increasing the critical thinking skills. This study will however investigate effect of MBI on the acquisition of creative thinking skill and interest beside achievement and critical thinking at college pre-service teachersô level in chemistry.

Students' Interest in Science Education

Njoku and Ezinwa (2014) conducted a study to find out if peer teaching strategy would lead to improved studentsô achievement in some chemistry difficult concepts. A sample of 160 SS 2 (82 students in experimental and 78 in control group) participated in the study. A quasi experimental pre-test-post-test control group research design was used. The instrument for data collection used were a 50-item multiple choice achievement test and a 24-item interest inventory. The experimental group was taught difficult concepts in chemistry using peer teaching and control group exposed to conventional (lecture) method for 9 weeks. The data collected was analyzed using mean scores, standard deviation scores and ANCOVA. It was found out that experimental group achieved significantly higher mean scores and developed significantly higher interest in the difficult concepts than the control group. The study focused on studentsô achievement and interest at SS level using peer teaching and lecture method, however the current study will investigate the creative and critical thinking skills acquisition, beside interest and achievement, at pre-service teacher level employing MBI and CI.

Igboanugu (2014) studies the effect of cooperative learning on studentsô interest in secondary school difficult chemistry concepts. The study adopts a quasi-experimental design. The population of the study comprised of all SS 2 chemistry students of Onitsha educational zone in Anambra state, Nigeria from which a sample of 184 students was selected through purposive random sampling. The instrument used for data collection was the Chemistry

Interest Inventory (CII) with a reliability of 0.93. ANCOVA was used to analyze the data. The result of the study revealed that cooperative learning is more efficacious in capturing studentsô interest than conventional method. Moreover, the study revealed that the interests of both male and female students are captured alike by cooperative learning. Since the study showed that cooperative learning is effective capturing studentsô interest, it becomes pertinent to find out if MBI will provide similar or even more gain on students especially at pre-service level.

Agogo, Odoh and Simon (2014) investigated into interest and sustenance as correlates of studentsô performance in Senior Secondary chemistry in Ogbadibo Local Government Area of Benue State, Nigeria. Descriptive survey design was employed. The sample of 242 chemistry studentsô S.S II was used. The instrument was the Interest and Sustenance in Chemistry Questionnaires (ISCQ). Mean and standard deviation were used to answer the research questions while the hypotheses were analyzed using Pearson Product Moment Correlation Coefficient before conversion to t-test for test of significance. From the analysis, it was found that there is a significant relationship between interest in chemistry and the studentsô performance in the subject. It was recommended that chemistry teachers should use all available instructional materials to arouse studentsô interest and sustain it so as to enhance performance. This study will be of relevance to the present study. Although the major area of interest is on sustenance, skill acquisition is incorporated using MBI in a quasi-experimental design procedure.

Okigbo and Okeke (2011) investigated the effects of games and analogies on secondary school studentsô achievement in mathematics. A total of 246 Junior Secondary Two (JS2) Mathematics students were involved in the study. A Solomon three- group design was adopted in the research. From the findings, it was observed that both games and analogies enhance learnersô interest in mathematics. Game was found to be more effective in improving studentsô interest in mathematics than analogy and that a non-significant difference existed between the mean interest scores of male and female mathematics students taught with either game or those taught with analogy. There was no interaction between method and gender on studentsô mean interest in mathematics. It was recommended that teachers should be encouraged to adopt game more than instructional analogy in teaching number and numeration and algebraic processes in mathematics.

Blunuz (2007) evaluates the effectiveness of a science methods course in promoting interest in science, interest in teaching science, and choice to teach science. Subjects were 53 pre-service teachers in two sections of a science methods course at a large American university. The course used hands-on activities at varying levels of inquiry to teach content and inquiry methods and to model effective teaching. The study involved analyses of pre/post course surveys, daily ratings, and final course ratings. End of course results showed that participants found course activities fun and interesting, and pre/post t-tests indicated that participants increased their interest in science and positive feelings about teaching science. Regression analysis found that the best predictors for interest in teaching scienceat the end of the course were ratings of course activities as funfollowed by the participantsô initial interest in science. Finding that fun was the best predictor suggests that a science methods course should provide a playful and risk-free learning environment in which pre-service teachers should have the freedom to explore their ñwonderings,ò curiosity, and questions. For pre-service teachers not initially interested in science, such a course not only models good teaching methods but can increase interest in science, an important motivator. The finding of this study has implication to the current one in the aspects of studentsô interest, method and pre-service teachers. However, the current study will use MBI and is not limited to the interest of pre-service teachers but their skills acquisition.

Hagay, Baram-Tsabari, Ametller, Cakmakci, Lopes, Moreira, and Pedrosa-de-Jesus, (2012) conducted a study to characterize the level of generalizability of studentsô science interests across countries and religions. 36-item Questionnaire presented on 5-point Likert-type scale was used for data collection. A convenience sample of 604 biology high school students in four countries: England (n=87), Portugal (n=109), Turkey (n=100) and Israel (n=308), which are the authorsô countries of residence. Mannï Whitney (Wilcoxon) tests were used to test for significant differences between two independent groups (e.g. males and females from the same country). Kruskal - Wallis tests were used to test for significant differences between three or more groups. In order to rank the importance of the three variables (gender, religion and country) a MANOVA was performed. Similarities among countries and religions were tested with a Pearson correlation test. Results indicate that students from four different countries show interest in similar science questions. The most intriguing questions were the ones that dealt with human health and new developments in reproduction and genetics. Religious affiliation had the strongest effect on studentsô interest level, followed by national affiliation and gender. The findings suggest that studentsô interest in one context is relevant to the development of interest-based learning materials in a different context. However, despite these similarities, cultural and sociological differences need to be taken into account. This study has direct bearing on the present study because science interest and gender are central but using MBI which may have direct bearing on the pre-service teachersô skill acquisition.

Holstermann, Grube and Susanne (2010) conducted a study which investigates the influence of hands-on activities on studentsô interest on hands-on activities. The study involved a total of 141 students from the 11th grade who completed questionnaires on interest in the hands-on activities, their experience with each activity, and the quality of the respective experience. ANCOVA and t-tests were used for the data analysis. However, findings indicated that the performance of various hands-on activities can influence studentsô interest differently. For seven hands-on activities, they identified a positive effect of hands-on experience on interest, while in one case practical work appeared to have influenced studentsô interest negatively. However, for most hands-on activities, no effect of experience on interest was found. The quality of hands-on experiences showed positive correlations with interest in the respective hands-on activities. The study grounds within the constructivism as the inquiry, but current study will employ construction of physical and mental modeling of resources in social supportive environment to determine prospective chemistry teachersô interest.

Nworgu (2004) investigated the effect of gender sensitization of science teachers on gender gap in science achievement and interest among students. The population comprised of all the JSS II students in all co-educational secondary schools in Nsukka local government area. The sample comprise of 245 JSS II students from six co-educational secondary schools in the area. The study adopted non equivalent control group design and two instruments were used in the study namely, Integrated Science Achievement Test (ISAT) and Integrated Science Interest Scale (ISIS). Mean, standard deviation and ANCOVA were used for data analysis. Findings revealed among others, that gender sensitization enhanced the overall achievement of students in science and reduced the gap that existed between male and female studentsô interest. It was recommended that government should organize regular in-service training in form of conferences, seminars and workshops, for science teachers on the use of innovative pedagogies with respect to gender related issues management in science classroom. This underscores the need to investigate the effect of innovative pedagogical strategies on studentsô interest in Biology. The current study is in agreement with this intent, to determine the effect of MBI (an innovative strategy) on skills acquisitions beside the interest and achievement on college pre-service chemistry teachers.

Trumper (2006) report the results of a study on studentsô interest in physics at the end of their compulsory schooling in Israel carried out in the framework of the ROSE Project. Factors studied were their opinions about science classes, their out-of-school experiences in physics, and their attitudes toward science and technology. Studentsô overall interest in physics was ñneutralò (neither positive nor negative), with boys showing a higher interest than girls. We found a strong correlation between studentsô ñneutralò interest in physics and their negative opinions about science classes. These findings raise serious questions about the implementation of changes made in the Israeli science curriculum in primary and junior high school, especially if the goal is to prepare the young generation for life in a scientific-technological era. A more in-depth analysis of the results led us to formulate curricular, behavioral, and organizational changes needed to reach this goal. The intents of the study towards raising science interest among young generation for sustainable life rhyme with the current study. However, this study extends beyond this limit to include effect of MBI on acquisition of critical thinking and creativity.

Gender Issues in Science Education

Abdullahi, Danladi and Mohammed (2015) investigate the effects of cooperative learning strategy on self-efficacy and academic achievement in chemistry among students in Colleges of Education in Nigeria. The population of the study comprised of 200 level chemistry students from 7 State Colleges of Education in the North-west geopolitical Zone of Nigeria. Simple random sampling was used to identify the sample. The sample of the study comprised of 207 level 200 students consisting of 165 males and 42 females. A pretest and posttest quasi experimental control group design was adopted for the study. The experimental group was exposed to cooperative learning strategy while the control group was exposed to lecture method. The Chemistry Achievement Test (CAT) and General Self-efficacy Scale (GSES) were used for data collection. Two hypotheses were stated and tested at p Ò 0.05

level of significance using t-test statistic. Major findings from the data analysis were: 1. there was no significant difference in the academic achievement (by gender) of students exposed to cooperative learning strategy. 2. There was no significant difference in the self-efficacy belief (by gender) of students exposed to cooperative learning strategy. While this study determine the effect of cooperative learning on self efficacy and achievement, the current study will find out the effect of MBI on skills acquisition (critical thinking and creativity) but both on college pre-service chemistry teachers.

Ezeudu and Obi (2013) investigated the effect of gender and location on studentsô achievement in chemistry in Nsukka local government area of Enugu state, Nigeria. The sample of the study was made up of 827 students comprising 473 males and 354 females. Eight secondary schools were sampled using simple random sampling techniques. A Proforma was the instrument which enable the researchers to copy results from the school past records in the respective schools through the help of the school principals was used to collect data for the study. Means and Standard Deviations were used to answer the research questions and t-test statistics were used to analyze the hypotheses. The findings showed that male students achieved significantly better than the female students in both urban and rural schools. Also there was no significant difference in the academic achievement of student in urban and rural schools. While this related study did not employ instructional strategy and used location, this study will adopt MBI to determine its effect on skill acquisition and interest beside studentsô achievement.

Bello and Aliyu (2012) study the effectiveness of the Dick and Carey Instructional Model that served as a guide to electrical/electronics technology education teachers in designing their instructions at the Nigeria Certificate of Education (NCE) level. The design employed was the Quasi-experimental research, the Non- equivalent Control Group design. The instrument for data collection was Electrical/Electronic Achievement Test (EEAT II), developed by the researcher. Some of the findings include Significant differences between the mean achievement scores of the experimental and control groups in the post-test; and this was not attributed to sex of the subjects (Male or Female) unlike in the school proprietorship (Federal or State Colleges of Education) when post-tested. Based on these, it was further recommended that the teachers should embark on using the guidelines proffered in the Dick and Carey Model when designing instructions. The study has direct implication with the current study with regard to the subjects, gender and achievement but differs in the method to be adopted which is MBI and the skills acquisition.

Alao and Abubakar (2010) investigated on gender enrolment gap and academic performance of college Physics students. A sample of eighteen female and eighteen male students were purposively selected as sample from the department of Physics/Computer science education of Federal college of Education (Technical), Omoku in Rivers state in the 2007/2008 academic session. The cumulative grade point average (CGPA) of the sample was analyzed using mean, standard deviation and percentages. Four hypotheses formulated were tested using t-test. It was revealed that there was no statistical significant difference in academic performance between female and male students. Based on this, it was recommended that teachers in the department of Physics/Computer should still improve on their pedagogy skills so as to be able to impact on the students, stressing the importance of Physics in Technology, giving them the necessary motivation to learn especially in their introductory courses.

Abdillah, Ong and Zulqarnain (2013) investigated gender and ethnicity differences in multiple intelligences among Form Four students through a cross sectional survey using an 80-item Malaysian-Based Multiple Intelligence Inventory (MBMI2), an adapted version which has appropriate validity and reliability established through a pilot study. The participants, comprising 426 science-based Form Four students drawn from nine secondary school classes in Manjung District, were selected using a cluster random sampling. In terms of gender, the analyses from the dataset using independent samples t-test indicated that females self-estimated themselves statistically significantly more dominant in verbal-linguistics, visual-spatial, interpersonal and intrapersonal intelligences as compared to their male counterparts. In terms of ethnicity, the analyses from the dataset using ANOVA indicated that Malays self-estimated themselves statistically significantly more dominant than Chinese in verbal-linguistics, visual-spatial, bodily-kinesthetic, naturalist, interpersonal and intrapersonal intelligences whilst Indians are more dominant than Chinese in self-estimation for verbal-linguistics, naturalist, interpersonal and intrapersonal intelligences. Implications from these findings is for enhancing the teaching and learning in science. The current study is also geared towards the effect of MBI on central issues in enhancing teaching and learning but at pre-service level.

Oladejo, Olosunde, Ojebisi and Isola (2011) examined the effect of using standardized and improvised instructional materials on academic achievement of secondary school physics students in Oyo State, Nigeria. The research design adopted was quasi-experimental. Purposive sampling was used to obtain a sample of three co-educational secondary schools. Each school provided one S.S. III class for the study. Two instruments were used in the study, the Physics Achievement Test (PAT) to measure studentsô achievement and Teachers Instructional Guide (TIG) to train the teachers in the experimental groups. The instrument was pilot tested to ascertain reliability. The reliability coefficient was 0.76. Three hypotheses were formulated and tested at 0.05 level of significance. Data were analyzed using ANOVA and ANCOVA. Findings revealed that there is a significant difference in the achievement of students taught using standard instructional materials, those taught with improvised instructional material and those in the conventional instruction. Also, there was no significant effect of gender on studentsô achievement in Physics although, females did better than males. Finally, there was no significant interaction effect of treatment and gender on student achievement in Physics. The researchers conclude that the utilization of improvised instructional materials promote and enhance effective teaching-learning process, thus, Physics teachers should be encouraged to use them in secondary education program. The findings of the study have bearing on the current study as it relates to achievement and gender issues. However, this study extends to the effect of MBI on skills acquisition.

Adekoya and Olatoye (2011) investigated the effect of three teaching strategies; demonstration, peer-tutoring, and lecture strategies of teaching on studentsꞌ achievement in pasture and forage crops which is an aspect of agricultural science. Lecture strategy served both as a teaching strategy as well as control since it is assumed to be a conventional strategy of teaching. A 3X2X2 pre-test, postï test experimental design with a control group was used in which a hundred and fifty randomly selected Senior Secondary School II (SSS II) Agricultural Science students were drawn from three schools. The data was analyzed using ANCOVA and Scheffe postï hoc analysis. There is significant main effects of treatment on studentsô achievement in aspects of pasture and forage crops. Also, students performed significantly at different levels in the three groups. There is no significant interaction effect of treatment and gender on studentsꞌ achievement in pasture and forage crops. While the study hinges on the effect of lecture strategies, the current study will determine the effect of MBI on skills acquisition at college level.

Preckel, Goetz, Pekrun, Kleine (2008) investigated gender differences in 181 gifted and 181 average-ability sixth graders in achievement, academic self-concept, interest, and motivation in mathematics. Giftedness was conceptualized as nonverbal reasoning ability and defined by a rank of at least 95% on a nonverbal reasoning subscale of the German Cognitive Abilities Test. Mathematical achievement was measured by teacher-assigned grades and a standardized mathematics test. Self-concept, interest, and motivation were assessed by questionnaire. Data was analyzed using Standard deviation and repeated measures analysis of variance. In both ability groups, boys earned significantly higher test scores but there were no gender differences in grades. Girls scored lower on measures of academic self-concept, interest, and motivation. Gender differences were larger in gifted than in average-ability students. Ability group differences for self-concept and interest were only found for boys in favor of the gifted. Results support the assumption that gender differences in self-concept, interest, and motivation in mathematics are more prevalent in gifted than in average-ability students. The issues of critical/creative potentials and gender influence investigated by this study square well with the intent of the current study. With the adoption of the MBI the gender difference may be minimized.

Eriba and Ande (2006) in a study attempted to find out if sex differences exist in calculating reacting masses from a set of chemical equations among secondary school students in Makurdi metropolis. A Calculation Achievement Test (CAT) was administered to thirty students randomly selected from Government secondary school, North-Bank, Makurdi. The instrument used for data collection was a Calculation. Achievement Test (CAT).The t-test statistic for independent samples was used to analyze the data obtained. The study established that boys performed better than girls on the achievement test. Eriba and Ande recommend that chemistry and mathematics teachers ensure integrative learning, transfer and application of knowledge among the females by giving them more attention/time during classes. In MBI students (male and female) are expected to construct mental models in an integrative social setting. This serves as part of the common ground for the two studies.

Keziah (2011) conducted a study to investigate the effect of gender on the use of computer in science class and its effect on the studentsô academic performance. It was a quasi-experimental design that used pre-test, treatment-control, and post-test. Using computers, the experimental group was taught two Biology lessons on photosynthesis and digestion in mammals while the control group was taught without computer using conventional teaching method. The study was guided by two research questions and two null hypotheses. A 20-item multiple-choice questions was produced by the researcher and used for both pre-test and post-tests. Validation of the instrument was achieved through the contributions from two senior colleagues, and a reliability coefficient of 0.76 was realized using Kuder Richardson correlation analysis. Data collected were analyzed using both mean scores and t-tests. Results showed that gender had no significant effect on the use of computer, but the use of computer in teaching improved the academic performance of the students. It therefore, recommended continued use of computers in schools, and government with other stakeholders should provide more computers and train teachers to further enhance computer integration in classrooms. The use of computers in this study bridged the gender gap in achievement. In this study a more favorable outcome is expected since students will be engaged with activities in social setting of the MBI.

Wolf and Fraser (2007) in a study compared inquiry and non-inquiry laboratory teaching in terms of studentsô perceptions of the classroom learning environment, attitudes toward science, and achievement among middle-school physical science students. Test of Science-Related Attitude (TOSRA), What Is Happening In this Class (WIHIC) and 9-item achievement test were used for data collection. The study employed MANOVA and ANOVA in data analysis. Learning environment and attitude scales were found to be valid and related to each other for a sample of 1,434 students in 71 classes. For a sub sample of 165 students in 8 classes, inquiry instruction promoted more student cohesiveness than non-inquiry instruction (effect size of one-third of a standard deviation), and inquiry-based laboratory activities were found to be differentially effective for male and female students. Whereas males benefited more from inquiry methods, females seemed to benefit more from non-inquiry approaches in terms of attitudes to science and classroom task orientation, cooperation and equity. While this study compared an inquiry and laboratory activities and unveils good hope in gender gap, findings of the current study will hopefully minimize the gender gap as it involves the conventional inquiry and the MBI.

Louis and Mistele (2011) conducted a study to develop a better understanding of the connections between studentôs achievement scores in mathematics and science, student gender, and self-efficacy. 7377 students from 239 school were sampled via Two stage sampling process was used (1st at school level and 2nd at classroom level).They employed Trends in International Mathematics and Science Study (TIMSS) 2007 eighth grade data to answer research questions. Four separate surveys/ assessments were used, first was a student achievement assessment in mathematics and science, the second was a student survey, the third was a teacher survey, and the fourth was a general school survey. Louis and Mistele were able to demonstrate that when controlling for self-efficacy, there is a statistically significant difference in the achievement scores between males and females by subject, where females score higher Algebra, but males score higher in the other mathematics subjects. Likewise, they were also able to demonstrate that there is a statistically significant difference in the achievement scores in Earth Science, Physics, and Biology, between males and females where males score higher in science subjects. In both mathematics and science examinations, they controlled for self-efficacy where in mathematics females hold lower self-efficacy then males and in science there is no difference between females and males in terms of self-efficacy. Louis and Mistele conjecture that mathematics and science classrooms that consider self-efficacy may impact studentôs achievement scores by subject, which can ultimately impact career choices in mathematics- and science-based fields. Though the study adopts survey design in mathematics, the findings have relevance to the current study in the attempt to understand the relationship between gender and studentsô achievement.

Omoniyi (2006) conducted a study to test the effect of a constructivist-based learning strategy - the Learning Cycle Approach (LCA) on male and female studentsô misconceptions on selected concepts in chemistry. The LCA was developed from Piagetôs developmental theory. Two instruments were developed along the guidelines set out by Piaget inspired studies and used for the study. The former was used to test the studentsô reasoning ability on how to solve giving problems in chemistry while the latter was used to test the studentsô practical skills in solving given scientific problems. Both TORA and TOPS covered the two selected concepts for the study - Heat and Temperature. Subjects for the study were 55 Nigerian Secondary Two (SSII) Students (30 males and 25 females) from a semi urban area of Ondo State, Nigeria were involved in the study, the findings shows that: (1)Female students performed significantly better than their male counterpart in the test of reasoning ability.(2) The subjects possessed low understanding of manipulative skills.(3)Female (57%) students responded better than males (43%) at formal operational levels while the greater proportion of males (62%) responded at the concrete levels as against 38% of females at concrete level respectively. The finding of this study is related to the current study as relate to gender and achievement of student in constructivist settings. However, the current study will immerse pre-service teachers in physical and mental modeling exercises in MBI.

Afuwape and Oludipe (2008) conducted a study on gender differences of integrated science achievement for graduating pre-service teachers over a period of 3 years. Data were drawn from studentsô (126 male and 127 female) final year results from a college of education in Nigeria. Mean, Standard deviation and t-score (two tailed) were used to analyze the data. Findings revealed that the gender gap in integrated science achievement, among the sample data, could be disappearing. This is a source of hope for the country because results such as those reported here are contrary to the general Nigerian stereotypical belief about maleôs and femaleôs performance in the subject. The study has a direct bearing on the present study especially as it relates to pre-service teachers. However, the study adopts longitudinal research design, the current study will adopt quasi-experimental design using MBI, which probably may bridge the gender gap more than reported.

Summary of the Reviewed Literature

The literature reviewed in this study established that effective chemistry teaching is indispensable for developing in students, at all educational levels, the requisite survival kit in todayφs knowledge-intensive and information/technology driven world. However, this is limited by a number of factors among which include the competence of most teachers in their ability to effectively use appropriate methods and instructional strategies in their service delivery ï a function of the pre-service training they received from the teacher producing institutions especially the Colleges of Education (COEs). The major reason for this problem advanced by some educators is that pre-service teachersô preparation programs in COEs are still based predominantly on traditional practices such as lecture, demonstration, expository methods. It was established in the literature that traditional approaches had not been profitable enough. This is noted in the passive nature assumed by students, massive poor achievement of students especially in chemistry and inability to acquire life skills (especially critical and creative thinking) which would have enabled them to be independent and fulfilled individuals and develop same in learners. It has been indicated in the literature that the riffle effect of such practices elicit gender difference in confidence level among students and relatedgender inequalities in science and technology. However, sustainable development requires the participation of all irrespective of sex. The need has been stressed foradopting instructional strategies that will break gender barriers, provide equal social collaborative learning environment and opportunities for girls and boys in science classrooms so that they can express themselves and participate actively in scientific activities. Further reflections of such needs/efforts have been mirrored in the empirical studies reviewed. The review in this regard covers studies conducted on achievement in sciences, interest and gender with very few in skills acquisition. While some of the reviews explore ex post factor, survey and quasi-experimental designs, different types of traditional approaches, inquiry and related strategies, few compared the effect of two types of inquiry instructional strategies.

The need for exposing the prospective science teachers at higher education levels to quality knowledge and skills, both practical and cognitive, remains a necessity. Science educators as reflected in the review, maintained that the task cannot be accomplished without a radical change from the use of teacher centered traditional practices in teacher preparation programs to the use of student centered (activity based) approaches grounded in cognitive and constructivist learning theories, such as the Conventional inquiry (CI). However, research findings indicate the continuous abuse of inquiry as verification activities, where students closely follow directions and memorizing what science teachers and text books have indicated as truth about the natural world. So despite the merit of such inquiry approach, it has not been properly utilized to produce the desired results. Hence, the proposition by science educators for more reformed innovative inquiry approaches such as Model-Based Inquiry (MBI), to align the conventional inquiry with knowledge and skills requirements of the 21^{st} century.MBI approach is a cognitive/constructivist (socio-cognitive) based instructional strategy which utilizes the generation of physical and conceptual models blended in inquiry process. Nevertheless, the paucity of the use of MBI in science teaching and learning at all levels of education system has been established and to the best knowledge of the researcher, the effect of this innovative strategy on achievement, skill acquisition and interest in chemistry at college pre-service teacher level has not been explored. Hence the gap this study intends to fill. Therefore the study aims at investigating the effects of MBI instructional technique to find out the extent it will stimulate male and female pre-service Chemistry teachersô academic achievement, skills acquisition and interest.

CHAPTER THREE

RESEARCH METHOD

This chapter presents the procedure adopted in carrying out this study under the following sub ï titles/headings; Design of the study, area of study, population of the study, sample and sampling technique, instrument for data collection, validation of the instrument, reliability of the instrument, experimental procedure, training package for teachers and research assistants, control of extraneous variables, method of data collection and method of data analysis.

Design of the Study

The study adopted the quasi-experimental research design. Specifically, the pre-test post-test non-equivalent control group experimental design was used. According to Nworgu, (2006) quasi-experimental design can be used when it is not possible for the researcher to randomly sample the subjects and assign them to treatment groups without disrupting the academic programs of the schools involved in the study. Also Quasi-experimental research design entails the researcher randomly assigning intact classes to treatment and control groups (Fraenkel and Wallen, 1996). This design was considered suitable because intact classes or pre-existing, nonequivalent/non equated groups were randomly assigned to experimental and control groups (Nworgu, 2006), to determine the effects of MBI instructional technique on studentsô achievement, skill acquisition and interest in pre-service chemistry teachers.

The design notation is graphically shown below:

Experimental Group:	O_1	X	O_2
	- - - - - - - - - - -		
Control Group:	O_1	$\sim X$	O_2

Where; O_1: represents pre-tests

O_2: represents post-tests

X: stands for the treatment using MBI instructional technique

∼X: stands for treatment with conventional inquiry approach.

- - : non-equivalent groups

Area of Study

The study was conducted in the North-West geopolitical zone of Nigeria. The area comprised of seven (7) states namely Jigawa, Kaduna, Kano, Katsina, Zamfara, Kebbi and Sokoto states. The area of study forms a block of educationally disadvantaged section of the country with attendant negative consequences. The key indicator of the scenario was reflected in the Road Map for Nigerian Education sector (Egwu, 2009) that out of the 38.75% of teachers with certificates below the NCE, the North-East and North-West regions constitute about 70% of the said percentage. This necessitates the introduction of Special Teachers Upgrading Program (STUP) with subsequent intervention of foreign organizations like Education Sector Support Program (ESSPIN) and most recently the Teacher Development Program (TDP) to resuscitate the ailing education standard in the area especially the instructional delivery aspect. There is a state college of education in each of the states in this geopolitical zone with almost similar operational characteristics such as the minimum standard, learning environment, funding, staffing etc.

Population of the Study

The population of the study comprised of all 200 level chemistry students from the7 State Colleges of Education in the North-West Geopolitical Zone of Nigeria numbering 945 (694 males and 251 females).

Sample and Sampling Technique

The sample of the study consists of 174 (151 males and 23 females) which cover the entire level 200 Pre-service chemistry teachers of the two state colleges of education. There is one state College of Education in each of the seven states that constituted the North West geo-political zone. Two states (Katsina and Zamfara states) were drown from these seven (7) states of the study area using simple random sampling by balloting without replacement. Level 200 chemistry students of the two state Colleges of Education i.e. Zamfara state College of Education, Maru and Isa Kaita College of Education, Dutsinma, Katsina state, from the randomly selected states made up the sample of the study. The two states Colleges of Education were randomly assigned to experimental and control group respectively. In each of these selected colleges, all level 200 Pre-service chemistry teachers were used in their intact classes.

Instruments for Data Collection

The instruments used in this study are: Chemistry Achievement Test (CAT), Test of Critical Thinking (TOCT), Creative Thinking Test (CTT) and the Chemistry Interest Inventory (CII).

The chemistry Achievement Test (CAT) was used to test achievement of students in chemistry. It was developed by the researcher and the items covered the entire content aspects of CHEM 221. It is a multiple-choice test consisting of 60 items (with four response options, a ï d). The researcher arrived at this number of items by reflecting on the format of a 2 credit course semester examination in Chemistry departments of most of the state colleges. The semester exam format consists of 40 objective questions in section A, 10 short answer question in section B and 2 essay questions for students to attempt in section C. Both sections B and C were collapsed to 20 objective questions which make up 60 items in the CAT. Each question carries 1 Mark giving a total of 60 marks. The distribution of the CAT items is contained in the test blue print (See Appendix B, p.181) with number of questions (in parentheses) from a particular content area measuring a particular domain of Bloomøs taxonomy. The multiple choice form of objective test items was used because it can more effectively measure many of the sample of learning outcomes measured by the short answer items, the alternative response item and the matching exercise (Sanders, 2002).

The TOCT was developed by the researcher within the confine of CHEM 221. Rubric was used in the construction of 7 questions in section A of the instrument. This is because rubric can be used to evaluate the depth and breadth of critical thinking, creativity and related open ended questions that require complex cognitive outcomes (Luft, 1997; McColskey and OõSullivan, 2000). The rubric adapted the scoring guide of Luft (1997) of Proficient (3 marks), Adequate (2 marks) and Limited (1 mark). Section B of TOCT consists of 15 questions (3 questions each on inference, recognition of assumption, deduction, interpretation and evaluation of arguments) adopting the Watson and Glaser (2002) format.

The Creative Thinking Test (CTT) was also developed by the researcher. Rubric was also used in the construction of 7 questions in section A of the instrument which covers the entire content area of the course. The rubric also adapted the scoring guide of Luft (1997) of Proficient (3 marks), Adequate (2 marks) and Limited (1 mark).Section B of the instrument consists of 5 questions which cover the geometry and the reaction mechanism which is the central theme of the course outline.

The CII used to test studentsô interest was also developed by the researcher. The consists of 30 items and were based on Four point Likert scale of Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD).

Validation of the Instrument

The Four Instruments (CAT, TOCT, CTT and CII) as well as the lesson plans were subjected to validation by 5 experts (4 from the department of science education, University of Nigeria, Nsukka & 1 from Chemistry Department, Jigawa State College of Education, Gumel). The experts examined the instrument items for face validation in terms of clarity of instrument to subjects, proper wordings of the items and whether the questions covered the skills being investigated. CAT was content validated in which the experts were requested to use the table of specification to ensure that the questions measured the skills indicated appropriately and adequately. Based on the expertsô suggestions, a revision was carried out on the final drafts of the instruments before subjecting them to field trial. (See Appendix N, p. 212).

Reliability of the Instruments

In order to obtain the reliability, the instruments (CAT, TOCT and CTT and CII) were trial tested at college of education Azare, Bauchi state in the North-east geopolitical zone. This college was chosen because it did not form part of the study area but uses the same NCCE minimum standard where CHEM 221 is offered.

The reliabilities of the instruments were computed as follows; Since CAT was scored dichotomously, Kudder-Richardson (K-R20) method was used to test its internal consistency and the reliability coefficient was found to be 0.81. The reliability for TOCT was determined through a test re-test method and the estimate of temporal stability was computed using Pearson product moment correlation. This is because TOCT has two versions (subjective and dichotomously scored sections) which are supposed to be measuring the same thing i.e. creativity. The reliability coefficient of the TOCT was found to be 0.85. However, the reliability of CTT was determined using Kendalôs Coefficient of Concordance (W). The technique was used because in CTT the rating is more subjective than objective. The instrument was administered on the same group of students. Then 3 copies of the CTT were given to three raters for independent scoring and the reliability was found to be 0.79. Cronbachôs Alpha was used to test the internal consistency of CII because there are no preferred answers, i.e. polytomously scored. The reliability of CII was found to be 0.87. With these satisfactory reliability coefficients, the items contained in the respective instruments were found to be adequately reliable and therefore appropriate for the current study. For evidences, See Appendices, H (CAT), p. 203; I (TOCT), p. 206; J (CTT), p. 207and K(CII), p. 208.

Training of Research Assistants

Before the actual instruction, training was organized for 2 participating lecturers and 4 assistants at five contacts (Monday to Friday) in week one of the semester for both experimental (MBI) and the control (CI) groups.

Day one of the **MBI** group (experimental) involved giving training on understanding of the MBI instructional technique. This was to ensure adequate understanding of the MBI instructional technique. Day two covered training on the use of lesson plans to drive home the meaning of MBI and its stages/steps. After the introductory section of the plan (test of previous knowledge and step 1; what we know and what we want know) participating lecturers were introduced to step 2 (generating the hypothesis). This is the step that students generate a hypothetical platform of understanding (model) which was validated at the end of each lesson. Step 3 (seeking evidences) entails scaffolding their students to identify sources of data and carryout in depth background reading on related concepts allied to the idea in question. This was followed by step 4 (constructing argument) in which students in groups utilized their deep content understanding in validating their initial hypothetical models and come up with an improved model. The revised model (physical or conceptual) was presented to whole class for authentication and selection of the best among all groupsô model. The lecturer guides transition from small to whole class discussion and facilitate flow of argument. After the selection of a model, each group of students compared it with their groupôs model and justified the difference(s). At the end of the day two training, the participants were issued the lesson plans to go home to read and understand its applications. Day three of the training involved the real application of what they learned in day one and two. The fourth and fifth dayôs contacts were used for application, clarification, question and answer sessions (See Appendix O, p. 213and Appendix P, p. 222).The exercises were repeated where necessary until all participants showed capability in handling the test instruments and lesson plans.

For **CI** (control) group, day on involved giving training on understanding of the CI instructional technique. This ensured adequate understanding of the CI. Day two covered training on the use of lesson plans to drive home the meaning of CI and its stages/steps. However the similarities in the lessonȏs objectives, introductory activities and test of previous knowledge in both instructional plans, the content of the lesson note in CI group differ from that of the MBI in steps 2 and 3. There were no model generation, validation and authentication activities in CI lesson. So participants were introduced to the investigative steps of CI (1 to 3). At the end of the day two training they were issued the lesson plans to go home to read and understand its applications. Day three of the training involved the real application of the steps in CI lesson plan. The fourth and fifth dayȏs contacts were used for application, clarification, question and answer sessions (See Appendix O, p. 213 and Appendix P, p. 222). The exercises were repeated where necessary until all participants showed capability in handling the test instruments and lesson plans.

Experimental Procedure

The conduct of the study took place during the second semester (2015/2016 session) school lesson periods. The time table of the colleges was followed for the conduct of the study. The regular course tutors were used. The college in which the MBI was used served as the experimental group while the other in which the conventional inquiry method was adopted served as the control group.

The first three days of week two was used for the administration of pre-test to both the experimental and control groups (i. e. CAT and CII on Monday, TOCT on Tuesday and CTT followed on Wednesday). Lessons for both experimental and control group commenced in the third week. The experimental group was taught with five MBI lesson plan of 4 hours (2 weeks per plan) and the control group was exposed to 5 conventional inquiry method lesson plan of 4 hours (2 weeks per plan). This treatment covered 10 weeks and terminates at the 12th week of the semester. During this period, the researcher supervised the experimental processes to ensure strict adherence to the prepared lesson procedures. The 13th week served as the post-testing period in which the instruments were administered in the first three days of the week to both experimental and control groups (i. e. CAT and CII on day 1, TOCT on day 2 and CTT followed on day 3). The exercise provides a post-test data for each of the three dependent variables (Achievement, Skill acquisition and Interest) after the treatment. The experimental procedure was videotaped.

Control of Extraneous Variables

The researcher took the following steps to control some extraneous variables:

a. Teacher Variable

This was controlled by uniform training organized for the research assistants. Lesson plans prepared by the researcher was made available to the participating teachers. This reduced teacherǿs effect on lesson plan and presentation. The researcher ensured that the ten weeks period slated for the study were strictly followed by teachers and that the teachers do not deviate from instruments specifications and instruction.

b. Initial Group Differences

This was checked by subjecting the data to Analysis of Covariance (ANCOVA) since the study was pre-test post-test, non-equivalent control group design.

c. Hawthorne Effect

This is a situation where the performance of research subject is affected due to the fact that the students are conscious of the fact that they were involved in an experiment. In order to reduce this problem, the researcher used normal course tutors in both the experimental and control groups and also assigned each college to a single treatment. Hence, the researcher was not directly involved in the treatments.

Methods of Data Analysis

The data collected from the administration of pre-test and post-test were analyzed using the Statistical Package for Social Sciences (SPSS), version IBM 20.0. Mean and Standard deviation were used to answer all the research questions. Hypotheses formulated for the study were tested at 0.05 level of significance using the Analysis of Covariance (ANCOVA). Descriptive analysis based on the observation from videotaped classroom instruction was done to assess the changes both in quality and quantity especially on studentsô interactions in model generation activities.

CHAPTER FOUR

RESULTS

The results from data analysis are presented in this chapter. These are presented in tables according to the research questions and hypotheses that guided the study.

Research Question 1:

What is the effect of Model Based Inquiry (MBI) instructional technique and CI on pre-service teachersô achievement in Chemistry?

Table 1: **Mean and Standard deviation of pretest and posttest scores of MBI instructional technique and CI on pre-service teachers' achievement in Chemistry**

Variable		Pre-test		Post-test		
Methods of Teaching	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**
MBI	70	21.96	5.18	38.49	5.29	16.53
CI	104	21.34	4.93	28.34	5.58	7.00

The result presented in Table 1 show that the MBI instructional technique had a pretest mean 21.96 with a standard deviation of 5.18 and a posttest mean 38.49 with a standard deviation of 5.29. The difference between the pretest and posttest mean for MBI instructional technique was 16.53. The CI had a pretest means 21.34 with a standard deviation of 4.93 and a posttest mean 28.34 with a standard deviation of 5.58. The difference between the pretest and posttest mean for CI is 7.00. For MBI instructional technique and CI, the posttest means were greater than the pretest mean with MBI instructional technique having higher mean gain. For standard deviation (SD), the maximum score for Chemistry Achievement Test (CAT) was 60 and its 1/5 is 12. Since the post SD for both groups (MBI: 5.29 and CI: 5.58) are below 12 for studentsô achievement in Chemistry, the relatively low SD therefore indicated homogeneity of scores clustered around the mean. Also, the relatively high mean scores with low SD indicated mastery of the content by students. This is noted in the pre-service teachers taught with MBI. Hence, pre-service chemistry teachers taught using MBI achieved higher than those taught with CI.

Hypothesis 1

HO_1: There is no significant difference in the mean achievement scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with Conventional Inquiry.

Table 2: **Analysis of Covariance (ANCOVA) of the difference in the mean achievement scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with Conventional inquiry**.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4822.338[a]	4	1205.585	44.024	.000
Intercept	6001.338	1	6001.338	219.148	.000
Achipre	260.707	1	260.707	9.520	.002
Treatment	1405.305	1	1405.305	51.317	.000
Gender	213.257	1	213.257	7.787	.006
Treatment * Gender	67.263	1	67.263	2.456	.119
Error	4628.035	169	27.385		
Total	192329.000	174			
Corrected Total	9450.374	173			

Achipre: Achievement pretest

The result in Table 2 shows that an F-ratio of 51.32 with associated probability value of 0.000 was obtained with regards to the difference in the mean achievement scores of pre-service Chemistry teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry. Since the associated probability (0.000) was less than 0.05, the null hypothesis (**HO_1**) was rejected. Thus, there is a significant difference in the mean achievement scores of pre-service Chemistry teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry.

Research Question 2: What is the effect of MBI instructional technique and CI on pre-service teachersô acquisition of creative thinking skill in Chemistry?

Table 3: **Mean and Standard deviation of pretest and posttest scores of MBI instructional technique and CI on pre-service teachers' acquisition of creative thinking skill in Chemistry**

Variable		Pretest		Posttest		
Methods of Teaching	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**
MBI	70	4.19	1.82	19.14	4.25	14.95
CI	104	3.22	1.75	5.49	2.61	2.27

The result presented in Table 3 show that for the acquisition of creative thinking skills, the pre-service teachers taught with MBI instructional technique had a pretest mean of 4.19 with a standard deviation of 1.82 and a posttest mean 19.14 with a standard deviation of 4.25. The difference between the pretest and posttest mean for group taught with MBI instructional technique was 14.95. The group taught using CI had a pretest means of 3.22 with a standard deviation of 1.75 and a posttest mean 5.49 with a standard deviation of 2.61. The difference between the pretest and posttest mean for CI group is 2.27. For MBI instructional technique and CI, the posttest means were greater than the pretest mean for the acquisition of creative thinking skill, with MBI having higher mean gain. This implies that MBI instructional technique improved pre-service teachersô acquisition of creative thinking skill in Chemistry more than CI. For the standard deviation (SD) however, the maximum score for creativity (CTT) was 36 and its 1/5 is 7.2. Since the post SD for both groups (MBI: 4.25 and CI: 2.61.) are below 7.2 for pre-service teachersô creative skills, the relatively low SD therefore indicated homogeneity of pre-service teachersô scores clustered around the mean.

Hypothesis 2

HO_2: There is no significant difference in the mean creative thinking skill acquisition scores of Pre-service teachers taught Chemistry with MBI and those taught with Conventional Inquiry.

Table 4: **Analysis of Covariance (ANCOVA) of the difference in the mean creative thinking Skill scores of pre-service teachers taught Chemistry with MBI and those taught with Conventional Inquiry.**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	7949.655[a]	4	1987.414	186.462	.000
Intercept	3081.807	1	3081.807	289.140	.000
Creatpre	140.775	1	140.775	13.208	.000
Treatment	3252.788	1	3252.788	305.181	.000
Gender	12.242	1	12.242	1.149	.285
Treatment * Gender	1.567	1	1.567	.147	.702
Error	1801.293	169	10.659		
Total	30739.000	174			
Corrected Total	9750.948	173			

Creatpre: Creativity pretest

The result in Table 4 shows that an F-ratio of 305.18 with associated probability value of 0.000 was obtained with regards to the difference in the mean creative thinking skill acquisition scores of pre-service Chemistry teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry method. Since the associated probability (0.000) was less than 0.05, the null hypothesis (**HO_2**) was rejected. Thus, there is a significant difference between mean creative thinking skill acquisition scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with Conventional Inquiry approach. This is in favor of the MBI group

Research Question 3: What is the effect of MBI instructional technique and CI on pre-service teachersôCritical thinking skill in Chemistry?

Table 5: **Mean and Standard deviation of pretest and posttest scores of MBI and CI on Pre-service teachers' Critical thinking skill in Chemistry**

Variable		**Pre-test**		**Post-test**		
Methods of Teaching	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**
MBI	70	8.11	1.83	19.83	3.70	11.72
CI	104	7.27	1.90	9.75	2.11	2.48

The result presented in Table 5 show that students taught with MBI instructional technique had a pretest mean of 8.11 with a standard deviation of 1.83 and a posttest mean 19.83 with a standard deviation of 3.70. The difference between the pretest and posttest mean for MBI instructional technique was 11.72. The CI group had a pretest means 7.27 with a standard deviation of 1.90 and a posttest mean 9.75 with a standard deviation of 2.11. The difference between the pretest and posttest mean for CI is 2.48. For MBI instructional technique and CI, the posttest means were greater than the pretest mean with MBI instructional technique having higher mean gain score than the CI instructional technique. For the standard deviation (SD), the maximum score for critical thinking skills was 36 and its 1/5 is 7.2. Since the post SD for both groups (MBI: 3.70 and CI: 2.11) are below 7.2 for the critical thinking skills, the relatively low SD therefore indicated homogeneity of scores clustered around the mean. The relatively moderate mean scores with low SD indicated mastery of critical thinking skill. This may also be said to be true of the students taught with MBI. Same is noted in terms SD for the critical thinking skills components. The relatively moderate post-test mean scores and low standard deviation scores for each of the skillôs components indicated improved acquisition of critical thinking skill among the pre-service teachers but more in favor of the MBI group.

Hypothesis 3

HO_3: There is no significant difference in the mean critical thinking skill scores of Pre-service teachers taught Chemistry with MBI and those taught with Conventional Inquiry.

Table 6: **Analysis of Covariance (ANCOVA) of the difference in the mean critical thinking Skill of pre-service teachers taught Chemistry with MBI and those taught with Conventional Inquiry.**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4307.875[a]	4	1076.969	135.073	.000
Intercept	1553.216	1	1553.216	194.803	.000
Critpre	23.237	1	23.237	2.914	.090
Treatment	1512.523	1	1512.523	189.699	.000
Gender	11.658	1	11.658	1.462	.228
Treatment * Gender	17.509	1	17.509	2.196	.140
Error	1347.481	169	7.973		
Total	38814.000	174			
Corrected Total	5655.356	173			

Critpre: Critical thinking pretest

Table 6 showed the ANCOVA for testing the difference in pre-service teachersô mean critical thinking scores in Chemistry. The result shows that an F-ratio of 189.70 with associated probability value of 0.000 was obtained with regards to the difference in the composite mean critical thinking skill acquisition scores of pre-service teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry method. Since the associated probability (0.000) was less than 0.05, the null hypothesis (**HO_3)** was rejected. Thus, there is a significant difference in the mean critical thinking skill acquisition scores of pre-service Chemistry teachers taught with MBI instructional technique and those taught with conventional inquiry in favor of the MBI group. This further confirmed that using MBI instructional technique improves critical thinking skill acquisition of pre-service chemistry teachers more than CI approach.

Research Question 4:

What is the effect of MBI instructional technique and CI on pre-service teachersô interest in Chemistry?

Table 7: **Mean and Standard deviation of pretest and posttest scores of MBI instructional technique and CI on pre-service teachers' interest in Chemistry**

Variable		Pretest		Posttest		
Methods of Teaching	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**
MBI	70	64.10	2.52	93.66	2.52	29.56
CI	104	62.54	1.83	67.88	9.05	5.34

The result presented in Table 7 show that the MBI instructional technique had a pretest mean of 64.10 with a standard deviation of 2.52 and a posttest mean 93.66 with a standard deviation of 2.52. The difference between the pretest and posttest mean for MBI instructional technique (i.e. the mean gain) was 29.56. The CI had a pretest means 62.54 with a standard deviation of 1.83 and a posttest mean 67.88 with a standard deviation of 9.05. The difference between the pretest and posttest mean (i.e. the mean gain) for CI is 5.34. Thus, for MBI instructional technique and CI, the posttest means were greater than the pretest mean with MBI instructional technique having higher mean gain (29.56 > 5.34). Considering the standard deviation, the maximum possible score from the interest inventory was 120 and its 1/5 was 24. Since the posttest SD for both MBI (2.54 < 24) and CI (9.05 < 24) was low with relatively high mean score, the mean interest scores for both groups were homogenous because the majority of the scores tightly clustered around the mean score of the post-test. The relatively high mean scores with low standard deviation scores of the MBI group also indicate that pre-service teachers in the MBI group develop more interest in chemistry than those in CI group. Hence, MBI was more efficacious in the development of pre-service teachersô interest in chemistry than CI approach.

Hypothesis 4

HO_4: There is no significant difference in the mean interest scores of pre-service teachers taught Chemistry with MBI and those taught with conventional inquiry.

Table 8: **Analysis of Covariance (ANCOVA) of the difference in the mean interest scores of pre-service teachers taught Chemistry with MBI and those taught with Conventional Inquiry.**

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	29581.041[a]	4	7395.260	176.629	.000
Intercept	55.474	1	55.474	1.325	.251
PreInterest	1752.524	1	1752.524	41.857	.000
Treatment	11542.077	1	11542.077	275.672	.000
Gender	15.805	1	15.805	.377	.540
Treatment * Gender	68.170	1	68.170	1.628	.204
Error	7075.833	169	41.869		
Total	1102148.000	174			
Corrected Total	36656.874	173			

PreInterest: Pretest Interest

The result in Table 8 shows that an F-ratio of 275.67 with associated probability value of 0.00 was obtained with regards to the difference in the mean scores of pre-service Chemistry teachers taught Chemistry with MBI instructional technique and those taught with conventional inquiry method. Since the associated probability (0.00) was less than 0.05, the null hypothesis (**HO_4**) was rejected. Thus, there is a significant difference in the mean interest scores of pre-service Chemistry teachers taught with MBI instructional technique and those taught with conventional inquiry method. This implies that the use of MBI instructional technique improves interest of pre-service chemistry teachers more than CI instructional technique.

Research Question 5

What is the influence of gender on pre-service chemistry teachersô achievement taught using MBI?

Table 9: **Mean and Standard deviation of pretest and posttest scores on the influence of gender on pre-service teachers' achievement in Chemistry taught using MBI**

Group	Gender	Pre-test			Post-test		Mean gain
		N	$\overline{X}$	SD	$\overline{X}$	SD	
MBI	Male	61	22.05	5.46	39.18	5.11	17.13
	Female	9	21.33	2.65	33.78	4.09	12.45

The data presented in Table 9 show the influence of gender on pre-service chemistry teachersô achievement when exposed to MBI. Result showed that the male pre-service teachers taught with MBI had a pretest mean of 22.05 with a standard deviation of 5.46 and a posttest mean of 39.18 with a standard deviation of 5.11.The difference between the pretest and posttest mean for the male pre-service teachers was 17.13. The female pre-service teachers taught chemistry using MBI had a pretest mean of 21.33 with a standard deviation of 2.65 and a posttest mean of 33.78 with a standard deviation of 4.09. The difference between the pretest and posttest mean for the female pre-service teachers was 12.45. Hence, the males taught with MBI achieved higher (17.13 > 12.45) than their female counterparts.

Hypothesis 5

HO_5: There is no significant difference in the mean achievement scores of male and Female pre-service Chemistry teachers when exposed to MBI.

The result in Table 2 (p.118) shows that an F-ratio of 7.79 with associated probability value of 0.01 was obtained with regards to the difference in the mean achievement scores of male and female pre-service Chemistry teachers when exposed to MBI. Since the associated probability (0.01) was less than 0.05, the null hypothesis (**HO_5)** was not retained. Hence, there is a significant difference in the mean achievement scores of male and female pre-service Chemistry teachers when exposed to MBI in favor of the males. This implies that the use of MBI result in difference in the mean achievement scores of male and female pre-service chemistry teachers for the experimental group.

Research Question 6

What is the influence of gender on pre-service teachersô Creative thinking skill in Chemistry taught using MBI?

Table 10: **Mean and Standard deviation of pretest and posttest scores of the influence of gender on pre-service teachers' Creative thinking skill in Chemistry taught using MBI**

Group	Gender	Pre-test			Post-test		Mean gain
		N	$\overline{X}$	SD	$\overline{X}$	SD	
MBI	Male	61	4.18	1.80	19.00	4.30	14.82
	Female	9	4.22	2.05	20.11	4.01	15.89

Results in Table 10 showing the influence of gender on pre-service Chemistry teachersô Creative thinking skill acquisition in Chemistry when taught using MBI indicate that the male pre-service teachers had a pretest mean of 4.18 with a standard deviation of 1.80 and a posttest mean of 19.00 with a standard deviation of 4.30. The difference between the pretest and posttest mean for the male pre-service teachers was 14.82 (i.e. the mean gain). The female pre-service teachers taught Chemistry using MBI had a pretest mean of 4.22 with a standard deviation of 2.05 and a posttest mean of 20.11 with a standard deviation of 4.01. The difference between the pretest and posttest mean for the female pre-service teachers was 15.89 (i.e. the mean gain). Hence, although for each of the groups, the posttest means were greater than the pretest means, the female pre-service teachers taught using MBI had a slightly higher mean in the posttest.

Hypothesis 6

HO_6: There is no significant difference in the mean creative thinking skill scores of male and female pre-service chemistry teachers when exposed to MBI.

The result in Table 4 (p. 122) shows that an F-ratio of 1.15 with associated probability value of 0.29 was obtained with regards to the difference in the mean creative thinking skill acquisition scores of male and female pre-service Chemistry teachers when exposed to MBI. Since the associated probability (0.29) was greater than 0.05, the null hypothesis (**HO_6**) wasaccepted. Thus, there is no significant difference in the mean creative thinking skill acquisition scores of male and female pre-service Chemistry teachers when exposed to MBI.

Research Question 7

What is the influence of gender on pre-service teachersô Critical thinking skill acquisition in Chemistry taught using MBI?

Table 11: Mean and Standard deviation of pretest and posttest scores of the influence of gender on pre-service teachers' Critical thinking skill in Chemistry taught using MBI

Group	Gender	Pre-test			Post-test		Mean gain
		N	$\bar{X}$	SD	$\bar{X}$	SD	
MBI	Male	61	7.95	1.85	19.82	3.69	11.87
	Female	9	9.22	1.30	19.89	3.98	10.67

Results in Table 11 show the influence of gender on pre-service teachersô Critical thinking skill acquisition in Chemistry when exposed to MBI. Result showed that the male pre-service teachers had a pretest mean of 7.95 with a standard deviation of 1.85 and a posttest mean of 19.82 with a standard deviation of 3.69. The difference between the pretest and posttest mean for the male pre-service teachers was 11.87. The female pre-service teachers taught Chemistry had a pretest mean of 9.22 with a standard deviation of 1.30 and a posttest mean of 19.89with a standard deviation of 3.98. The difference between the pretest and posttest mean for the female pre-service teachers was 10.67. However, for each of the groups, the posttest means were greater than the pretest means with the male students having a slightly higher mean in the posttest than the females.

Hypothesis 7

HO_7: There is no significant difference in the mean critical thinking skill scores of male and female pre-service chemistry teachers when exposed to MBI.

The result in Table 6 (p. 122) shows that an F-ratio of 1.46 with associated probability value of 0.23 was obtained with regards to the difference in the mean critical thinking skill acquisition scores of male and female pre-service Chemistry teachers when exposed to MBI. Since the associated probability (0.23) was greater than 0.05, the null hypothesis (**HO_7**) was accepted. Thus, there is no significant difference in the mean critical thinking skill acquisition scores of male and female pre-service Chemistry teachers when exposed to MBI. This implies that the use of MBI result in no difference in the mean critical thinking skill acquisition scores of male and female pre-service Chemistry teachers.

Research Question 8

What is the influence of gender on male and female pre-service chemistry teachersô interest in Chemistry when taught using MBI?

Table 12: **Mean and Standard deviation of pretest and posttest scores of the influence of gender on male and female pre-service teachers' interest in Chemistry taught using MBI**

Group	Gender		Pre-test		Post-test		Mean gain
		N	$\bar{X}$	SD	$\bar{X}$	SD	
MBI	Male	61	64.28	2.42	93.80	2.50	29.52
	Female	9	62.89	2.42	92.67	2.60	29.78

Results in Table 12 showing the influence of gender on pre-service Chemistry teachersô interest in Chemistry when taught with MBI indicate that the male pre-service teachers had a pretest mean of 64.28 with a standard deviation of 2.42 and a posttest mean of 93.80 with a standard deviation of 2.50. The difference between the pretest and posttest mean for the male students was 29.52. The female pre-service teachers taught Chemistry with MBI had a pretest mean of 62.89 with a standard deviation of 2.42 and a posttest mean of 92.67 with a standard deviation of 2.60. The difference between the pretest and posttest mean for the female pre-service teachers was 29.78. However, for each of the groups, the posttest means were greater than the pretest means with the female pre-service teachers having a slightly higher mean in the posttest. Hence, the female had a slightly higher mean gain score than their male counterparts (29.78 > 29.52) in interest in chemistry.

Hypothesis 8

HO_8: There is no significant difference in the mean interest scores of male and female pre-service chemistry teachers when exposed to MBI.

The result in Table 8 page 112 shows that an F-ratio of 0.38 with associated probability value of 0.54 was obtained with regards to the difference in the mean interest scores of male and female pre-service Chemistry teachers when exposed to MBI. Since the associated probability (0.54) was greater than 0.05, the null hypothesis (**HO_8**) was accepted. Thus, there is no significant difference in the mean interest scores of male and female pre-service Chemistry teachers when exposed to MBI. This implies that the use of MBI result in no significant difference in the mean interest scores of male and female pre-service chemistry teachers.

Hypothesis 9

HO_9: There is no significant interaction effect of treatment and gender on pre-service teachersô mean achievement scores in Chemistry.

The result in Table 2 (p. 118) shows that an F-ratio of 2.46 with associated probability value of 0.12 was obtained with regards to the interaction effect of treatments and gender on pre-service chemistry teachersô mean achievement scores in Chemistry. This indicates that the effect of treatment (MBI) remain constant regardless of pre-service chemistry teachersô gender. Since the associated probability (0.12) was greater than 0.05 ($p = 0.12$: $p > 0.05$) the null hypothesis (**HO_9**) was therefore accepted. Thus, there was no significant interaction effect of treatments and gender on pre-service teachersô mean achievement scores in Chemistry.

Hypothesis 10

HO_{10}: There is no significant interaction effect of treatment and gender on pre-service teachersô mean creative thinking skill scores in Chemistry.

The result in Table 4 (p. 120) shows that an F-ratio of 0.15 with associated probability value of 0.70 was obtained with regards to the interaction effect of treatments and gender on pre-service Chemistry teachersô means creative thinking skill acquisition scores in Chemistry. Since the associated probability (0.70) was greater than 0.05 ($p = 0.70$: $p > 0.05$), the null hypothesis (**HO_{10}**) was accepted. Thus, there is no significant interaction effect of treatments and gender on pre-service teachersô mean creative thinking skill acquisition scores in Chemistry. This implies that the method did not have different effect on gender but rather remain constant independent of the pre-service chemistry teachersô genders.

Hypothesis 11

HO_{11}: There is no significant interaction effect of treatment and gender on pre-service teachersô mean critical thinking skills scores in Chemistry.

The result in Table 6 (p. 122) shows that an F-ratio of 2.20 with associated probability value of 0.14 was obtained with regards to the interaction effect of treatments and gender on pre-service teachersô means critical thinking skill acquisition scores in Chemistry. Since the associated probability (0.14) was greater than 0.05 ($p = 0.14$: $p > 0.05$), the null hypothesis (**HO_{11}**) was accepted. Thus, there is no significant interaction effect of treatments and gender on pre-service teachersô mean critical thinking skill acquisition scores in Chemistry. This indicated that the effect of treatment did not vary with the genders of pre-service teachers in critical thinking skill acquisition scores in Chemistry.

Hypothesis 12

HO_{12}: There is no significant interaction effect of treatment and gender on pre-service teachersô mean interest scores in Chemistry.

The result in Table 8 (p. 124) shows that an F-ratio of 1.63 with associated probability value of 0.20 was obtained with regards to the interaction effect of treatments and gender on pre-service teachersô mean interest scores in Chemistry. Since the associated probability (0.20) was greater than 0.05, the null hypothesis (**HO_{12}**) was accepted. Thus, there was no significant interaction effect of treatments and gender on pre-service Chemistry teachersô mean interest scores in Chemistry. This indicates that the effect of treatment (MBI) is not dependent on pre-service teachersô genders in mean interest scores in Chemistry.

Analysis of the Video Taped Instructional Delivery

The analysis of the videotaped classroom interaction of both the experimental (MBI) and control (CI) groups was carried out to integrate and assess the qualitative changes of studentsô activities. The video covered aspects of achievement, creative and critical thinking as well as the interest among both genders. The following analysis represents the observations while inference is in chapter five.

The classroom interactions though structured differently in MBI compared to CI, revealed that the level and frequency of students participation was different, with the former being higher than the later. This is substantiated by the differentials in the in depth content coverage in MBI which is required at the evidence seeking step compared to CI. The disparities between the stages and nature of the activities in the two approaches indicate artificial separation between investigative science and deep content knowledge understanding in CI as compared to MBI which combined both aspects. The video revealed that there was always a provision for pre-service teachers in MBI to develop an initial model (conceptual or mental models) which is authenticated at the end of each lesson. The activities engaged in by pre-service teachers in modeling as revealed by the video coverage, require them to be creative, use different materials and approaches which triggered their imaginations and come with up unique models, solutions, and ideas. Furthermore, such activities as observed from the video enabled them to analyze and evaluate given information, draw inferences, made tacit assumptions and recognized the relationships between whole and its units. In CI, it was observed that pre-service teachers were involved in procedural investigation and argumentation but no generation of model. This may account for the difference in the instructional delivery outcomes of the approaches. It is also clear in the video that intra-group engagement in terms of sharing responsibilities and tasks accomplishment which propel their enthusiasm is higher in MBI than CI group. This evident in the processes involved in model generation activities up to the selection of a whole class model in MBI. This is substantiated by the level of participation of both genders (even though females were few) in MBI reflected in their presentations and groupôs leadership responsibilities.

Summary of the Findings

The findings of this study are presented as follows:

1. Pre-service teachers taught chemistry with MBI achieved significantly higher than those taught with Conventional Inquiry
2. Pre-service teachers taught chemistry with MBI scored significantly better than those taught with Conventional Inquiry in creative thinking skill acquisition
3. Pre-service teachers taught chemistry with MBI scored significantly better than those taught with CI in critical thinking skills acquisition
4. There is a significant difference in the mean interest scores of pre-service teachers taught chemistry with MBI compared to those taught using Conventional Inquiry.
5. Gender has significant effect on pre-service teachersô mean achievement scores in Chemistry when exposed to MBI
6. Gender has no significant effect on pre-service teachersô mean creative thinking skill acquisition scores in Chemistry using MBI

7. Gender has no significant effect on the pre-service teachersô mean critical thinking skills acquisition in Chemistry using MBI.
8. Gender has no significant effect on pre-service teachersô mean interest scores in Chemistry using MBI.
9. The interaction effect of treatment and gender on pre-service teachersô mean achievement scores in Chemistry is not significant
10. The interaction effect of treatment and gender on pre-service teachersô mean scores of creative thinking skills acquisition in Chemistry is not significant.
11. The interaction effect of treatment and gender on pre-service teachersô mean scores of critical thinking skills acquisition in Chemistry is not significant.
12. The interaction effect of treatment and gender on pre-service teachersô mean interest scores in Chemistry is not significant.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND SUMMARY

This research work is aimed at determining the effect of Model-Based Inquiry (MBI) on achievement, skills acquisition and interest of pre-service Chemistry teachers. In this chapter, result of the study was discussed and presented under the following sub-headings: discussion of findings, conclusion reached from the findings of the study, summary of the study, educational implications of the findings, recommendations, limitations of the study and suggestions for further studies.

Discussion of the Findings

The findings of this study were discussed under the relevant sub-headings in line with the research questions and hypotheses.

Effects of MBI instructional technique and CI on pre-service teachers' achievement in Chemistry

The findings of this study showed that pre-service teachers taught using MBI scored higher than those taught with CI (with a mean gain of 16.53 > 7.00). (See Table 1, p.117.). This difference was found to be significant. The findings of this study on pre-service teachersô achievement using MBI are consistent with the findings of earlier studies conducted by Arts (2008) between traditional and guided inquiry as well as Sadeh and Zion (2009) who employed open and guided inquiry approaches. Guided inquiry proved more effective in the former and open inquiry in the latter on studentsô achievement. This is not unconnected with the interactive aspect of the inquiry strategy (both MBI and CI) which offers students unique opportunities to be actively engaged in meaningful learning. However, in MBI, beside the studentsô interactive opportunities, the modeling activities focus learners not only on material activity (as in CI) but also on deep subject matter understanding (Windschitl, Thompson & Braaten, 2008). This comprehensive understanding of the content enable pre-service teachers through model generation developed mental models which are further translated through their imaginative power into either the conceptual or physical models. Example, in determining the relative stabilities of carbonium ions, pre-service teachers (in CI group) conclude at the end of the activities that it is determined by the number of alkyl groups attached to it. Hence, the order of stability is: tertiary carbonium ions (sp^2 carbon is bonded to three alkyl groups) > secondary carbonium ions (sp^2 carbon atom is bonded to two alkyl groups) > primary ones (sp^2 carbon is bonded to one alkyl group and two hydrogen atoms). But in MBI, modeling the relative stabilities encompassed the underlying explanations based on these analyses (i.e. from the content preliminaries such as the reactions of alkenes to the interactions between the hybrid orbitals and electrons in pi and sigma bonds in the stability of different carbonium ions) were addressed. Therefore the significant difference in achievement in favor of the MBI group may be explained by the variation in the pattern of activities between the MBI and CI. The level of such interaction and enthusiasm is very much obvious in the video as pre-service teachers were diligently carrying out the activities collaboratively interacting with themselves and resources with the teacher facilitating the construction of cognitive imprints guided by studentsô testing of ideas. This agrees with Dewey, Piaget and Vygotsky who maintained that knowledge is constructed by the individual learners and is embodied in human experience, perceptions, imaginations, and mental and social constructions. Moreover, as prospective teachers, the experiences obtained in MBI will hopefully impact positively on their instructional delivery capability. The tempo will in due course improve teacher preparation for greater teacher effectiveness and may eventually improve their studentsô achievement at secondary and basic education levels (Okeke-Oti & Adaka, 2012).

Effects of MBI instructional technique and CI on pre-service teachers' creative thinking skills acquisition in Chemistry.

The findings of this study revealed that the pre-service teachers taught Chemistry with MBI instructional technique acquired the skill of creative thinking significantly better than their counterparts taught Chemistry using Conventional Inquiry approach (with a mean gain of 14.95 > 2.27). The result of the null hypothesis showed that the creativity skills acquisition scores of pre-service teachers taught Chemistry with MBI instructional technique differ significantly from those taught with CI (See Table 4, p. 120). The findings of this study compared favorably with that of Abayomi (2014) who found out that learnersô active participation in learning by doing improved creativity. The activities engaged in by students in learning by doing are to some extent central in the inquiry processes in the current study. The findings are also consistent with the finding of Yager and Akay (2008) in which they reported that students exhibit significant creativity skills when exposed to Science Technology and Society (STS) with constructivist teaching practices. Further related is the findings of Yang (2014) who discovered studentsô significant improvement on creativity skills through the use of blended digital game-based learning instructional strategy. In this strategy, Yang incorporates instructor orchestration and scaffolding, provision of learning aids, and the use of collaborative learning. The common thread that runs through the themes of these research findings unveils the rudiments of the activity based instructional techniques. Both MBI and CI though unique, are inquiry approaches which aim at stimulating studentsô curiosity and acquisition of scientific skills and so fall within the same continuum of activity oriented strategies. However, the result of this study places the MBI above CI in skill acquisition. The significant acquisition of creativity skills by the MBI pre-service teachers more than those of the CI group may be explained by the difference between the stages and the nature of the activities in the two instructional strategies. Unlike in MBI, activities in CI for example there is artificial separation between investigative science and deep content knowledge understanding. However, in MBI there was always a provision for pre-service teachers to develop an initial platform of understanding (a model) to inform their previous knowledge, questions and hypotheses and data generated are not only used to characterize how outcome are related to conditions but also why the conclusion is reached in particular way. Hence, conversations (steps) in MBI were structured in such a way that pre-service teachers carry out the prescribed activities guided by an idea to be tested or validated through the generation of data from an in depth background reading/study of the content. Example, for pre-service teachers to model the relative stabilities of carbocations, they were supported to do the activities contained in the four set of classroom conversations. One of the conversations in MBI has provision for the pre-service teachers to develop an initial platform of understanding (a model) on the relative stabilities. Pre-service teachers were then requested at one of the steps to seek for evidence through in depth subject matter study to enable them identify the basic underlining characteristics/conditions and explanations central to stabilities of organic reaction intermediates (i.e. from the content preliminaries such as the reactions of alkenes to the interactions between the hybrid orbitals and electrons in pi and sigma bonds in the stability of different carbonium ions). The data so gathered was then used to verify their initial group model and come up with an improved model that will be presented to and critiqued by whole class for final selection of a whole class model. This practice support pre-service teachersô intellectual engagement utilizing the underlying content and consequently become pressed to reason scientifically by purposefully articulating relationships between ideas, evidence, and explanations which culminate into significant creative skill acquisition than with CI. This is evident in the video coverage on the novelty displayed by the pre-service teachers (MBI group) in the use of materials for models generation (cardboard, wood bran, meshes of paper, groundnut, clay, and local foods paste), colorful presentations of models depicting accuracy and precision with some groups animating sections of the models (e.g. mechanism of Markovnikoffôs rule). They also exhibit fluency in issues related to environmental sustainability such as the need to replace non biodegradable polymers with biodegradable ones and designing syntheses (at molecular level) that are cost effective in waste disposal and regulations through green chemistry. Moreover, pre-service teachers in the MBI demonstrated high level of flexibility in identifying the entrepreneurial potentials in Chem 221 with waste to wealth being unique among numerous propositions. The acquisition of these creative skills was more feasible with MBI because pre-service teachers were given the opportunities to connect ideas with deep subject matter knowledge and socially interact (with support from peers) and manipulate learning resources with teacher as facilitator. This is supported by socio-cultural and socio-cognitive learning theories as advocated by Dewey, Piaget and Vygotsky who emphasized active learning to foster growth of knowledge and positive attitudes through interaction with the world, people and things. This will ultimately help pre-service teachers develop sustainability related competencies required for the 21st century such as sound thinking and creative problem solving. Such skills will enable them to participate in solving local, national, and global problems that threaten our collective well-being in the dynamic world. Their ability to solve novel problems, communicate and collaborate, create new products and processes, deal with uncertainties, adapt to continuous change of the 21st century will therefore be a greater advantage both personally and professionally.

Effects of MBI instructional technique and CI on pre-service teachers' critical thinking skills acquisition in Chemistry.

The findings of this study revealed that the pre-service teachers taught Chemistry with MBI instructional technique improved significantly in critical thinking skills acquisition compared to their counterparts taught Chemistry using Conventional Inquiry approach. The MBI group had an overall posttest mean scores of 19.83 while the CI group had a lower posttest mean scores of 9.75. Further analysis of these data revealed that out of critical thinking skills components considered in this study, interpretation had the highest posttest mean score (MBI: 2.51, CI:1.78) followed by deduction (mean score MBI: 2.36, CI: 2.92).

Next to this is the recognition of assumption (mean score MBI: 2.27, CI: 1.78) while evaluation of argument and inference took the 4^{th} and 5^{th} positions with the mean scores MBI: 2.10, CI: 1.46 and MBI: 1.71, CI: 1.50 respectively. The inference component of critical thinking skills which has to do with the ability to form an idea, opinion or a conclusion after a series of reasoning and speculating outcomes of a situation had a slightly small difference between the mean scores in MBI group and that of the CI group. Thus, Pre- service teachers in both MBI and CI groups displayed almost similar capability in drawing conclusions with due reasoning from the facts related to several possibilities on mechanisms for a single reaction. This indicated a slight difference in the acquisition of inference component of critical thinking skills between MBI and CI groups. Since assumption is something presupposed or taken for granted, recognition of assumption component of critical thinking skill indicated that pre-service teachers in MBI group acquired this skill better than those in CI. Hence, pre-service teachers in MBI group were able to make tacit assumptions at the beginning of a line of argument more significantly than CI group, especially in the initial hypothetical model creation. Deduction has to do with understanding relationships between the whole and its component parts and between cause and effect. The higher mean scores of the MBI group indicated that the MBI group acquired the skill of deduction component of critical thinking skills better than the CI group. Hence the pre-service teachers taught using MBI approach were able to utilize the content knowledge during evidence seeking step to recognize relationships existing between the concepts in a particular model better than the CI group in which model generation was not incorporated. Example, pre-service teachers in MBI group, as revealed by the video presented and argue out the geometries of methane and ethane with ease based on their background knowledge on hybridization and effects of repulsions between electron pairs in the bonds between atoms and/or lone pairs of electrons as postulated by VSEPR theory. Interpretation has to do with justifying results, arguments or procedures. The MBI group had higher mean score than the CI group in the interpretation component of critical thinking skill. By implication, pre-service teachers exposed to MBI instructional technique were able to better judge whether or not each of the proposed conclusions that logically follow beyond a reasonable doubt from the information gathered toward tentative model creation (final group model). This was depicted most especially in the last lesson (summary) in which pre-service teachers designed a grand model portraying specific models (lesson 1 to 4) clearly and logically mapped out. Evaluation however means expressing and defending an opinion. The mean score for evaluation of argument component of critical thinking skill in MBI group is significantly higher than that of CI group. This indicate that pre-service teachers taught with MBI displayed better abilities to judge the quality, credibility, worth or practicality for using an established criteria and explain how the criteria are met or not met. These were likely possible during the construction of argument step in modeling in which pre-service teachers present their physical or conceptual group model, argue and defend it after which model authentication follows. Such opportunity was not obvious in the CI group. The relatively high mean scores and low standard deviation scores for each of the components and the overall critical thinking skills also confirmed the acquisition of critical thinking skills more among pre-service teachers in MBI group than the CI group.

For the composite score, results also indicate that, like the component scores, pre-service teachers taught with MBI acquire critical thinking skill significantly higher than those in the CI group (with mean gain 11.72 > 2.48). A justification for example was glaring during the interactive and group assignment and presentations during which they display brazen higher order thinking skills. Such skills include their ability to analyze situations, evaluate and interpret relationships. For instance, pre-service teachers exposed to MBI utilize their experiences to unravel the mystery of what causes explosion occurring in houses built on rubbish dumps and identify polypeptide links as what commonly relates nylon (a synthetic non biodegradable polymer) with protein (a biodegradable) more than those in CI group. Thus, MBI instructional technique offers more opportunity for critical thinking skill acquisition than the CI approach. This finding is in line with the study of Yan (2014) who found out a significant improvement on critical thinking skills acquisition through the use blended digital game-based learning instructional strategy. In this strategy, Yang incorporates instructor orchestration and scaffolding, provision of learning aids, and the use of collaborative learning. In a related study, Panasam and Nuangchalem (2010) discovered that science process skills and analytical thinking could be significantly improved in students through project-based and inquiry learning activities. In this study, students in both MBI and CI were given interactive opportunities to manipulate learning resources more than in the related studies. However, in MBI, beside the studentsô interactive opportunities, the model generation activities focus pre-service teachers not only on material activity (as in CI) but also on deep subject matter understanding (Windschitl, Thompson & Braaten, 2008). This provides them the opportunity to develop mental models of their ideas and to subsequently translate same into simplified physical or conceptual representations. This process in MBI starts with pre-service teachers to developing an initial platform of understanding (a model) to inform their previous knowledge, questions and hypotheses and data generated are not only used to characterize how outcome are related to conditions but also why the conclusion is reached in particular way. Consequently, pre-service teachers in the MBI group outperformed the CI group having more of the ability to identify central issues and assumptions in an argument, recognize important relationships, make correct inferences from data, deduce conclusions, interpret whether conclusions are warranted on the basis of the data given and evaluate evidence. These set of basic elements are crucial in critical thinking skill development. The activities that culminate in to the development/acquisition of critical thinking skill are typical of the position of Piaget, Dewey and Vygotsky in the construction of authentic knowledge. Critical thinking skills are crucial in this millennium because they enable students to deal effectively with social, scientific, and practical problems (Shakirova, 2007).

Effects of MBI instructional technique and CI on pre-service teachers' interest in Chemistry

The result in Table 7 (p. 123) indicate that pre-service teachers taught with MBI instructional technique had a posttest mean score of 93.66 with a mean difference of 29. 56 while the students taught with Conventional Inquiry (CI) approach obtained a posttest mean score of 67.88 with a mean difference of 5.34 (mean gain 29.56 > 5.34). The result indicated that the difference is significant. Thus, pre-service teachers taught using MBI developed interest in chemistry lesson more than their counterparts taught using CI. The relative high mean scores and low standard deviation scores of pre-service teachersô interest scores also confirmed the development of more interest among the MBI group than the CI group. Although there have been continued inconsistencies in research outcomes in the area of interest, the finding of this study conforms with Njoku and Ezinwa (2014) who discovered that experimental group developed significantly higher interest in learning of difficult concept in chemistry than the control group using peer teaching. In addition, Igboanugu (2014) also revealed that cooperative learning is more efficacious in enhancing studentsô achievement and interest in chemistry. At pre-service level Blunuz and Jerrett (2007) found out that the best predictors for interest in science teaching explores activities in which prospective teachers have the freedom to explore their ñwonderings,ò curiosity and questions. Contrary to the findings of this study, Soyibo (1991) noted that studentsô interest in biology has continued to dwindle and this affects the level of biology achievement and science related courses. In this study, the interest of students in chemistry was enhanced by inquiry for both

MBI and CI groups. However, the MBI approach used had a more significant effect on pre-service teachersô interest in chemistry than the CI group. This is likely due to the unique studentsô interactive opportunities offered by MBI in which the model generation activities focus pre- service which centers on testing of idea grounded in deep subject matter understanding. This deep content understanding in modeling activities offered students the opportunity to link conceptual understanding and meta-cognition and are further translated into model generating activities which according to Gubert and Buckley (2010) increased cognition and positive attitude. Given that interest is an intent state that influences an individualôs action, itôs built up more in MBI than in CI group could be attributable to these unique activities. Thus, pre-service teachers in MBI group were more engaged in group tasks in which the sharing of responsibilities propels their enthusiasm towards task accomplishment at different steps of the instruction such as generating the hypotheses about the model to argument construction step in which they generate the tentative model followed by its authentication. For example, from the class observation and the video, most students in groups were eager to collaborate, generate and present a unique group model that will be selected to serve as standard for all groups at the end of the model assessment. It was also clear that some appreciable numbers of pre-service teachers (within group) were zealous to be at the stage to present the generated model. The students were able to interact within group, with materials, ask themselves and the teachers questions on the issues not clear to them. Hence, in line with Vygostky, such a strategy that provides students with ample opportunities to socially interact and co-operatively engage in some types of activities with support from the teacher and more knowledgeable peers is germane for enhancing interest in science. Dewey as cited in Oh, Jia, Lorentson and LaBanca (2012) in the same token maintains that such interest is a motive that engaged students toward an occupation and the gaining of experience. In this 21st century, it is noted that chemistry in particular offer prospective career opportunities to students and as such arousing studentsô interest in chemistry could promote vocational interest in it and related careers in the dynamic world. For prospective teachers in particular, it will not only model good teaching methods but can increase interest in science which is an important motivator.

Influence of gender on pre-service teachers' achievement in Chemistry when taught using MBI.

The findings of this study as shown in Table 9 (p. 125) revealed that male pre-service teachers had a posttest mean score of 39.18 with a mean gain of 17.13 while the female pre-service teachers obtained a posttest mean score of 33.78 with a mean gain of 12.45. However, for each of the groups, the posttest means were greater than the pretest means with the male pre-service teachers having a higher mean in the posttest. This is an indication that gender may have some influence on pre-service teachersô achievement in Chemistry. The null hypothesis authenticate that there was a significant difference in the mean achievement scores of male and female pre-service Chemistry teachers when exposed to MBI. Thus, male pre-service teachers benefitted significantly more than their female counterparts regardless of the provision of initial platform of understanding (a model), a combination of material activity and deep subject matter in MBI. The finding of this study disagrees with that of Abdullahi, Danladi and Mohammed (2015) which revealed no significant difference in the academic achievement (by gender) of pre-service chemistry students exposed to cooperative learning strategy. However, result of the study confirmed the research findings of Ezeudu and Obi (2013), Eriba and Ande (2007) which established that boys performed better than girls in achievement test in chemistry. Louis and Mistele (2011) also found a similar result in which male students outperformed female students in mathematics and sciences and Wolf and Fraser (2006) as well discovered inquiry -laboratory activities to be differentially effective in favor of males than females. The achievement in favor of boys in this regard probably suggests that girls may perform lower than boys in science education. Miller & Halpern (2014) and Njoku (2000) maintain that this might be due to socio-cultural factors which jointly and separately depress femalesô participation and achievement in science at all levels of education. In this study, pre-service teachersô socio-cultural background in North West geopolitical zone, especially the malesô and femalesô social interaction orientations might have overwhelmed the opposite sexes to equally utilize the unique achievement opportunities in MBI. The composition of MBI group peers (with few girls) might have further contributed to the outcome of the study. This is in line with the views of Legewie & DiPrete (2012) who documented that social composition of the student body (composition of classroom peers) affects achievement, independent of the studentôs own social background, than is any school factor. However, this social context embodies the reciprocal influence of stereotyped science as masculine (Nosek et al. 2009) and probably places females at disadvantage. Miller & Halpern (2014) further support the result of this study that gender stereotypes may influence cognitive sex differences through a complex phenomenon known as stereotype threat (being at risk of confirming a negative stereotype about oneôs social group). Thus, the negative gender stereotypes pre-service teachers hold about their chemistry abilities can lower their performance in chemistry achievement test and according to Miller & Halpern (2014) can even cause differences in brain activation. Besides, it is empirically proved that a particular treatment (instructional technique) did not have a significant effect on the content knowledge acquisition scores but had a significant effect on skills acquisition (Sandeg and Odabasi, 2009). Hence, the established gender disparity on achievement in this study is not a precursor that there will be a similar gender disparity on skill acquisition using MBI. The differing abilities among genders in academic achievement shaped by cognitive and social context is reflected in Vygotskyôs view that human development (e.g. social characteristics, communication styles, cognitive ability and academic background) originate and develop out of social and cultural interaction. As knowledge is situated in the culture and within a historical context, meaning is the result of participation in social activities. Nevertheless, the result of this study indicates that the female pre-service teachers are capable of doing chemistry as reflected in the difference between the mean gain scores of males and females in MBI. **Influence of gender on pre-service teachers' creative skills acquisition in Chemistry when taught using MBI**

The findings of this study as shown in Table 10 (p.126) revealed that male pre-service teachers had a posttest mean score of 19.00 with a mean gain of 14.82 while the female pre-service teachers obtained a posttest mean score of 20.11 with a mean gain of 15.89. For each of the groups, the posttest means were greater than the pretest means. Result is indicative that female pre-service teachers performed slightly better than their male counterparts in the acquisition of creative thinking skills when taught using MBI instructional technique. However, this difference was not significant. Thus, gender may have no influence on pre-service teachersô Creative thinking skill acquisition in Chemistry. Influence of past experiences and practices on learning may account for the slight difference in the mean gain between males and females. This finding is similar to that of Gyuse, Achor and Chianson (2015) which discovered that there was no significant difference between mean creativity level of male and female students. However, the finding of this study is dissimilar to that of Abayomi (2015) who discovered that female students showed a higher improvement in creativity than their male counterparts when exposed to learning by doing. Despite the fact that male pre-service teachers significantly outperformed their female counterparts in achievement for probable reasons aligned to studentsô socio-cognitive and stereotypical perspectives, the unique activities/conversations in MBI offered opportunity for both genders to operate equally to such an extent, though not significant, for females to acquire creative skill slightly higher than their male counterparts. The absence of significant influence of gender on the acquisition of creativity skill in chemistry as revealed in this study was evidenced in the MBI instructional delivery video coverage. They displayed novelty on the use of materials for models generation/construction, colorful presentations of models depicting accuracy and precision with some groups animating sections of the models (e.g. mechanism of Markovnikoffôs rule). Additionally, novelty was also identified in two separate tasks that require pre-service teachers to first draw the geometry of methane using ball and stick model and secondly insert their model of methane into a tetrahedron showing the four faces of the geometry. Majority of pre-service teachers used the same ball and stick model of methane drawing to reflect the four faces of the tetrahedron while few drew additional diagram to show the tetrahedrons. They exhibit fluency in issues related to environmental sustainability such as the need to replace non biodegradable polymers with biodegradable ones and designing syntheses (at molecular level) that are cost effective in waste disposal and regulations through green chemistry. Moreover, pre-service teachers in the MBI demonstrate high level of flexibility in identifying the entrepreneurial potentials in Chem 221 with waste to wealth and production of household materials such as dye, fresheners as being unique among numerous propositions. The acquisition of these creative skills was possible because the manipulative activities in MBI stimulated both male and female pre-service teachers but slightly more in favor of the females. These is supported by cognitive learning theorists such as Dewey, Piaget and Vygotsky who emphasized active learning to foster growth of knowledge and positive attitudes through interaction with the world, people and things. Since sustainable development is participatory (males and females) and involves equity (Nwosu, 2015), this will ultimately help male and female pre-service teachers develop sustainability related competencies required for the 21st century such as sound thinking and creative problem solving. Such skills will enable them to participate in solving local, national, and global problems that threaten our collective well-being in the dynamic world. Their ability to solve novel problems, communicate and collaborate, create new products and processes, deal with uncertainties, adapt to continuous change of the 21st century will therefore be a greater advantage both personally and professionally.

Influence of gender on pre-service chemistry teachers' critical skills acquisition in Chemistry when taught using MBI

The findings of this study as shown in Table 11 (p.127) revealed that male chemistry pre-service teachers had a posttest mean score of 19.82 with a mean gain of 11.87 while the female chemistry pre-service teachers obtained a posttest mean score of 19.89 with a mean gain of 10.67 For each of the groups, the posttest means were greater than the pretest means. Results showed that male pre-service teachers did not perform significantly better than their female counterparts in the acquisition of critical thinking skills when taught using MBI instructional technique. The finding of this study is similar to that of Heong, Yunos & Hassan (2011) and Myer and Dyer (2006)which showed that no higher order thinking skill and critical thinking skill differences respectively existed between male and female students in higher education. The non existence of significant gender influence on the acquisition of critical thinking skill unveiled by this study could be elucidated by the fact that MBI instructional technique offered unique and equal opportunity devoid of the influences of socio-cognitive and stereotypical orientations for both males and females pre-service teachers to become stimulated/excited in the manipulative activities culminating into the development of these rationality traits. These attributes eventually promote studentsô cognitive, higher order thinking skill and learning satisfaction. The activities that culminate in to the development/acquisition of critical thinking skill are typical of the position of Piaget, Dewey and Vygotsky in the construction of authentic knowledge. Critical thinking skills are crucial in this millennium because they enable students to deal effectively with social, scientific, and practical problems (Shakirova, 2007). In a nutshell, students (both male and females) who are able to think critically are able to solve problems effectively. Merely having knowledge or information is not enough to be effective in the workplace (and in their personal lives), students must be able to solve problems to make effective decisions, and they must be able to think critically. The outcome indicated that pre-service teachers developed higher mental abilities which could be transferred to totally different situations. This is substantiated by the almost similar male and female pre-service teachersô post test mean scores in the components of critical thinking skills.

Influence of gender on pre-service chemistry teachers' interest in Chemistry when taught using MBI.

The result presented in Table 12 (p. 128) revealed that male chemistry pre-service teachers had a posttest mean score of 93.80 with a mean gain of 29.52 while the females obtained a posttest mean score of 92.67 with a mean gain of 29.78. Although both males and females showed improved interest, females had a slightly higher mean gain above males (0.26). The result of this study therefore indicates that gender have no influence on studentsô interest in Chemistry when taught with MBI. Conversely, the finding of Hagay, Baram-Tsabari, Ametller, Cakmakci, Lopes, Moreira, and Pedrosa-de-Jesus, (2012) contradicts the result of this study in which they found that gender had a strong effect on studentsô level of interest. The result of this study also contradicts the finding of Trumper (2006) which revealed that studentsô overall interest in physics was ñneutralò (neither positive nor negative) but with boys showing a higher interest than girls. Nevertheless, the result of this study confirms the earlier finding of Igboanugu (2014) which revealed that the interests of both male and female students in secondary school difficult chemistry concepts are captured alike by cooperative learning. The finding of this study is also similar to Nworgu (2004) who found out that gender sensitization enhanced overall achievement of students in science and reduce gap that existed between male and female students in interest. The absence of gender influence on studentsô mean interest score in this study is in line with Deweyôs emphasis that all students should have the opportunity to take part in their own learning. Hence MBI provided the environment where all students irrespective of their gender actively participated in the learning process. This is likely due to the unique studentsô interactive opportunities the instructional technique offered in which the model generation activities focus pre- service teachers not only on material activity culminating in to testing of predictions but also center on testing of idea grounded in deep subject matter understanding. Since sustainable development is participatory (males and females) and involves equity (Nwosu, 2015) and interest is a motive that engaged students toward an occupation and the gaining of experience, interest in chemistry could promote both male and female pre-service teachersô vocational interest in it and related careers in the dynamic world. For prospective teachers in particular, it will not only model good teaching methods but can increase interest in science which is an important motivator.

Interaction effect of treatment and gender on pre-service teachers' achievement

The data on Table 2 (p. 120) revealed that there was no significant interaction effects of treatments and gender on pre-service teachersô mean achievement scores in Chemistry. This means that the method did not have different effects on pre-service teachersô achievement depending on gender. Rather the method has constant effects on achievement independent of the studentsô gender. Hence, method was more effective on achievement than pre-service teachersô genders. In this study, all pre-service teachers (boys and girls) benefitted equally from MBI instructional technique in terms of achievement. This thus gives the support that the difference in achievement in favor of the male pre-service teachers is possibly related to socio-cognitive and stereotypical issues but not the MBI. This result is not in agreement with Adegoke (2011) who found a significant interaction effect between treatment and cognitive style preference. Nevertheless, the finding of this study is found to be similar to that of Oladejo, Olosunde, Ojebisi and Isola (2011) who discovered that there was no significant interaction effect of treatment and gender on student achievement in Physics. The outcome of the study is also similar to Adekoya and Olatoye (2011) who found out that there is no significant interaction effect of treatment and gender on studentsô achievement in pasture and forage crops. The absence of interactive effect of method and gender on the studentsô achievement in this study could be attributed to the fact that MBI instructional technique provided the opportunity for all the students irrespective of gender to be actively involved in interactive learning situations, hence all pre-service teachers benefitted equally irrespective of their gender.

Interaction effect of treatment and gender on pre-service teachers' creative thinking skills acquisition in Chemistry

The findings of this study from Table 4 revealed that there is no significant interactive effect of method and gender on the pre-service teachersô creative thinking skill acquisition in chemistry. This means that the method did not have different effects on acquisition of creative skills in chemistry depending on gender rather the method has constant effects on acquisition of creative skills independent of the pre-service teachersô gender. The finding of this study agrees with that of Nwagbo and Chukelu (2011) who discovered that there was no interaction between method and gender on studentsô process skill acquisition in biology practical activities. The findings is however dissimilar to Njoku (1997) whose findings revealed that sex groupings and school location had significant interaction effect on studentsô acquisition of chemistry practical skills. This implies that for Njokuôs study, male and female students did not benefit equally due to school locations. The findings of this present study revealed that there is no interactive effect of method and gender on pre-service teachersô creative thinking skills. This could be explained by the fact that both male and female students are provided equal environment to operate and this environment was gender friendly and benefitted all the students. The treatment is constant hence more efficacious in the acquisition of creative thinking skills for both male and female pre-service teachers. They all utilize the MBI interactive provisions particularly during seeking evidences phase to authenticate their group models propelled by the desire come up with the best model.

Interaction effect of treatment and gender on students' critical thinking skills acquisition in Chemistry is not significant.

The findings of this study from Table 6 (p. 122) revealed that there is no significant interactive effect of method and gender on the pre-service teachersô critical thinking skill acquisition in chemistry. This means that the method did not have different effects on acquisition of critical thinking skills in chemistry. Thus, method has constant effects on acquisition of critical thinking skills independent of the studentsô gender. The finding of this study agrees with that of Nwagbo and Chukelu (2011) who discovered that there was no interaction between method and gender on studentsô process skill acquisition in biology practical activities. The findings however contradicts Njokuôs (1997) whose findings revealed that sex groupings and school location had significant interaction effect on studentsô acquisition of chemistry practical skills. The finding is also dissimilar to Ellinwood (1997) who found a significant interaction effect between computer programming instruction group (logo and non-logo) and gender on the higher-order thinking skills and mathematical achievement of first grade students. The females in the Logo group performed significantly better on the Computation subscale than the females in the non-Logo group. This implies that the male and female students did not benefit equally due to school locations and method respectively. The findings of the present study revealed that there is no interactive effect of method and gender on pre-service teachersô critical thinking skills. This could be explained by the fact that both male and female students are provided equal environment to operate and this environment was gender friendly and benefitted all the students. They all utilize the MBI interactive provisions particularly during seeking evidences phase to authenticate their group models propelled by the desire come up with the best model. Hence acquisition of more critical thinking skills by the MBI pre-service teachers irrespective of gender was mainly due to the treatment.

Interaction effect of treatment and gender on pre-service teachers' interest in Chemistry

The outcome of this study as shown in Table 8 (p. 124) showed that there was no significant interaction effect of method and gender on the pre-service teachersô mean interests scores in chemistry. This means that the method did not have different effects on studentsô interest in biology; depending on gender rather the method has constant effects on their interest independent of the pre-service teachersô gender. Hence the effect increase in studentsô interest was mainly due to the method. This finding is supported by that of Okigbo and Okeke (2011) who revealed that there was no interaction between method and gender on studentsô mean interest in mathematics. The absence of interaction effect of method and gender on the studentsô interest in chemistry indicated that MBI approach benefitted both male and female pre-service teachers equally in enhancing their interest in chemistry. This could be explained by the fact that the interactive nature of MBI especially from the step where they seek evidences up to model authentication guided by analytical processes to arrive at judgment that is directed by a specific end purpose of producing a unique group model. These attribute caused both males and females pre-service teachers to benefit equally and so were found to be interested in chemistry.

Conclusion

Based on the findings and implications, the following conclusions were made:

The use of MBI instructional technique significantly increased the pre-service teachersô means scores in achievement, creative and critical thinking skills acquisition in chemistry compared to CI.

The use of MBI instructional technique also improved the interest of pre-service chemistry teachers compared to CI.

Gender has significant effect on pre-service chemistry teachersô mean score of achievement with MBI. However, gender has no significant effect on pre-service teachersô means scores of creative and critical thinking skills acquisition and interest in chemistry when taught with MBI.

The interaction effects of treatment and gender on pre-service chemistry teachersô means scores on achievement, creative and critical thinking skills acquisition were not significant. Finally, the interaction effect of treatment and gender on pre-service teachersô means interest in chemistry is not significant. These indicated that treatment had a constant effect on pre-service chemistry teachersô achievement, acquisition of creative thinking skill, critical thinking skill and interest, irrespective of studentsô gender.

Educational Implications of the Findings

Based on the findings of this study, the following educational implications were derived.

The findings revealed that the group exposed to MBI approach had higher achievement mean scores than those taught with Conventional Inquiry instructional technique. This implies that MBI approach is more effective than the Conventional Inquiry approach on achievement of pre-service chemistry teachers. Hence the use of MBI in teaching chemistry will benefit the pre-service chemistry teachers in becoming fulfilled individuals who can solve science and science related issues now and in the future. As prospective teachers, they will thus be able to utilize the experiences obtained from the activities in MBI to improve the adoption of innovative strategies that will improve studentsô achievement in science for enhanced future education base and careers in science.

The result of this study has shown that MBI approach enhanced the pre-service teachersô creative and critical thinking skills in chemistry. This implies that MBI is more efficacious than the Conventional inquiry instructional technique in the acquisition of the two skills. Thus, MBI will avail pre-service teachers the opportunity for the acquisition of sustainability related competencies required for the 21st century. As prospective teachers exposure to MBI will improve the quality of their certificate for success in classrooms and personal lives.

The result of the study also gives credence to the claim that females are not inferior to males in skills acquisition especially of creativity and critical thinking as well as interest. This implies that with MBI instructional technique, male and female students have equal learning opportunities.

The interaction effect of method and gender not being significant revealed by the study indicated that the method (MBI) is more efficacious than gender in ensuring achievement, acquisition of creative and critical thinking skills and interest of pre-service chemistry teachers. This implies that gender disparities resulting from socio-cultural context, cognitive abilities and stereotypes in home and schools can be eradicated using effective and innovative teaching methods such as MBI as seen in this study.

Since MBI proved to be more efficacious than the CI, the results of this study therefore have implication for pre-service and in-service training institutions. Adoption of the MBI by teacher educators will avail them the opportunity to orientate their subjects on ñhow to do itò with realistic experience for improved studentsô achievement, interest and careers in science.

These findings have implications for education planners and most specifically the pre-service teachersô regulatory bodies such as the National Commission for Colleges of Education (NCCE). They need to reflect and advocate for the adoption of innovative instructional strategies such as the MBI in curriculum reviews and related issues. They also need to constantly organize workshops and seminar for the teachers on the field in order to sensitize them to new, more productive approaches like the MBI.

Recommendations

Based on the findings and conclusion reached in this study, the following recommendations are hereby made:

1. The National Commission for Colleges of Education (NCCE) should incorporate MBI instructional technique in the N. C. E. minimum standard, especially in the science courses. The curricular content packages in the minimum standard should be restructured to aid pre-service teachersô training through MBI.
2. College of Education Teacher educators (lecturers) should use MBI in teaching pre-service teachers. This will assist the prospective teachers to acquire the required professional knowledge, attitudes and skills which would enable them to become competent chemistry teachers with the capacity to further encourage the spirit of critical thinking and creativity in the learners and to apply the skills and knowledge to solve day-to-day problems in the dynamic world.
3. The state and local government in conjunction with the Federal Ministry of Education should endeavor to organize in-service training in form of workshops, seminars, conferences and symposia regularly for science teachers to enable them update their knowledge, attitudes and skills on the use of innovative teaching strategies such as

MBI. Professional organizations such as Science Teachers Association of Nigeria (STAN) and other donor agencies such as DFID should follow suit.

4. Textbook writers should specify guides that will help students to be creative and critical thinkers and independent learners. Science text books should also be reviewed to include better improved inquiry instructional methods employed in science education. This will help the students to be aware that learning is their responsibilities and will be ready to face challenges in any learning situation. Textbook writers should also see the need to avoid gender stereotyping of pictures, illustrations, activities and science textbooks content. The science textbook writers should also endeavor to update the textbooks to reflect the basic scientific skills that will meet the need of the 21st century society.

Limitations of the Study

The following limitations were observed regarding this study:

1. Though the researcher trained the chemistry lecturers involved in this study, whose academic qualification are the same, other extraneous variables like lecturersô personality and teaching environment may have affected the results of this study.
2. The impossibility to randomize the sample and assign subjects to treatment groups.

Suggestions for Further Studies

Considering the findings of this study, suggestions for further studies were made in the following areas:

1. The study could be replicated to encompass a considerable larger sample size so that generalization could be made.
2. The study could be replicated in other parts of the country to ascertain the effect of MBI instructional technique in other subject areas like physics, mathematics and biology with other variables.

3. The replication of the research is invited particularly targeting various levels of studentsô age, socio-economic status and location.

Summary of the Study

The main purpose of this study was to investigate the effect of Model-Based Inquiry (MBI) and Conventional Inquiry (CI) instructional technique of teaching on pre-service teachersô achievement, acquisition of skills and interest in chemistry. This desire was motivated by the need for the prospective teachers to acquire sustainability related competencies (creative and critical thinking skills) for survival in the 21^{st} century and develop same in their students. Studies found that most of the methods adopted in teaching failed to encourage studentsô acquisition of creative and critical thinking skills in science. Students have been reduced or have reduced themselves to mere recipient of information. There was emphasis on the students knowing only the products of scientific inquiry rather than being involved in the process of doing science through activity based strategies such as the inquiry. Consequently the performance of prospective teachers in chemistry and the development of requisite survival competencies have not been satisfactory. Hence this study was conducted in attempt to find out if the use of an innovative instructional technique such as MBI could redeem the current situation by allowing pre-service teachers to integrate modeling into inquiry instructional technique. This is to stimulate prospective teachersô achievement, acquisition of creative and critical thinking and interest in chemistry irrespective of gender. Eight research questions and twelve null hypotheses guided the study. The hypotheses were tested at 0.05 level of significance.

Related literatures were reviewed under three broad headings conceptual, theoretical frameworks and related empirical studies. The conceptual framework was further sub-divided into chemistry education delivery, concept of inquiry, concept of model-based inquiry, NCE chemistry education, concepts of achievement, skills acquisition, interest and gender. The literature has it that an inquiry-based learning approach has the potential for enhancing the studentsô achievement and interest in science. However there is dearth of studies that considered the acquisition of creative and critical thinking skills as factors in Model-based inquiry instructional technique, hence the need for the study. The theoretical framework hinges on Constructivism (socio-cognitive) which ground in Dewey and Piagetsô cognitive theories of learning. The theorists believed that leaning is enhanced in activity-based social environments.

This study adopted a non-equivalent control group (quasi experimental) design. The population of the study comprised of 945 NCE II chemistry students from 7 states Colleges of Education (COE) in North West geopolitical zone. The sample comprised of 174 NCE II chemistry students of Zamfara state COE, Maru and Isa Kaita COE dutsinma, Katsina state, randomly drawn through simple random sampling by balloting. The two states COE were randomly assigned to experimental and control groups respectively and their intact classes consisting of males and females were used. The experimental groups were taught CHEM 221 using Model-Based Inquiry while the control groups were taught the same course using Conventional Inquiry instructional technique. The intact classes were taught by the regular CHEM 221 lecturers in each of the colleges.

The following validated research instruments were used ï Chemistry Achievement Test (CAT), Creative Thinking Test (CTT), Test of Critical Thinking (TOCT), Chemistry Interest Inventory (CII) and two instructional programs, one Model-Based Inquiry lesson plan and the second on Conventional inquiry lesson plan. All the instruments were validated and used for the study. The internal consistency reliability coefficient estimate for CAT was 0.81 using K-R 20, Pearson product moment correlation coefficient of TOCT was 0.85, Kendalôs Coefficient of Concordance of CTT was 0.79 and Cronbachôs Alpha for CII was 0.87.

The extraneous variables which would have competed with the independent variables of this study in explaining the outcome were controlled through measures adopted by the researcher; for teacher variable, uniform training of graduate research assistants was employed, the use of ANCOVA for initial group differences and for Hawthorne effect normal course tutors were used.

Data collected with the help of the research instruments was descriptively and inferentially analyzed using means, standard deviation and ANCOVA. Descriptive analysis based on the observation from videotaped classroom instruction was done to assess the changes both in quality and quantity especially on studentsô interactions in model generation activities.

The study yielded the following results:

1. The use of MBI had significant effect on the pre-service teachersô achievement in chemistry.
2. The use of MBI had significant effect on pre-service teachersô means scores of creative thinking skills in chemistry.
3. The use of MBI had significant effect on pre-service teachersô means scores of critical thinking skills in chemistry.
4. The pre-service teachers taught with MBI gained more interest in Chemistry.
5. Gender has significant effect on pre-service teachersô mean achievement scores when taught chemistry with MBI.
6. Gender has no significant effect on pre-service teachersô mean scores of creative thinking skills when taught chemistry with MBI.
7. Gender has no significant effect on pre-service teachersô mean scores of critical thinking skills when taught chemistry with MBI.

8. Gender has no significant effect on pre-service teachersô mean interest scores in chemistry using MBI.
9. The interaction effect of treatment and gender on the studentsô mean achievement in chemistry is not significant.
10. The interaction effect of treatment and gender on pre-service teachersô means scores of creative thinking skills in chemistry is not significant.
11. The interaction effect of treatment and gender on pre-service teachersô mean score of critical thinking in chemistry is not significant.
12. The interaction effect of treatment and gender on pre-service teachersô means interest scores in chemistry is not significant.

The findings of the study were extensively discussed. The educational implication, conclusion and recommendation were highlighted. Limitations of the study and suggestion for further research were also provided.

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APPENDIX A

THE COURSE OUTLINE FOR CHEM: 221

CHEM 221 ORGANIC CHEMISTRY I 2 Credits Compulsory

(MECHANISM IN EACH OF THE VARIOUS REACTIONS IN THE COURSE IS NECESSARY)

Chemistry and molecular geometry of alkanes. Electrophilic and nucleophilic addition. Oxidative cleavage and its application in structural determination (e.g. Ozonolysis). Relative stabilities of carbonium ions. The Markownikoffӧs rule
Free radical addition. Reduction Polymerization, addition of polymers from alkenes and vinyl compounds, natural and synthetic rubber. Conjugated dienes: electrophilic 1, 2 ï and 1, 4 ï additions to conjugated dienes. Resonance orbital interaction.
Alkyne chemistry: acidity of ъ C ſ C ъ and reactions of ъ C ſ C ъ.

The objectives of this course as stated in the New National Commission for Colleges of Education (NCCE) minimum standard are as follows;

1. describe the geometry of saturated hydrocarbons
2. identify electrophiles and nucleophiles in a chemical reaction
3. state Markonikuffӧs rules and its application on unsymmetrical olefins
4. describe the reactions of unsaturated hydrocarbons including dienes

APPENDIX B

TABLE OF SPECIFICATION FOR THE CHEMISTRY ACHIEVEMENT TEST (CAT)

COMPONENTS OF THE CAT	KNOWLEDGE **10%**	COMPREHENSION **15%**	APPLICATION **20%**	ANALYSIS **25%**	SYNTHESIS **15%**	EVALUATION **15%**	TOTAL **100%**
Classification/geometry And nomenclature **20%**	(1), 5,	(2), 4,14	(2), 41,1	(3), 43, 35,57	(2), 44,58	(2), 45,28	12
Physical and chemical Properties of alkanes **20%**	(1), 3,	(2), 2,26	(2), 8, 42	(3), 16,30, 60	(2), 6,9	(2), 7,59	12
Physical and chemical Properties of alkenes **25%**	(2), 27,38	(2), 17,36	(3), 48,10 12	(4),11, 29,37,50	(2), 13,51	(2), 49, 56	15
Physical and chemical Properties of alkynes **15%**	(1), 39	(1), 18	(2), 52,47	(2), 19,20,	(1), 21	(1), 33,	8
Polymerization **5%**	Dž	(1), 15	(1), 31	(1), 32	(1), 34	(1), 46	5
Conjugated diene and Chemical properties of Rubber **15%**	(1), 24	(1), 22	(2), 25,53	(2), 54,23	(1), 40	(1), 55	8
TOTAL **100%**	6	9	12	15	9	9	60

APPENDIX C

CHEMISTRY ACHIEVEMENT TEST (CAT)

CHEMISTRY 221 (ORGANIC CHEMISTRY 1)

INSTRUCTIONS TIME: 1hr

1. Studentôs I D Number................................ Sex: Male ☐ Female ☐
2. Attempt all questions in the question paper
3. Tick (ã) against the letter (a ï d) of your choice and erase or cancel an earlier choice, if you have changed your mind.
4. Use HB pencil only.

1) Which of the following features dominate the shape of organic compounds?

a. planer

b. tetrahedron

c. Tetrahedral

d. Trigonal planer

2) The general formula for Alkanes is

a. CnH_{2n-2}

b. CnH_{2n+2}

c. CnH_{2n}

d. CnH_{2n+1}

3) The carbon atoms in an alkane molecule areé

a. Sp hybridized

b. Sp^2 hybridized

c. Sp^3 hybridized

d. Sp^4 hybridized

4) $CH_3C(CH_3)_2CH_3$ is named as

a. butane

b. methylbutane

c. dimethylbutane

d. 2,2-dimethylpropane

5) Which of the following is a saturated hydrocarbon?

a .C_2H_6

b C_2H_4

c C_2H_2

d C_3H_6

6) Alkanes are said to be hydrophobic because é ..

a. they dissolve in water

b. they do not dissolve in water

c. they dissolve in acid

d. they do not dissolve in acid

7) Which of the following statements is true about alkanes?

a. Branched alkanes boils at higher temperature than the corresponding normal alkanes

b. Cycloalkanes have lower boiling point than the corresponding unbranched alkanes.

c. The straight chain alkane has more surface area for Vander waalôs attraction than branched alkanes.

d. They have electron rich centers

8) The catalytic hydrogenation of alkene will give rise toé

a. haloalkane

b. unsaturated hydrocarbon

c. hydrogen halide

d. saturated hydrocarbon

9) How many monochlorinated products are possible in the chlorination of higher alkanes?

a. 4 & 2 b. 3 c. 1 & 3 d. 2

10) Which of the following is a typical electrophilic addition reaction?

a. $CH_3CH_2^+$ + HBr

b. CH_3CHO + HCN

c. CH_3CH_3 + HBr

d. $CH_3CCl_2CH_3 + H_2$

11) Which of the following is a nucleophile?

a. HCN b. HBr c. $NaHSO_3$ d. H_2SO_4

12) The breakage of carbon-carbon double bond through oxidation is calledé

a. reduction

b. cracking

c. oxidative cleavage

d. combustion

13) The electrophilic addition to an alkene result in a product with the electrophile bonded to the carbon atom that already hold the highest number of hydrogen atoms This statement is in accordance with :

a. Hookôs law
b. Boyleôs law
c. Hundôs rule
d. Markownikovôs rule

14) Which of the following carbonium ion is most stable?

CH_3	H	H	H
a. CH_3-C+	b. CH_3-C+	c. CH_3-C+	d. H-C +
CH_3	CH_3	H	H

15) The joining togetherr of many small molecules to form very large molecule is reffered to as.

a. photosynthesis

b. polymerization

c. halogenation

d. electrolysis

16) Which of the following are liquid at room temperature?

a. methane and ethane

b. propane and butane

c. pentane and hexane

d. heptanes and octane

17) Diens in which the double bonds alternate with single bonds are called..

a. isolated dienes

b. cumulated dienes

c. multi dienes

d. conjugated diens

18) A hydrocarbon which contains a triple bond in its structure is referred to as:

a. alkyne b. alkane c. alkene d. alkyl

19) Alkynes are regarded as unsaturated hydrocarbons because of:

a. the presence of long chain structure

b. the presence of electron rich center.

c. the absence of pi electron in its structure

d. the presence of hydrogen atoms in its structure

20) Alkynes are nearly insoluble in water because:

a. they contain hydrogen
b. they do not form ion
c. they are non polar
d. they behave like acid

21) Hydration of alkynes gives rise to -------as the major product

a. aldehyde

b. alkane & aldehyde

c. alcohol & ketone

d. ketone

22) Natural rubber consists of:

a. 2-methyl-1,3-diene

b. 2-methylbutane

c. 2-methyl-1,2-diene

d. 2-chlorobut-3-dien

23) Vulcanized natural rubber has the following characteristics **except**

a. elasticity

b. stickiness

c. durability

d. greater tensile strength

24) Addition of sulphur and heating to the soft rubber in order to become hard is calledé .

a. degredation

b. elasticity

c. vulcanization

d. cross lincage

25) Alpha diketone is produced whené

a. alkane is treated with oxygen

b. alkene is treated with aqueous potassium permanganate.

c. alkyne is treated with alcohol

d. alkyne is treated with aqueous potassium permanganate

26) A family of hydrocarbon in which each member differs from the preceding one by CH_2 is called:

a. homologous series

b. alkane series

c. hydrocarbon series

d. alkyl group

27). The existence of two or more organic compounds with the same molecular formula but different structural arrangement of atoms in the molecule is referred to as:

a. esterification

b. isomerism.

c. electrolysis

d. photosynthesis

28). The arrangement of atoms around carbon becomes not tetrahedral when;

a. there is a functional group in the organic compound structure

b. a carbon atom carries a positive or negative charge

c. the carbon forms double or triple bond

d. the carbon form multiple single bonds

29). Hydrogenation of alkenes gave rise to

a. hydropropene

b. propene

c. propyne

d. propane

30). Which of the following statements is true about alkane?

a. the density of normal alkane increases with increase in the number of carbon atom

b. branched alkanes boil at higher temperature than normal alkane with the same number of carbon atoms

c. Alkanes with even number of carbon atoms melt at lower temperature than the alkanes with odd number of carbon atoms.

d. all of the above

31).The stage at which a monomer unit adds to active centre with the regeneration of the active centre after each addition is called:

a. initiation stage.

b. propagation stage

c. termination stage

d. ionization stage.

32).Which of the following is <u>not</u> a stage in the chain reaction polymerization?

a. propagation stage

b. termination stage

c. ionization stage

d. initiation stage

33). Internal alkyne contains the triple bond located at:

a. the end of the chain

b. the middle and the center of the chain

c. two ends of the chain

d. the center of the chain

34). Chain reaction polymerization can be initiated via all of the following except:

a. alkyl group

b. free radical

c. anion

d. cation

35). Which of the following atoms lie in the same plane in methane geometry?

a. 2 hydrogen atoms

b. 2 hydrogen atoms and the carbon atom

c. 3 hydrogen atoms

d. 3hydrogen atoms and the carbon atom

36). An electron- deficient specie which attack an electron rich center in a chemical reaction is called?

a. Electrophile

b. Nucleophile

c. Isomer

d. monomer

37). Aldehydes are more reactive than ketones due to

a. presence of carbonyl carbon

b. inductive effect

c. presence of double bond

d. presence of Oxygen

38). An electrically neutral atom or group of atoms possessing unpaired electrons is called?

a. Isomer

b. monomer

c. electrophyle

d. free radical

39). Terminal alkynes have their triple bonds located até é é

a. the center of the chain

b. middle of the chain

c. end of the chain

d. top of the chain

40). If the double bonds in a dienes alternate with single bonds, the resulting specie is called?

a. Conjugated dienes

b. Isolated dienes

c. Cumulated dienes

d. Straight chain dienes

41). Which of the following is not a determinant of physical properties of organic compounds?

a. structure of the functional group

b. dipole moment of the molecule

c. stability of electrons of sigma bond

d. hydrogen bonding

42) The bond angle in tetrahedral geometry is

a. 105.9^0

b. 180.5^0

c. $109,5^0$

d. 160^0

43). What is the hybrid orbital of each carbon in ethane?

a. sp^2

b. sp

c. sp^3

d. s^2p

44) What is the shape of bonding orbitals in methane?

a. tetrahedral

b. trigonal planer

c. linear

d. tetrahedral planer

45) What is the geometry of an organic compound having 2 atoms and 1 triple bond in its molecule?

a. tetrahedral

b. trigonal planer

c. linear

d. tetrahedral planer

46) Which of the following is the actual sequence of bond breaking and forming during organic reaction?

a. reaction coordinate

b. bond fission

c. bond fusion

d. reaction mechanism

47) Which of the following reaction is very common to Alkynes?

a. addition reaction

b. substitution reaction

c. elimination reaction

d. condensation reaction

48) A reaction used in structural determination of an alkene molecule is called;

a. substitution

b. ozonolysis

c. elimination

d. addition reaction

49) The ´ electrons in alkene invite the attack of

a. electrophile

b. free radical

c.electrophile and free radical

d. electron or free radical

50) The reaction of alkenes with asymmetrical molecules include the following except;

a) addition of bromine water

b) addition of HBr

c) addition of conc. Sulphuric acid

d) catalytic hydrogenation

51) Alkenes are raw materials used in making the following common polymers except;

a. polyesters & polyethene

b. polyethene

c. polypropene & polystyrene

d. polystyrene

52) Which of the following have the highest boiling point?

a. ethyne

b. ethane

c. ethene

d. 1, 3 butene

53) The stability of conjugated diene is enhanced by the following except

a. resornance stability

b. delocalization of charge

c. less óSô character

d. hybridization energy

54) When HBr adds on to 1,3,Butadiene, the most predominant product is

a. 3, Bromo-1-butene

b. 1 Bromo-2-butene

c. 3 dibromo-1-butene

d. 1,4,dibromo-2-butene

55) The 1,2, and 1,4 used in the electrophilic addition of conjugated diene describe the

a. IUPAC nomenclature

b. positions of the two double bond in molecular structure

c. addition takes place at either carbon 1,2 or 1,4 of the 4 carbon atom system

d. addition takes place at carbon 1,2 and 1,4 of the 4 carbon atom system

56. Which of the following organic compound group have the general molecular formula of C_nH_{2n}?

a. aromatic hydrocarbon

b. alkanes

c. alkynes

d. cycloalkanes

57. Methane has the same electron pair geometry with;

a. ethane and cyclohexane

b. ammonia and water

c. water and alcohol

d. HF and alcohol

58. As soon as more complex molecules are encountered, each atom must be examined as;

a. a center for a particular geometry

b. separate individual geometries

c. a determinant of a particular geometry

d. part of the entire molecular geometry

59. Which of the following has the potential of undergoing combustion with less oxygen to give carbon (1V) oxide and water only?

a. C_2H_2

b. C_2H_4

c. CH_3O

d. CH_4

60. In substitution reaction with halogens involving the breakage of covalent bond, the type which produces free radicals is/are,

a. heterolysis b. homolysis c. heterolysis and homolysis d. hetero-homolysis

APPENDIX D

CHEMISTRY ACHIEVEMENT TEST (CAT)

MARKING SCHEME

1. C
2. B
3. C
4. D
5. A
6. B
7. C
8. D
9. D
10. A
11. A
12. C
13. D
14. A
15. B
16. C
17. D
18. A
19. B
20. C
21. D
22. A
23. B
24. C
25. D
26. A
27. B
28. C
29. D
30. A
31. B
32. C
33. D
34. A
35. B
36. A
37. B
38. D
39. C
40. A
41. B
42. C

43. A
44. A
45. C
46. D
47. A
48. B
49. A
50. D
51. D
52. A
53. C
54. A
55. C
56. D
57. B
58. A
59. D
60. B

APPENDIX E

TEST OF CRITICAL THINKING (TOCT)

CHEMISTRY 221 (ORGANIC CHEMISTRY 1)

INSTRUCTIONS TIME: 1hr 30 min

1. Studentôs I D Number................................ Sex: Male ☐ Female ☐
2. Attempt all questions in **SECTION A** on the paper provided
3. Tick (ã) against the letter of your choice in **SECTION B** and erase or cancel an earlier choice, if you have changed your mind.
4. Use HB pencil only for **SECTION B**.

SECTION A

1. Land that has been used as a site for rubbish dumps has sometimes been used later as building land. There have been cases of explosions occurring in houses built on such land. From your study of organic chemistry, what could be the course of the explosion?
2. When methane reacts with chlorine, the product varies with the amount of chlorine in the mixture. Why does the amount of chlorine in the mixture determine what the product would be?
3. A student said that the reason why alkenes are unsaturated is that, they can be made by removing water from alkanols. Was the student correct?
4. Justify the statement that, in the reaction between ethene and bromine, the double bond breaks and bromine adds on to the molecule.
5. What do you think went wrong with acetylene lamps to make them explode?
6. After an organic reaction involving the breakage of ů and ´ bonds, ethanal was formed. The chemist who conducted the experiment correctly claimed that there were two different structures for the starting material. What were they?
7. What relates Nylon ï a synthetic non-biodegradable compound with some naturally biodegradable occurring compounds

SECTION B (TOCT)

INFERENCE

After each statement of fact, you will find several possible inferences i.e., conclusions that you might draw from the stated facts. Examine each inference separately, and make a decision as to its degree of truth or falsity.

Statement

Often it is possible to think of several mechanisms for a single reaction. The task of the chemist is to perform experiments that will help to discover which mechanism gives the better explanation.

Inference 1

Molecules in reaction mechanism appear to have the tendency to change the way they react.

A This true

B This is probably true

C There is inadequate data to support this statement

D This is false

E This is probably false

Inference 2

Reaction conditions determine the reaction of a molecule in given reaction mechanism

A This true

B This is probably true

C There is inadequate data to support this statement

D This is false

E This is probably false

Inference 3

A mechanism for a reaction in water may not explain the same reaction if is carried out in another solvent

A This is true

B This is probably true

C There is inadequate data to support this statement

D This is false

E This is probably false

RECOGNITION OF ASSUMPTION

Each statement is followed by several proposed assumptions. You are to decide for each assumption whether a person, in making the given statement, is really making that assumption i.e., taking it for granted, justifiably or not.

Statement

Alkanes are particularly important to us owing to their use as fuels

Assumption 1

The importance of fuels in general to us is equal to that of alkanes

Yes

No

Assumption 2

Alkanes would have been useless besides their use as fuels.

Yes No

Assumption 3

Alkanes must be serving as the major source of our energy

Yes

No

DEDUCTION

In the following statements mark 'YES' under 'Conclusion that follows' and If you think it is not a necessary conclusion from the statements given mark 'NO' under 'Conclusion that follows. Jjust stick to the given statements (premises) and judge whether each conclusion necessarily follows.

Statement

One of the peculiar characteristics of plastic is the fact that it is durable (degrades slowly) but this characteristic is not friendly with the environment.

Deduction 1

Plastics have longer lasting adverse effects to the environment

Yes

No

Deduction 2

Parasitic relationship exists between plastics and the environment

Yes

No

Deduction 3

There is the need for a biodegradable substitute to plastics.

Yes

No

INTERPRETATION

The following exercise consists of a short paragraph followed by several suggested conclusions. If you think that the proposed conclusion follows beyond a reasonable doubt, mark 'YES' under the conclusion that follows. If you think that the conclusion does not follow beyond a reasonable doubt from the facts given, mark 'NO'. **Remember to judge each conclusion independently**.

Statement

If ethane is passed into a solution that contains chloride ions but no bromine, there is no reaction. However if bromine is added to the solution, a reaction occur. If you were to analyze the products you would find that along with 1,2-dibromoethane, there was a considerable amount of 1-bromo-2-chloroethane,

Interpretation 1

No reaction when ethane was passed into the solution containing chloride ions because chloride ions cannot react with ethane directly

Yes

No

Interpretation 2

If you were a bromine molecule approaching the ´ bond of an alkene, the first thing you would notice would be the negative charge of the electrons forming the bond

Yes

No

Interpretation 3

Chloride ions are negatively charged and react rapidly with positively charged ions. But the reaction with bromine, positive ions a not produced.

Yes

No

EVALUATION OF ARGUMENTS

Identify arguments that are strong and arguments that are weak.

NOTE For an argument to be strong, it must be both important and directly related to the question. An argument is weak if it is not directly related to the question regardless of its importance.

Statement

Are the carbonium ions formed during the initial stage of Markovniconikoffõs addition reactions the most energetically stable ones?

Evaluation 1

No; stability of carbonium ions depend on how hydrogen attaches itself to the intermediate

Strong

Weak

Evaluation 2

No; stability of carbocations is determined by the nature of halogenoalkane.or the halide added.

Strong

Weak

Evaluation 3

Yes; all other things being equal, they will be the ones that give the most methyl groups attached to the carbon atom carrying the positive charge.

Strong

Weak

APPENDIX F

RUBRICS FOR SECTION **A** OF TOCT

S/N	Questions	Proficient (3Marks)	Adequate (2 Marks)	Limited (1 Mark)
1	Land that has been used as a site for rubbish dumps has sometimes been used later as building land. There have been cases of explosions occurring in houses built on such land. From your study organic chemistry, what could be the course of the explosion?	Methane is released when the rubbish decomposes under the ground. It can happen that the methane escapes into houses built over the sites. The explosion is the rapid burning of methane if for example, a spark starts the reaction.	Methane is released when the rubbish decomposes under the ground. It can happen that the methane escapes into houses built over the sites	Methane is released when the rubbish decomposes under the ground
2	When methane reacts with chlorine, the product varies with the amount of chlorine in the mixture. Why does the amount of chlorine in the mixture determine what the product would be?	With only a little chlorine, the number of chlorine radical greatly outnumbered the methane molecule. When the methyl radicals are made in the propagation step, they react with chlorine radicals to form chloromethane. This mops up the chlorine radicals quickly so that the few are left to make dichloromethane, trichloromethane, etc.	With only a little chlorine, the number of chlorine radical greatly outnumbered the methane molecule. When the methyl radicals are made in the propagation step, they react with chlorine radicals to form chloromethane	With only a little chlorine, the number of chlorine radical greatly outnumbered the methane molecule.
3	A student said that the reason why alkenes are unsaturated is that, they can be made by removing water from alkanols. Was the student correct?	No, in organic chemistry unsaturation has nothing to do with water. The name means that an unsaturated compound could contain more hydrogen atoms than it has at present.	No, in organic chemistry unsaturation has nothing to do with water.	The student is not correct
4	Justify the statement that, in the reaction between ethene and bromine, the double bond breaks and	The statement is not quite right. We say that alkenes contain a double bond, but strictly a double bond does not exist. There are two	The statement is not quite right. We say that alkenes contain a double bond, but strictly a double bond does	The statement is not quite right. We say that alkenes contain a double bond,

	bromine adds on to the molecule.	bonds, the ů and the ΄. Only the ΄ breaks. So the sentence should be stated as thus; the ΄ bond breaks rather than the double bond.	not exist. There are two bonds, the ů and the ΄. Only the ΄ breaks.	but strictly a double bond does not exist.
5	What do you think went wrong with acetylene lamps to make them explode?	People possibly attempted to light the ethyne before all the air was swept out of the burner or the burner leaked and air could get into where the calcium dicarbide was stored.	People possibly attempted to light the ethyne before all the air was swept out of the burner or the burner leaked	the burner leaked and air could get into where the calcium dicarbide was stored.
6	After an organic reaction involving the breakage of ů and ΄ bonds, ethanal was formed. The chemist who conducted the experiment correctly claimed that there were two different structures for the starting material. What were they?	The reaction is ozonolysis. Indicate the reaction through equation The original alkene could have been either cis-but-2-ene or trans-but-2-ene. Draw the structures of the two conformations	The reaction is ozonolysis. The original alkene could have been either cis-but-2-ene or trans-but-2-ene. Draw the structures of the two conformations	The original alkene could have been either cis-but-2-ene or trans-but-2-ene.
7	What relates Nylon ï a synthetic non-biodegradable compound with some naturally biodegradable occurring compounds?	Polypeptides or proteins. They all have peptide links.	Polypeptides or proteins	They are polymers

MARKING SCHEME FOR SECTION **B** OF TOCT

Inference 1. C

Inference 2. A

Inference 3. A

Assumption 1. No

Assumption 2. No

Assumption 3. Yes

Deduction 1. Yes

Deduction 2. Yes

Deduction 3. Yes

Interpretation 1. Yes

Interpretation 2. Yes

Interpretation 3. No

Evaluation 1. Weak

Evaluation 2. Weak

Evaluation 4. Strong

APPENDIX G

CREATIVE THINKING TEST (CTT)

CHEMISTRY 221 (ORGANIC CHEMISTRY 1)

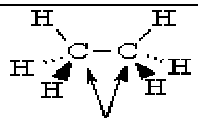
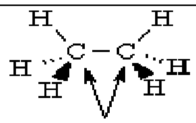
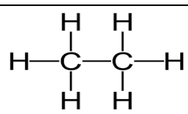
INSTRUCTIONS TIME: 1hr 30 min

1. Studentös I D Number............................... Sex: Male ☐ Female☐
2. Attempt all questions in sections in the papers provided
3. Use the color pencils provided where appropriate

1. Assuming you are the head basic science department in a rural junior secondary school and faced with the scarcity of preservatives. Identify possible way of supplementing preservatives for your school.
2. Draw a 3 dimensional (3-D) representation to show how the two tetrahederals in ethane are centered on each carbon
3. Ethanal was formed after an ozonolysis reaction. The chemist who conducted the experiment correctly claimed that there were two different structures for the starting material. What are the possible ways of representing the structures of the two starting materials?
4. Identify the way (s) you would complement the supply of fuel (petrol) in a situation where petrol is too scarce and expensive?
5. Polymers used domestically cause serious environmental problems. Identify the best alternative to these polymers such that the environmental problems are minimized
6. Chemists in this millennium are focused on how to achieve sustainable future. Identify measure(s) to be taken in preventing pollution at molecular level
7. Identify ways you can empower yourself from the chemistry courses
8. Draw the geometry of methane using ball and stick model. You are expected to use different colors for balls and sticks.
9. Insert your ball and stick model of methane (in 1 above) into a tetrahedron to show the four faces of the geometry.
10. Show the mechanism for radical reaction of a named alkene with HBr indicating clearly the direction/movements of electrons (use different colors)
11. Draw the structures of the following and state their respective class of dienes.
    a. 2,5 heptadiene
    b. 2,3 hexadiene
    c. 3,5 octadiene
12. Show what happens diagrammatically, if a free radical approaches the pi (´) bond in ethene polymerization during the chain propagation step.

APPENDIX H

RUBRICS FOR CREATIVE THINKING SKILLS (CTT)

S/N	Questions	Proficient (3 Marks)	Adequate (2 Marks)	Limited (1 Mark)
1	Assuming you are the head basic science department in a rural junior secondary school and faced with the scarcity of preservatives. Identify possible way of supplementing preservatives for your school.	Enumerate 3 or more ways including formalin/formaldehyde (methanal in solution with water) others that inhibit bacterial activities such as lactic acid, nitrite, nitrate etc	Enumerate or more ways including formalin/formaldehyde (methanal in solution with water)	Identify one method
2	Draw a 3 dimensional (3-D) representation to show how the two tetrahederals in ethane are centered on each carbon	 Tetrahedral Comment on the ñstickò out, wedges & thin lines	 Tetrahedral No comment on the ñstickò out, wedges & thin lines.	
3	Ethanal was formed after an ozonolysis. The chemist who conducted the experiment correctly claimed that there were two different structures for the starting material. What are the possible ways	At least 3 ways to include ball and stick model, 3-D model and normal thin lines representation.	Less than three ways to include the 3-D or ball and stick models	Only a single way of representing the structures

	of representing the structures of the two starting materials?			
4	Identify the way (s) you would complement the supply of fuel (petrol) in a situation where petrol is too scarce and expensive?	Identify any three or more ways but to include if alcohol is cheap, gasohol can be an alternative. This is a mixture which consists of 80% alcohol and 20% petrol	Identify any 3 ways without the mention of gasohol	Identify less than 3 ways
5	Polymers used domestically cause serious environmental problems. Identify the best alternative to these polymers such that the environmental problems are minimized	The use of biodegradable polymers that can be decomposed by microorganisms, bacteria, fungi or algae. Give an example of at least one of such polymer (polylactic PLA, polyhydroxyalkanoates PHA)	The use of biodegradable polymers that can be decomposed by microorganisms, bacteria, fungi or algae	The use of biodegradable polymers
6	Chemists in this millennium are focused on how to achieve sustainable future. Identify measure(s) to be taken in preventing pollution at molecular level	Through Green chemistry by designing syntheses that use and generate substances that cause little or no toxicity to health or to environment. State one implication (coast effective in waste disposal, simple regulations, etc)	Through Green chemistry by designing syntheses that use and generate substances that cause little or no toxicity to health or to environment.	Production on biodegradable products
7	Identify ways you can economically empower yourself from CHEM. 221	Identify 3 or more entrepreneurial opportunities based on exposure to the course	Identify 2 entrepreneurial opportunities based on exposure to the course	Identify only 1 entrepreneurial opportunity

RUBRICS FOR CREATIVE THINKING SKILLS (CTT) CONTINUED

S/N	Questions	Proficient (3 Marks)	Adequate (2 Marks)	Limited (1 Mark)
8	Draw the geometry of methane using ball and stick model. You are expected to use different colors for balls and sticks.	The use of color, ball and socket or any appropriate Representation, correct orientation of carbon atom, and angle of 109^0.	The use ball and socket or any appropriate Representation, correct orientation of carbon atom, and angle of 109^0.	The use ball and socket or any appropriate Representation, correct orientation of carbon
9	Insert your ball and stick model of methane (in 8 above) into a tetrahedron to show the four faces of the geometry.	Indicate faces of tetrahedron using same structure in 8 above	Indicate faces of tetrahedron by drawing another structure	Drawing indicating tetrahedral structure
10	Show the mechanism for radical reaction of a named alkene with HBr indicating clearly the direction/movements of electrons (use different colors)	.Correct reaction mechanism of a named alkene with HBr indicating intermediate, with electrons movement (colored)	Correct reaction mechanism indicating intermediate, with no electrons movement	Correct reaction with no mechanism and no electrons movement
11	Draw the structures of the following and state their respective class of dienes.	Correct structures and classifications of the 3 dienes	Correct structures and classifications of the 2 dienes	Correct structures and classifications of the 1 diene
12	Show what happens if a free radical approaches the pi (´) bond in ethene polymerization during the chain propagation step	Show the radical that propagate the reaction, sigma and pi bonds//electrons, radical formation with pi electrons (colored) indicating CH_2 radical	Show the radical that propagate the reaction, pi sigma and bond//electrons, radical formation with pi electrons indicating CH_2 radical	Show the pi, sigma and bond//electrons, radical formation with pi electrons indicating CH_2 radical

APPENDIX I

CHEMISTRY INTEREST INVENTORY (CII)

INSTRUCTIONS TIME: 30 minutes

Studentôs I D Number................................ Sex: Male ☐ Female ☐

Below is a list of statements to ascertain your disposition towards chemistry as a course in your college. Please respond to whether you Strongly Agree (**SA**), Agree (**A**), Disagree (**D**) or Strongly Disagree (**S**)

S/N	QUESTIONNAIRE ITEMS	SA	A	D	SD
1	I donôt like being in the lass during chemistry lesson				
2	my course of study should not be related to chemistry				
3	I enjoy taking part in discussion about chemistry				
4	I would like to study courses related to chemistry in the university				
5	I like telling people what I learn in chemistry				
6	I enjoy chemistry lesson very well				
7	I feel happy copying notes of chemistry				
8	I find it enjoyable to teach chemistry to my junior ones/mates				
9	I will not like to attempt any question related to topics in chemistry				
10	Studying Chemistry is interesting				
11	I perform better in chemistry than most other subjects				
12	The study of chemistry is important to all				
13	I would like to have as much as chemistry lesson as possible in school				
14	I study hard to become a scientist				
15	I study hard to become a chemistry lecturer				
16	I do not like to answer questions during chemistry lesson				
17	I always volunteer to call the chemistry lecturer whenever it is time for the subject				
18	I distract the attention of my classmates during chemistry lesson				
19	The duration for chemistry lesson seems longer compared to other subjects				
20	I find it very enjoyable to participate in group activities during chemistry lesson				
21	I rejoice whenever the chemistry lecturer is absent from class				
22	I enjoy solving past questions in chemistry on my own				
23	I spent most of my time reading chemistry notes				
24	During holidays, I like to teach chemistry in the holiday education program				
25	I am always willing to discuss the usefulness of chemistry any where				
26	Learning chemistry makes people happy				
27	I am very attentive in all chemistry lessons				
28	I hardly give up when solving chemistry problems				
29	I discourage my friends from becoming chemistry teachers				
30	I advised my friends against choosing chemistry as a subject for external examination				

APPENDIX J

Distribution of students' population in the various state colleges of education

S/NO	Name of Institution	Gender		Total
		(Male)	(Female)	
1	Jigawa state College of education Gumel.	98	49	147
2	Saâadatu Rimi College of education, Kano.	119	63	182
3	Isah Kaita College of Education Dutsinma, Katsina State.	90	14	92
4	Kaduna State College of Education Gidan waya.	47	20	67
5	Zamfara State College of Education Maru.	61	09	70
6	Shehu Shagari College of Education Sokoto.	212	54	266
7	Kebbi State College of Education.	67	42	109
8	Total	694	251	945

Source: Office of the Heads of Department of the Colleges (2015)

APPENDIX K

Chemistry Achievement Test Reliability Computation Using K-R_{20}

S/N	R	W	p	q	pq
1	16	14	0.47	0.53	0.25
2	17	13	0.43	0.57	0.25
3	14	16	0.53	0.47	0.25
4	15	15	0.50	0.50	0.25
5	18	12	0.40	0.60	0.24
6	12	18	0.40	0.60	0.24
7	9	21	0.30	0.70	0.21
8	6	24	0.20	0.80	0.16
9	11	19	0.37	0.63	0.23
10	7	23	0.23	0.77	0.18
11	15	15	0.50	0.50	0.25
12	16	14	0.53	0.47	0.25
13	13	17	0.43	0.57	0.25
14	13	17	0.43	0.57	0.25
15	17	13	0.57	0.43	0.25
16	16	14	0.53	0.47	0.25
17	19	11	0.63	0.37	0.23
18	12	18	0.40	0.60	0.24
19	14	16	0.47	0.53	0.25
20	15	15	0.50	0.50	0.25
21	15	15	0.50	0.50	0.25
22	19	11	0.63	0.37	0.23
23	16	14	0.53	0.47	0.25
24	15	15	0.50	0.50	0.25
25	14	16	0.47	0.53	0.25
26	13	17	0.43	0.57	0.25
27	16	14	0.53	0.47	0.25
28	15	15	0.50	0.50	0.25
29	12	18	0.40	0.60	0.24
30	17	13	0.57	0.43	0.25
31	13	17	0.43	0.57	0.25
32	11	19	0.37	0.63	0.23
33	12	18	0.40	0.60	0.24
34	17	13	0.57	0.43	0.25
35	17	13	0.57	0.43	0.25
36	14	16	0.47	0.53	0.25
37	14	16	0.47	0.53	0.25
38	12	18	0.40	0.60	0.24
39	8	22	0.27	0.73	0.20
40	8	22	0.27	0.73	0.20
41	24	6	0.80	0.20	0.16
42	23	7	0.77	0.23	0.18
43	21	9	0.70	0.30	0.21
44	17	13	0.57	0.43	0.25

45	21	9	0.70	0.30	0.21
46	17	13	0.57	0.43	0.25
47	13	17	0.43	0.57	0.25
48	19	11	0.63	0.37	0.23
49	24	6	0.80	0.20	0.16
50	15	15	0.50	0.50	0.25
51	12	18	0.40	0.60	0.24
52	9	21	0.30	0.70	0.21
53	6	24	0.20	0.80	0.16
54	12	18	0.40	0.60	0.24
55	14	16	0.47	0.53	0.25
56	15	15	0.50	0.50	0.25
57	6	24	0.20	0.80	0.16
58	11	19	0.37	0.63	0.23
59	7	23	0.23	0.77	0.18
60	15	15	0.50	0.50	0.25

R = Number of Examinees that choose correct option
W = Number of examinees that choose wrong options
p = Proportion of examinees that choose correct option
q = Proportion of examinees that choose wrong options
pq = Product of proportion of those that choose correct option and those that choose wrong options
S^2 = Variance of the total score on the test
n = Number of items in the test
K-R(20) = Kuder-Richardson formula 20

$$K - R(20) = \frac{n}{n-1}\left[1 - \frac{\Sigma pq}{S_{b^1}^2}\right]$$

$$= \frac{60}{60-1}\left\{1 - \frac{13.88}{65.54}\right\}$$

$$= \frac{60}{59}\,(1 - 0.21)$$

$$= 1.02(0.79)$$

$$= 0.81$$

APPENDIX L

Test of Critical Thinking Reliability Computation Using Pearson Product moment Correlation

Correlations

CORRLATION OF FIRST (X) AND SECOND (Y) ADMINISTRATION OF TEST OF CREATIVE THINKING

Correlations

		X	Y
X	Pearson Correlation	1	.845**
	Sig. (2-tailed)		.000
	N	30	30
Y	Pearson Correlation	.845**	1
	Sig. (2-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

APPENDIX M

Creative Thinking Test Reliability using Kendall's Coefficient of Concordance

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Rater1	20	5.9000	1.71372	3.00	8.00
Rater2	20	5.2000	2.21478	2.00	11.00
Rater3	20	6.0000	1.37649	4.00	9.00

Kendall's W Test

Ranks

	Mean Rank
Rater1	2.02
Rater2	1.65
Rater3	2.32

Test Statistics

N	20
Kendall's W[a]	.789
Chi-Square	4.753
Df	2
Asymp. Sig.	.093

a. Kendall's Coefficient of Concordance

APPENDIX N

CHEMISTRY INTEREST INVENTORY RELIABILITY COMPUTATION USING CRONBACH ALPHA

Reliability

Scale: ALL VARIABLES

Case Processing Summary

		N	%
Cases	Valid	30	100.0
	Excluded[a]	0	.0
	Total	30	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.876	30

APPENDIX O

MBI LESSON PLAN (EXPERIMENTAL GROUP)

The lesson plan for the experimental group is based on the proposal of Windschitl et.al. (2007). They have identified four conversations in authentic MBI centered on the level/ability of the learners. These are; organizing what we know and what we need to know, generating hypothesis, seeking evidence and constructing argument.

LESSON PLAN 1

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Chemistry and Molecular Geometry of Alkanes.

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry texts, cardboard papers, Masking tapes, indelible markers (different colors), Clay (for modeling)

OBJECTIVE : At the end of the lesson, students should be able to describe the geometry of saturated hydrocarbons

PREVIOUS KNOWLEDGE: They were taught hybridization and the chemistry of hydrocarbons

Test of previous knowledge:

The teacher kick starts the inquiry process by asking questions (whole class) related to their experience centered on the different classes of hydrocarbons to assess their entry knowledge. The questions are;

a. What is hybridization?
b. Identify the relationship between hybridization and the atomic orientations in an organic compound
c. Students are expected to raise areas of misconceptions and ask questions that may open-up their related knowledge..

PRESENTATION: The lesson was presented based on the following steps of MBI

1. What we know and what we want to know.

The teacher after ascertaining the level of studentsôprevious knowledge should give an outline of the tasks in form of questions to be answered by the students in groups of about 10 guided by the following questions/activities;

ŏ Identify different types of bonding and figure out the crucial determinant of organic compound characteristics,

ŏ What is hybridization?

ŏ Identify the type of hybrid orbitals

2. Generating hypothesis.

The teacher articulates studentsô experience on the above questions and then provides guidance for students to propose sketch model (guess) of different molecular geometries of Methane and Ethane to form conceptual diagram using the cardboard papers.

In groups, students should come up with representational models of the 2 saturated hydrocarbons taken one after another.

3. Seeking evidence.

The teacher scaffolds the students to identify sources of data to prove (or otherwise) the orientation of atoms in their respective group models.

Students study and brainstorm the following questions/ activities to seek evidences to prove (or otherwise) their models,

ŏ what are the broad categorization of organic compounds?

ŏ Identify sp^3, sp^2 and *sp* hybridization as basis for;

i) classifying organic compounds,

ii) molecular geometry in organic compounds,

iii) determinants of bond angles

ŏ How is ů bond formed?

ŏ what is the place of molecular geometric orientations and the physical and chemical characteristics of the saturated hydrocarbons?

4. Constructing arguments.

The teacher intervened to clear misconceptions, guide transition from small groups to whole class discussion, facilitate the flow of argument and utilize studentsô experiences to create a whole class tentative representational models of the geometries of the

hydrocarbons by group presentations.

ŏ In groups, students should use the representational sketch (in the cardboard) to come up with a physical models of the geometries of the identified saturated hydrocarbons

Students in groups will present their constructed models. Authentication of models follows. This will be guided by the following;

ǒ identify what their respective models fail to predict/consider if any,

ǒ should our model change in the light of any evidence from other group(s)?,

ǒ What makes our model different from other groups and why?

EVALUATION; The Teacher evaluated the lesson by introducing propane (having three tetrahedrons) to find studentsô level of flexibility. They are expected to briefly describe the geometry of propane in such a way that it triples the geometry of methane and $1^{1}/2$ of ethane but with different orientations.

LESSON PLAN 2

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: The chemistry of Alkene and Akynes 1

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry texts, cardboard papers, Masking tapes, indelible markers (different colors)

OBJECTIVE: By the end of the lesson students should be able to identify Electrophiles and Nucleophiles in a chemical reaction

PREVIOUS KNOWLEDGE: They were taught chemistry of alkane, alkenes and alkynes.

Test of previous knowledge

The teacher should ask questions related to reactions of the three classes of hydrocarbon;

What are reactions that are peculiar to saturated and unsaturated hydrocarbons?

PRESENTATION: The lesson was presented based on the following conversations:

1. What we know and what we want know.

The teacher utilizes studentsô experience related to different classes of hydrocarbons to identify what they know about their reactions. The teacher further assists students in identifying other possibilities of representing their experiences on reactions of the hydrocarbons.

Students Participate fully in the discussion. Attempt to commit their set of ideas ï which may kick start new questions of interest and insight about the relationships between reactions of different classes of the hydrocarbons guided by the following questions/activities, ŏ with examples, identify the three classes of reagents commonly encountered in organic reactions,

ŏ with relevant examples, identify the possible ways of breaking covalent bonds,

ŏ differentiate between carbonium, carbanion and carbocation,

ŏ what are the five classes of organic compound reactions that may be initiated by the attack of the reagents (above) on substrate?

ŏ compare certain reactions of different classes of the hydrocarbons and identify possibilities of common linkages and related products.

2. Generating hypothesis.

Provide generous support such that students (in groups) come up with a workable sketch representation of their experience on cardboard papers (model) to be authenticated later

Students collaboratively develop a working framework (whole class) using the alkene group general formula from which groups hypotheses could be generated using a named alkene. Students will utilize the following as a guide;

ŏ based on the discussions, use the alkene general formula to design a fame work (comprehensive chart) of the reactions of alkenes,

ŏ in groups, develop a model of reactions of a named alkene.

3. Seeking evidence.

The teacher scaffolds students to identify requisite sources of information to authenticate their assumptions.

Students study and brainstorm the following questions/ activities to seek for evidences to prove (or otherwise) their assumption;

ŏ re-visit extensively, the reactions of the alkanes, alkenes and alkynes (reaction mechanism is necessary),

ŏ do all groups of hydrocarbon undergo substitution and addition reactions?

ŏ which of the group(s) of hydrocarbon exhibit cleavage and how?

ŏ establish the fact that a common boarder exists between the groups of hydrocarbon with polymerization.

4. Constructing arguments.

The teacher intervene to clear misconceptions, guide transition from small groups to whole class discussion, facilitate the flow of argument and utilize studentsô experiences to create new content knowledge (tentative model).

Students in groups will present their models. Authentication of models follows. This will be guided by the following;

ŏ identify what their respective models fail to predict/consider if any,

ŏ should our model change in the light of any evidence from other group(s)?,

ŏ what makes our model different from other groups and why?

EVALUATION; The Teacher evaluates the lesson by replacing a named alkene by an alkyne to ascertain studentsô level of flexibility (eg, ethane replaced with ethyne)

LESSON PLAN 3

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Chemistry of Alkenes and Alkynes 2

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry texts, cardboard papers, Masking tapes, indelible markers (different colors)

OBJECTIVE: At the end of the lesson, students should be able to state Markonikoffôs Rule and its application on unsymmetrical Olefins

PREVIOUS KNOWLEDGE: They have learnt the reactions of the alkenes and alkynes.

Test of Previous knowledge.

The teacher asked questions to ascertain the level studentsô previous knowledge;

What are the reactions that are peculiar to unsaturated hydrocarbons?

PRESENTATION: The lesson was presented based on the following steps;

1. What we know and what we want know.

The teacher utilizes studentsô experience to identify what they know about the preliminary relationships between alkenes and alkynes in terms of their reactions Students Participate fully in the discussion. Attempt to commit their set of ideas ï which may kick start insights about the relationships between their reactions guided by the following questions/activities,

ŏ relate the stability of carbocation sourced from halogenation reaction of alkene group with Markovnikofôs rule,

ŏ what contrast an organic compound in your 1st model from a carbonium ion?

2. Generating hypothesis.

The teacher provides generous support so that students (in groups) articulate their experiences and subsequently propose a board cardsketch model (guess) of the relationship in the stability of the carbocations in form of a conceptual diagram.

In groups, students should come up with a representational model of the relationship of stability of the carbonium ions in form of a conceptual diagram.

3. Seeking evidence.

The teacher scaffold students to identify sources of data to prove (or otherwise) their assumptions,

Students study and brainstorm the following questions/ activities to seek for evidences to prove (or otherwise) their assumption;

ŏ identify different types of carbocations possible,

ŏ relate their roles (functions) with their hybridization,

ŏ do each of the ions contains only one type of bond (single, double or triple) throughout?

ŏ study the electrophilic additions to compounds containing at least two double bonds,

ŏ identify possible carbocations from such organic compounds,

ŏ are there remarkable differences between these carbocations and those with only single, double or triple bonds?

ŏ relate the stability of carbocation sourced from halogenation reaction of a named group of hydrocarbon with Markovnikoffôs rule.

ŏ compare the roles of electrons in ´ and ů bond in stabilizing the different types of carbocations so far identified.

4. Constructing arguments.

The teacher intervene to clear misconceptions, guide transition from small groups to whole class discussion, facilitate the flow of argument and utilize studentsô experiences to create a tentative model.

Students in groups will present their models. Authentication of models follows. This will be guided by the following;

ŏ identify what their respective models fail to predict/consider if any,

ŏ should our model change in the light of any evidence from other group(s)?

ŏ what makes our model different from other groups and why?

EVALUATION; the teacher evaluates his lesson by using some organic compounds containing single, double, triple and a diene for students to establish their relationships in terms of stability.

LESSON PLAN 4

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Polymerization

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry textbooks, cardboard papers, Masking tapes, indelible markers (different colors)

OBJECTIVE : At the end of the lesson, students should be able to describe the reactions of unsaturated hydrocarbons including dienes.

PREVIOUS KNOWLEDGE: They have related experiences in the chemistry of alkenes.

Test of previous knowledge

The teacher asked questions on the importance of alkenes group (products). Give examples of reaction from which some of the products were formed.

PRESENTATION: The lesson was presented based on the following steps;

1. What we know and what we want know.

The teacher recapitulates and articulates studentsô experiences on the journey so far in carbon chemistry. Emphasize the importance of alkene in polymerization process.

Students respond to and participate actively in the recapitulation process. Use models they generated previously to allow for easy flow of the discussion process and the following guide;

ŏ trace the sources of some named polymerization products from the classes of hydrocarbon,

ŏ classify the products as simple or complex polymerization product,

2. Generating hypothesis.

The teacher supports students to propose a relationship between the two polymerization products.

In groups, students should come up with a representational model of the relationship between the two products.

3. Seeking evidence.

The teacher scaffold students to identify sources of data to prove (or otherwise) their assumptions,

Students study and brainstorm the following questions/ activities to seek for evidences to prove (or otherwise) their assumptions;

ŏ types of polymerization

- Free radical addition

-If benzoyl peroxide is used as an initiator of polymerization of fluoroethane, Discuss the initiation, propagation and termination stages for the reaction

- trace the formation of butyl rubber

- Identify the process of reduction Polymerization

- identify the process and examples of addition of polymers from alkenes and vinyl compounds

ŏ Is there any relationship between natural and synthetic rubber?

ŏ critically analyze the interactions between polymerization products and the environment

4. Constructing arguments.

The teacher intervene to clear misconceptions, guide transition from small groups to whole class discussion, facilitate the flow of argument and utilize studentsô experiences to create new content knowledge (tentative model).

Students in groups will poster present their models. Authentication of models follows. This will be guided by the following;

ŏ identify what their respective models fail to predict/consider if any,

ŏ should our model change in the light of any evidence from other group(s)?

ŏ what makes our model different from other groups and why?

EVALUATION; The Teacher evaluates the lesson by giving a small group project on polymerization products and the environment.

LESSON PLAN 5 (SUMMARY)

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Course outline summary

INSTRUCTIONAL MATERIALS: Models generated from lessons 1- 4

OBJECTIVE : At the end of the lesson, students should be able to model a map of the relationships between concepts in CHEM 221 course contents

PREVIOUS KNOWLEDGE: They have related experiences from lessons 1- 4

PRESENTATION: The lesson was presented based on the following steps of MBI

1. What we know and what we want know.

    The teacher recapitulates and articulates studentsô experiences on the journey so far in modeling exercises from lessons 1- 4

    Students respond to and participate actively in the recapitulation process. Use models they generated previously to allow for easy flow of the discussion process.

2. Generating hypothesis.

    The teacher supports students to propose a relationship between the respective models generated so far in the course.

    In groups, students should come up with a representational model reflecting the relationships between the concepts in the course out line

3. Seeking evidence.

    The teacher scaffolds students to revisit the sources of data from lessons 1- 4 to prove (or otherwise) their assumptions.

4. Constructing arguments.

    The teacher intervene to clear misconceptions, guide transition from small groups to whole class discussion, facilitate the flow of argument and utilize studentsô experiences to create new content knowledge (tentative model).

    Students in groups will present their models. Authentication of models follows. This will be guided by the following;

    ŏ identify what their respective models fail to predict/consider if any,

    ŏ should our model change in the light of any evidence from other group(s)?

    ŏ what makes our model different from other groups and why?

EVALUATION; The Teacher evaluates the lesson by exchanging a particular segment of the whole course model with a related item (eg exchange butane with ethane) to test studentsô versatility.

APPENDIX P

LESSON PLAN ON CONVENTIONAL INQUIRY METHOD (CONTROL GROUP)

LESSON PLAN 1

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Chemistry and Molecular Geometry of Alkanes.

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry texts, cardboard papers,

OBJECTIVE :At the end of the lesson, students should be able to describe the geometry of saturated hydrocarbons

PREVIOUS KNOWLEDGE: They were taught hybridization and the chemistry of hydrocarbons

Test of previous knowledge:

The teacher kick starts the inquiry process by asking questions (whole class) related to their experience centered on the different classes of hydrocarbons and assessed their entry knowledge. The questions are;

a. What is hybridization?
b. Identify the relationship between hybridization and the atomic orientations in an organic compound
c. Students are expected to raise areas of misconceptions and ask questions that may open-up their related knowledge..

PRESENTATION: The lesson was presented based on the following steps

Step 1: Introductory activity on identification of the basis of molecular geometry

The teacher gave an outline of the tasks to be accomplished by the students in groups of about 10 guided by the following questions/activities;

ŏ Identify different types of bonding and figure out the crucial determinant of organic compound characteristics,

ŏ What is hybridization?

ŏ Identify the types of hybrid orbitals

Step 2:The teacher provided guidance for students to propose different molecular geometries of Methane and Ethane

Students studied and brainstorm the following questions/ activities to seek evidences to identify the chemistry and geometries of alkanes

ŏ what are the broad categorization of organic compounds?

ŏ Identify sp^3, sp^2 and *sp* hybridization as basis for;

i) classifying organic compounds,

ii) molecular geometry in organic compounds,

iii) determinants of bond angles

ŏ How is ů bond formed?

ŏ what is the place molecular geometric orientations and the physical and chemical characteristics of the saturated hydrocarbons?

Step: 3 The teacher intervened and clear misconceptions, guide transition from small groups to whole class discussion, facilitated the flow of argument and utilize studentsô experiences to create a whole class geometries of methane and ethane hydrocarbons by group presentations.

EVALUATION; The Teacher evaluated the lesson by introducing propane (having three tetrahedrons) to find studentsô level of flexibility. They are expected to briefly describe the geometry of propane in such a way that it triples the geometry of methane and $1^1/2$ of ethane but with different orientations.

LESSON PLAN 2

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: The chemistry of Alkene and Akynes 1

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry textbooks

OBJECTIVE : By the end of the lesson students should be able to identify Electrophiles and Nucleophiles in a chemical reaction

PREVIOUS KNOWLEDGE: They were taught the chemistry of alkane, alkenes and alkynes.

Test of previous knowledge

The teacher asked questions related to reactions of the three classes of hydrocarbon; What are reactions that are peculiar to saturated and unsaturated hydrocarbons?

Step: 1 The teacher utilized studentsô experience related to different classes of hydrocarbons to identify what they know about their reactions. The teacher further assists students in identifying other possibilities of representing their experiences on reactions of the hydrocarbons.

Students Participated fully in the discussion. Attempt to commit their set of ideas ï which may kick start new questions of interest and insight about the relationships between reactions of different classes of the hydrocarbons guided by the following questions/activities,

ŏ with examples, identify the three classes of reagents commonly encountered in organic reactions,

ŏ with relevant examples, identify the possible ways of breaking covalent bonds,

ŏ differentiate between carbonium, carbanion and carbocation,

ŏ what are the five classes of organic compound reactions that may be initiated by the attack of the reagents (above) on substrate?

ŏ compare certain reactions of different classes of the hydrocarbons and identify possibilities of common linkages and related products.

Step: 2 The teacher scaffolds students (in groups) to identify requisite sources of information to authenticate their assumptions.

Students (in groups) study and brainstorm the following questions/ activities to seek for evidences on,

The chemistry of different groups of hydrocarbons

ŏ re-visit extensively, the reactions of the alkanes, alkenes and alkynes (reaction mechanism is necessary),

ŏ do all groups of hydrocarbon undergo substitution and addition reactions?

ŏ which of the group(s) of hydrocarbon exhibit cleavage and how?

ŏ identify the acidic trend among the classes of the hydrocarbons

ŏ establish the fact that a common boarder exists between the groups of hydrocarbon with polymerization.

Step: 3 The teacher intervened to clear misconceptions, guide transition from small groups to whole class discussion, facilitated the flow of argument and utilize studentsô experiences to create new content knowledge during and after group presentations.

EVALUATION; The Teacher evaluated the lesson by replacing a named alkene by an alkyne to ascertain studentsô level of flexibility (eg, ethane replaced with ethyne).

LESSON PLAN 3

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Chemistry of Alkenes and Alkynes 2

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any other organic chemistry textbooks.

OBJECTIVE : At the end of the lesson, students should be able to state Markonikoffös Rule and its application on unsymmetrical Olefins

PREVIOUS KNOWLEDGE: They have learnt the reactions of the alkenes and alkynes

PRESENTATION: The lesson was presented based on the following steps;

Test of Previous knowledge.

The teacher asked questions to ascertain the level studentsô previous knowledge;

What are the reactions that are peculiar to unsaturated hydrocarbons?

Step: 1The teacher utilized studentsô experience to identify what they know about the preliminary relationships between alkenes and alkynes in terms of their reactions Students Participate fully in the discussion. Attempt to commit their set of ideas ï which may kick start insights about the relationships between their reactions guided by the following questions/activities,

ǒ relate the stability of carbocation sourced from halogenation reaction of alkene group with Markovnikofös rule,

Step: 2 The teacher guides students to study and brainstorm the following questions/ activities;

ǒ identify different types of carbocations possible,

ǒ relate their roles (functions) with their hybridization,

ǒ do each of the ions contains only one type of bond (single, double or triple) throughout?

ǒ study the electrophilic additions to compounds containing at least two double bonds,

ǒ identify possible carbocations from such organic compounds,

ǒ are there remarkable differences between these carbocations and those with only single, double or triple bonds?

ǒ relate the stability of carbocation sourced from halogenation reaction of a named group of hydrocarbon with Markovnikoffös rule.

Step: 3 The teacher intervened to clear misconceptions, guide transition from small groups to whole class discussion and facilitate the flow of argument and utilize studentsô experiences toward the stated objective (during and after group work presentations)

EVALUATION; the teacher evaluated the lesson by using some organic compounds containing single, double, triple and a di-ene for students to establish their stability.

LESSON PLAN 4

LEVEL : NCE 11

DURATION: 4 hours

TOPIC: Polymerization

INSTRUCTIONAL MATERIALS: University Organic chemistry: The fundamentals, or any` other organic chemistry textbooks

OBJECTIVE: At the end of the lesson, students should be able to describe the reactions of unsaturated hydrocarbons including dienes.

PREVIOUS KNOWLEDGE: They have related experiences in the chemistry of alkenes.

Test of previous knowledge

The teacher asks questions on the importance of alkenes group (products). Give examples of reaction from which some of the products were formed.

PRESENTATION: The lesson was presented based on the following steps;

Step: 1 The teacher recapitulates and articulates studentsôexperiences on the journey so far in carbon chemistry. Emphasize the importance of alkene in polymerization process. Students responded to and participated actively in the recapitulation process. Use their experiences so far, to allow for easy flow of the discussion process and the following guide;

ŏ trace the sources of some named polymerization products from the classes of hydrocarbon,

ŏ classify the products as simple or complex polymerization product,

Step: 2 The teacher scaffolds students in their groups to identify sources of data and brainstorm the following questions/ activities;

ŏ types of polymerization

- Free radical addition

-If benzoyl peroxide is used as an initiator of polymerization of fluoroethane, Discuss the initiation, propagation and termination stages for the reaction

- trace the formation of butyl rubber
- Identify the process of reduction Polymerization
- identify the process and examples of addition of polymers from alkenes and vinyl compounds

ŏ Is there any relationship between natural and synthetic rubber?

ŏ critically analyze the interactions between polymerization products and the environment

Step: 3 The teacher intervened to clear misconceptions, guide transition from small groups to whole class discussion, facilitate the flow of argument and utilize studentsô experiences to have a holistic idea on the reactions of unsaturated hydrocarbons in polymerization processes,

EVALUATION; The Teacher evaluated the lesson by giving a small project on polymerization products and the environment.

LESSON PLAN 5 (SUMMARY)

LEVEL : NCE 11

DURATION: 4 hours

INSTRUCTIONAL MATERIALS: Notes/studentsô findings generated from lessons 1- 4

OBJECTIVE: At the end of the lesson, students should be able to produce a summary chart of concepts in CHEM 221 course contents

PREVIOUS KNOWLEDGE: They have related experiences from lessons 1- 4

PRESENTATION: The lesson was presented based on the following steps;

Step: 1 The teacher recapitulates and articulates studentsô experiences on the journey so far in exercises from lessons 1- 4

Students respond to and participate actively in the recapitulation process. Use their notes and findings generated previously to allow for easy flow of the discussion process

In groups, students should propose a starting/central organic compound to start the chart.

Step: 2 The teacher scaffolds students to revisit their sources of data from lessons 1- 4 to come up with a group summary chart

step: 3 The teacher intervened to clear misconceptions, guide transition from small groups to whole class discussion, facilitated the flow of argument and utilized studentsô experiences to create a whole class summary chart.

EVALUATION; The Teacher evaluated the lesson by exchanging a particular segment of the whole course model with a related item (eg replace the ethane with butane) to test studentsô versatility.

`

APPENDIX Q

EVIDENCE OF VALIDATION

The experts checked and validated the instruments with the lesson plans. They were served with introduction letters embodying the request to;

1. Validate the four instruments (CAT, TOCT, CTT & CII), the lesson plans, the purpose of the study, research questions, the hypotheses and the test blue print for the CAT,
2. Check the submitted package to ascertain their conformity, meaningfulness and logical sequence based on the topics covered,
3. Check their suitability and clarity with a view to identifying relevant information(s) vital to the study but not reflected
4. Kindly remove all ambiguous or irrelevant statement that would help improve the understanding of the instrument.

The following table provides the five (5) validatorsô comments on the instruments and others submitted for the validation.

ITEMS	VALIDATORSô COMMENTS	COMMENTS EFFECTED
PURPOSE	- Separate critical thinking from creativity for specific purposes 2 & 3 - Remove ñmale and femaleò from statements 4, 5 & 6. - Replace ñunderò with ñafterò for statements 4, 5 & 6	See page 14
RESEARCH QUESTIONS	- Separate critical thinking from creativity and reflect as appropriately in other statements	See page 15
HYPOTHESES	- Separate critical thinking from creativity and reflect as appropriately in other statements - Missing interaction effects of gender and treatment on critical thinking , creativity, achievement and interest	See page 17
TOCT	- Questions should cover the content area to be taught to students - Remove the general section of the instrument (section B) and use content base to increase the items in the instrument. - Replace ñwhat causes the explosionò with	Items are now content based and course content covered. See appendixes, E, p. 194; F, p.198.

	ñfrom your study of chemistry what would have been the cause of the explosionò - Question 2 to include ñwhat product would beò - Write the statements in section A to reflect the general aspect of the instrument.	
CTT	- Questions should cover the content area to be taught to students - Remove the general section of the instrument (section B) and use content base to increase the items in the instrument. - Write the statements in section A to reflect the general aspect of the instrument. - Question 3, no such reference, present question in full and independently.	Items are now content based and course content covered. See appendixes G, p. 201; H, p. 203.
CII	- Out of the 49 statements, 1, 3, 4, 5, 6, 7, 8, 9, 13, 16, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28 & 30 survived. Others were attitude not interest - Add little negative items after weeding out the attitude statements.	See appendix I, p. 206
LESSON PLANS	- Remove Chem 123 - State all questions to be asked - Step 1, lesson 1 (MBI), include ñin form of questions to be answered - Write the lesson plans sequentially	See appendixes O, p. 213; P, p. 222.
CAT	- Correct questions 1, 2, 3, 4,5, 7,15, 23, 41 & 52	See appendix C, p. 182
TEST BLUE PRINT	- Question 1 missing - Assign percentage to the content and cognitive dimension of the test blue print. - Questions 3 (not knowledge but application) - Recast questions 46, 47 and 49 to fit evaluation - Recast questions 9, 51, 21, 40 to fit synthesis	See appendix B, p. 181

APPENDIX R

SCHEME OF WORK FOR MBI (Model-Based Inquiry)

WEEKS	DAY	ACTIVITY/LESSON	LESSON/TOPICS TAUGHT
1	1	Understanding MBI	The MBI and its steps/conversations
	2	Discussion on the MBI lesson plan	Link day 1and the use of lesson plan
	3	Use of lesson plan	Study the lesson plan and its application
	4	Application	Lesson plan 1 & 2
	5	Application	Lesson 3, 4 & 5
2	**1**	Pre-test	CAT & CII
	2	Pre-test	TOCT
	3	Pre-test	CTT
3 & 4	LESSON PLAN 1		Alkane Goemetry (Physical Model Of Methane And Ethane)
5 & 6	LESSON PLAN 2		Electrophiles & Nucleophiles
7 & 8	LESSON PLAN 3		Application of Markonikoffôsrule
9 & 10	LESSON PLAN 4		Polymerization & dienes
11&12	LESSON PLAN 5		Modeling of concepts in chem. 221 course outline
13	**1**	Post-test	CAT & CII
	2	Post-test	TOCT
	3	Post-test	CTT

APPENDIX S

SCHEME OF WORK FOR CIM (Conventional Inquiry Method)

WEEKS	DAY	ACTIVITY/LESSON	LESSON/TOPICS TAUGHT
1	1	Understanding CIM	The CIM and its steps
	2	Discussion on the CIM lesson plan	Link day 1and the use of lesson plan
	3	Use of lesson plan	Study the lesson plan and its application
	4	Application	Lesson plan 1 & 2
	5	Application	Lesson 3, 4 & 5
2	**1**	Pre-test	CAT & CII
	2	Pre-test	TOCT
	3	Pre-test	CTT
3 & 4	LESSON PLAN 1		Alkane Goemetry (methane and ethane)
5 & 6	LESSON PLAN 2		Electrophiles & Nucleophiles
7 & 8	LESSON PLAN 3		Application of Markonikoffös rule
9 & 10	LESSON PLAN 4		Polymerization & dienes
11&12	LESSON PLAN 5		Summary chart of concepts in chem. 221 course outline
13	**1**	Post-test	CAT & CII
	2	Post-test	TOCT
	3	Post-test	CTT

APPENDIX T

TRAINING PACKAGE FOR TEACHERS AND RESEARCH ASSISTANTS

Experimental Group (MBI)

The training package covered 5 days activities involving the teachers and research assistants. This is presented as follows:

DAI 1; the researcher started with the explanation/discussion on the concept of inquiry. This was for the participants to have a full understanding of the inquiry before the introduction of the MBI.

DAY 2; discussion on MBI continued. The steps in MBI were explained and why the arrangement. The theoretical application of the MBI followed. The participants were issued with copies of the lesson plans to study them at home.

DAY 3; the lesson plans were used in application with the respective topics to assess the level of participants understanding of modeling.

DAY 4; the day started with the real application of lesson plans 1 & 2 in which one of the participants presented and other participants serve as students or audience. The researcher facilitated the real application.

DAY 5; the application of lesson plans 3, 4 & 5 was carried out in which one of the participants presented and other participants served as students or audience. The researcher facilitated the real application.

Control group (CI)

The training package covered 5 days activities (as in experimental group) involving the teachers and research assistants. This is presented as follows:

DAI 1; the researcher started with the explanation/discussion on the concept of inquiry. This is for the participants to have a full understanding of the concept inquiry.

DAY 2; discussion on CI continued. The steps in CI were explained and why the arrangement. The theoretical application of the CI followed. The participants were issued with copies of the lesson plans to study them at home.

DAY 3; the lesson plans were used in application with the respective topics to assess the level of participants understanding of the inquiry processes.

DAY 4; the day started with the real application of lesson plans 1 & 2 in which one of the participants presented and other participants served as students or audience. The researcher facilitated the real application.

DAY 5; the application of lesson plans 3, 4 & 5 was carried out in which one of the participants presented and other participants served as students or audience. The researcher facilitated the real application.

APPENDIX U

MODEL BASED INQUIRY (MBI) INSTRUCTIONAL TECHNIQUE TEMPLATE

STEPS	TEACHERôS ACTIVITIES	STUDENTSô ACTIVITIES
Step 1 What we know and what we want know	The teacher articulates students previous knowledge, clear misconception (if any) and give an outline of the task to be accomplished in groups of 10 guided by series of questions or activities	Students respond to whole class introductory questions, raise areas of misconception and attempt the leading questions/activities
Step 2 Generating hypothesis	Lead students to generate a sketch model based on studentsô prior knowledge which will be authenticated at the end of the lesson	Students generate a group working model (initial) which they will authenticate at the end of the lesson
Step 3 Seeking evidence	The teacher scaffold students to carry out an in depth background reading, investigations and brainstorming on certain concepts, questions or activities that will serve as a source of data for validating their initial model	Students in groups conduct in depth background reading, investigations and brainstorming on certain concepts, questions or activities, generate and articulate necessary information to verify their group initial model
Step 4 Constructing argument	The teacher moderate studentsô group model presentations facilitate the flow of arguments, guide transition from small groups to whole class discussions and guide students to decide on a whole class tentative model.	Students articulate their data, verify, generate and present their group models to whole class for authentication. Agree on a particular group model and 1. Identify what their group model fail to consider if any 2. Should their group model change in the light of any evidence from the whole class tentative model 3. Makes their group model differ from the whole class tentative model and why?

CONVENTIONAL INQUIRY (CI) INSTRUCTIONAL TECHNIQUE TEMPLATE

The conventional inquiry template provides a complete inquiry processes without modeling activities.

STEPS	TEACHERõS ACTIVITIES	STUDENTSô ACTIVITIES
Step 1	The teacher articulates students previous knowledge, clear misconception (if any) and give an outline of the task to be accomplished in groups of 10 guided by series of questions or activities	Students respond to whole class introductory questions, raise areas of misconception and attempt the leading questions/activities
Step 2	The teacher scaffold students to carry out an in depth background reading to study and brainstorm certain concepts, questions or activities that will serve as a source of data to seek evidences.	Students in groups conduct in depth background reading to study and brainstorm certain concepts, questions or activities, generate and articulate necessary information to seek evidences that will support their claims
Step 3	The teacher intervene to clear misconceptions, guide transition from small groups to whole class discussions and facilitate flow of argument.	Students present their group work, create new content knowledge in the inquiry process and at the end.

APPENDIX V

THE ANALYSIS OUTPUT

Research question 1 and 5 (Achievement)

Between-Subjects Factors

		Value Label	N
Treatment	1	MBI	70
	2	CI	104
Gender	1	Male	151
	2	Female	23

Descriptive Statistics

	Treatment	Gender	Mean	Std. Deviation	N
Achipost	MBI	Male	39.1803	5.11373	61
		Female	33.7778	4.08588	9
		Total	38.4857	5.29080	70
	CI	Male	28.5222	5.86022	90
		Female	27.1429	3.15880	14
		Total	28.3365	5.58189	104
	Total	Male	32.8278	7.64004	151
		Female	29.7391	4.78841	23
		Total	32.4195	7.39097	174
Achipre	MBI	Male	22.0492	5.46329	61
		Female	21.3333	2.64575	9
		Total	21.9571	5.17921	70
	CI	Male	21.2889	5.05752	90
		Female	21.6429	4.12510	14
		Total	21.3365	4.92588	104
	Total	Male	21.5960	5.22070	151
		Female	21.5217	3.55310	23
		Total	21.5862	5.02376	174

Hypotheses 1, 2 and 3 (Achievement)

Tests of Between-Subjects Effects

Dependent Variable:Achipost

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4822.338[a]	4	1205.585	44.024	.000
Intercept	6001.338	1	6001.338	219.148	.000
Achipre	260.707	1	260.707	9.520	.002
Treatment	1405.305	1	1405.305	51.317	.000
Gender	213.257	1	213.257	7.787	.006
Treatment * Gender	67.263	1	67.263	2.456	.119
Error	4628.035	169	27.385		
Total	192329.000	174			
Corrected Total	9450.374	173			

a. R Squared = .510 (Adjusted R Squared = .499)

Estimated Marginal Means

1. Grand Mean

Dependent Variable:Achipost

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
32.158[a]	.600	30.974	33.341

a. Covariates appearing in the model are evaluated at the following values: Achipre = 21.5862.

2. Treatment

Dependent Variable:Achipost

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
MBI	36.453[a]	.934	34.609	38.298
CI	27.862[a]	.752	26.378	29.346

a. Covariates appearing in the model are evaluated at the following values: Achipre = 21.5862.

3. Gender

Dependent Variable:Achipost

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	33.831[a]	.434	32.974	34.688
Female	30.484[a]	1.118	28.277	32.691

a. Covariates appearing in the model are evaluated at the following values: Achipre = 21.5862.

4. Treatment * Gender

Dependent Variable:Achipost

Treatment	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
MBI	Male	39.067[a]	.671	37.742	40.392
	Female	33.840[a]	1.744	30.396	37.283
CI	Male	28.595[a]	.552	27.505	29.685
	Female	27.129[a]	1.399	24.368	29.890

a. Covariates appearing in the model are evaluated at the following values: Achipre = 21.5862.

Research question 2 and 6 (Creative)

Between-Subjects Factors

		Value Label	N
Treatment	1	MBI	70
	2	CI	104
Gender	1	Male	151
	2	Female	23

Descriptive Statistics

	Treatment	Gender	Mean	Std. Deviation	N
Creatpost	MBI	Male	19.0000	4.30116	61
		Female	20.1111	4.01386	9
		Total	19.1429	4.25385	70
	CI	Male	5.4556	2.65703	90
		Female	5.7143	2.39963	14
		Total	5.4904	2.61436	104
	Total	Male	10.9272	7.48697	151
		Female	11.3478	7.80215	23
		Total	10.9828	7.50759	174
Creatpre	MBI	Male	4.1803	1.80285	61
		Female	4.2222	2.04803	9
		Total	4.1857	1.82012	70
	CI	Male	3.2889	1.81903	90
		Female	2.7857	1.18831	14
		Total	3.2212	1.75132	104
	Total	Male	3.6490	1.85903	151
		Female	3.3478	1.69515	23
		Total	3.6092	1.83641	174

Hypotheses 4, 5 and 6 (Creative)

Tests of Between-Subjects Effects

Dependent Variable:Creatpost

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	7949.655[a]	4	1987.414	186.462	.000
Intercept	3081.807	1	3081.807	289.140	.000
Creatpre	140.775	1	140.775	13.208	.000
Treatment	3252.788	1	3252.788	305.181	.000
Gender	12.242	1	12.242	1.149	.285
Treatment * Gender	1.567	1	1.567	.147	.702
Error	1801.293	169	10.659		
Total	30739.000	174			
Corrected Total	9750.948	173			

a. R Squared = .815 (Adjusted R Squared = .811)

Estimated Marginal Means

1. Grand Mean

Dependent Variable:Creatpost

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
12.565[a]	.374	11.827	13.304

a. Covariates appearing in the model are evaluated at the following values: Creatpre = 3.6092.

2. Treatment

Dependent Variable:Creatpost

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
MBI	19.254[a]	.589	18.091	20.416
CI	5.877[a]	.476	4.937	6.816

a. Covariates appearing in the model are evaluated at the following values: Creatpre = 3.6092.

3. Gender

Dependent Variable:Creatpost

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	12.164[a]	.271	11.628	12.699
Female	12.966[a]	.698	11.589	14.343

a. Covariates appearing in the model are evaluated at the following values: Creatpre = 3.6092.

4. Treatment * Gender

Dependent Variable:Creatpost

Treatment	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
MBI	Male	18.709[a]	.426	17.869	19.549
	Female	19.799[a]	1.092	17.644	21.954
CI	Male	5.619[a]	.347	4.934	6.304
	Female	6.134[a]	.880	4.397	7.872

a. Covariates appearing in the model are evaluated at the following values: Creatpre = 3.6092.

Resarch question 3 and 7 (Critical)

Between-Subjects Factors

		Value Label	N
Treatment	1	MBI	70
	2	CI	104
Gender	1	Male	151
	2	Female	23

Descriptive Statistics

	Treatment	Gender	Mean	Std. Deviation	N
Critpost	MBI	Male	19.8197	3.69463	61
		Female	19.8889	3.98260	9
		Total	19.8286	3.70261	70
	CI	Male	9.5222	1.91521	90
		Female	11.2143	2.75062	14
		Total	9.7500	2.11215	104
	Total	Male	13.6821	5.77393	151
		Female	14.6087	5.38296	23
		Total	13.8046	5.71751	174
Critpre	MBI	Male	7.9508	1.84776	61
		Female	9.2222	1.30171	9
		Total	8.1143	1.83005	70
	CI	Male	7.3111	1.80912	90
		Female	7.0000	2.48069	14
		Total	7.2692	1.90161	104
	Total	Male	7.5695	1.84575	151
		Female	7.8696	2.34141	23
		Total	7.6092	1.91348	174

Hypotheses 7, 8 and 9 (Critical)

Tests of Between-Subjects Effects

Dependent Variable:Critpost

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4307.875[a]	4	1076.969	135.073	.000
Intercept	1553.216	1	1553.216	194.803	.000
Critpre	23.237	1	23.237	2.914	.090
Treatment	1512.523	1	1512.523	189.699	.000
Gender	11.658	1	11.658	1.462	.228
Treatment * Gender	17.509	1	17.509	2.196	.140
Error	1347.481	169	7.973		
Total	38814.000	174			
Corrected Total	5655.356	173			

a. R Squared = .762 (Adjusted R Squared = .756)

Estimated Marginal Means

1. Grand Mean

Dependent Variable:Critpost

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
15.059[a]	.325	14.418	15.701

a. Covariates appearing in the model are evaluated at the following values: Critpre = 7.6092.

2. Treatment

Dependent Variable:Critpost

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
MBI	19.660[a]	.517	18.640	20.680
CI	10.458[a]	.409	9.651	11.266

a. Covariates appearing in the model are evaluated at the following values: Critpre = 7.6092.

3. Gender

Dependent Variable:Critpost

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	14.667[a]	.234	14.204	15.129
Female	15.452[a]	.606	14.256	16.648

a. Covariates appearing in the model are evaluated at the following values: Critpre = 7.6092.

4. Treatment * Gender

Dependent Variable:Critpost

Treatment	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
MBI	Male	19.752[a]	.364	19.034	20.470
	Female	19.569[a]	.960	17.674	21.463
CI	Male	9.581[a]	.300	8.990	10.173
	Female	11.335[a]	.758	9.839	12.832

a. Covariates appearing in the model are evaluated at the following values: Critpre = 7.6092.

Research question 4 and 8 (Interest)

Between-Subjects Factors

		Value Label	N
Treatment	1	MBI	70
	2	CI	104
Gender	1	Male	151
	2	Female	23

Descriptive Statistics

	Treatment	Gender	Mean	Std. Deviation	N
PreInterest	MBI	Male	64.2787	2.41613	61
		Female	62.8889	2.42097	9
		Total	64.1000	2.44446	70
	CI	Male	62.4333	1.76132	90
		Female	63.2857	2.16364	14
		Total	62.5481	1.83218	104
	Total	Male	63.1788	2.23632	151
		Female	63.1304	2.22188	23
		Total	63.1724	2.22808	174
PostInterest	MBI	Male	93.8033	2.49546	61
		Female	92.6667	2.59808	9
		Total	93.6571	2.51883	70
	CI	Male	68.0889	9.57366	90
		Female	66.5714	4.32727	14
		Total	67.8846	9.04606	104
	Total	Male	78.4768	14.73582	151
		Female	76.7826	13.53096	23
		Total	78.2529	14.55642	174

Hypotheses 10, 11 and 12 (Interest)

Tests of Between-Subjects Effects

Dependent Variable:PostInterest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	29581.041[a]	4	7395.260	176.629	.000
Intercept	55.474	1	55.474	1.325	.251
PreInterest	1752.524	1	1752.524	41.857	.000
Treatment	11542.077	1	11542.077	275.672	.000
Gender	15.805	1	15.805	.377	.540
Treatment * Gender	68.170	1	68.170	1.628	.204
Error	7075.833	169	41.869		
Total	1102148.000	174			
Corrected Total	36656.874	173			

a. R Squared = .807 (Adjusted R Squared = .802)

Estimated Marginal Means

1. Grand Mean

Dependent Variable:PostInterest

Mean	Std. Error	95% Confidence Interval	
		Lower Bound	Upper Bound
80.206[a]	.741	78.743	81.670

a. Covariates appearing in the model are evaluated at the following values: PreInterest = 63.1724.

2. Treatment

Dependent Variable:PostInterest

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
MBI	92.599[a]	1.159	90.311	94.888
CI	67.814[a]	.932	65.973	69.654

a. Covariates appearing in the model are evaluated at the following values: PreInterest = 63.1724.

3. Gender

Dependent Variable:PostInterest

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	80.662[a]	.538	79.600	81.725
Female	79.751[a]	1.382	77.022	82.480

a. Covariates appearing in the model are evaluated at the following values: PreInterest = 63.1724.

4. Treatment * Gender

Dependent Variable:PostInterest

Treatment	Gender	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
MBI	Male	92.094[a]	.870	90.377	93.811
	Female	93.105[a]	2.158	88.845	97.365
CI	Male	69.231[a]	.705	67.840	70.622
	Female	66.396[a]	1.730	62.982	69.811

a. Covariates appearing in the model are evaluated at the following values: PreInterest = 63.1724.