# Application of the Learning Theories in Teaching Chemistry: Implication for Global Competitiveness

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***Abstract***
*The relevance of chemistry in economy, industry, health and as the center of all other sciences is well known. New expectations arising from education reforms to improve on students' learning outcomes and to enable them face the challenges in a rapidly growing, innovative competitive world presuppose that teaching and learning prepare students for the world of tomorrow. The traditional teaching methods preponderantly used in the chemistry classroom have proven to be ineffective in promoting students' understanding of chemistry concepts leading to persistent failure of the subject in public examinations. Analyses of chemistry results of two African countries (Nigeria and Kenya) over a period presented in this paper reveal that students register dismal failure in the subject. This makes it increasingly difficult for students to qualify for the competitive job market or to enroll for science-related courses in the universities after secondary education. Models of constructivist teaching methods designed in this paper show how the learning theories within the constructivists' perspective differ from the traditional approaches in promoting lifelong learning capable of enabling students acquire skills and competencies to be effective throughout their lives. The paper has implications for teachers, curriculum developers and for the chemistry students.*

**Keywords:** Learning theories, Constructivism, Traditional teaching methods, Chemistry, Global competitiveness, Performance



## Introduction

Chemistry is a central science that forms the indispensable foundation of many disciplines such as biology, physics, medicine, plant sciences, nuclear chemistry, engineering, geology, cosmetics, and environmental science [29].

Disciplines within chemistry are traditionally grouped by the type of matter or kind of study in question. This includes the study of matter; the study of chemical processes using physical concepts such as, the analysis of material samples for their properties or characteristics. Chemistry protects and preserves our health, culture and heritage. Chemistry provides important understanding of the world. It is a practical science that impacts on our day-to-day living. The life we live is chemistry, the water we drink, the energy we use to cook and materials we use at home are products of chemistry. Chemistry impacts on the dynamism of our intra and extra movements. It is a science that lives at the heart of many matters in the society. Thus, the knowledge of chemistry in ever increasing innovative world is a sine qua non because achievement in chemistry is crucial for ensuring economic competitiveness. This implies that lack of conceptual understanding of chemistry content beginning from the secondary school level may impact negatively on students in a world that is becoming more global, innovative, dynamic, competitive and requiring quality and efficiency in the workforce. It is therefore critical to continue to address the issue of students' persistent poor performance in chemistry.

Research has shown that students in developing countries such as Nigeria and Kenya who register chemistry at the West African Secondary School Certificate Examinations (WASSCE) and Kenya Secondary Certificate Examinations (KSCE) perform poorly [21]; [22]; [23] despite world-wide attention on improving students' learning outcomes.

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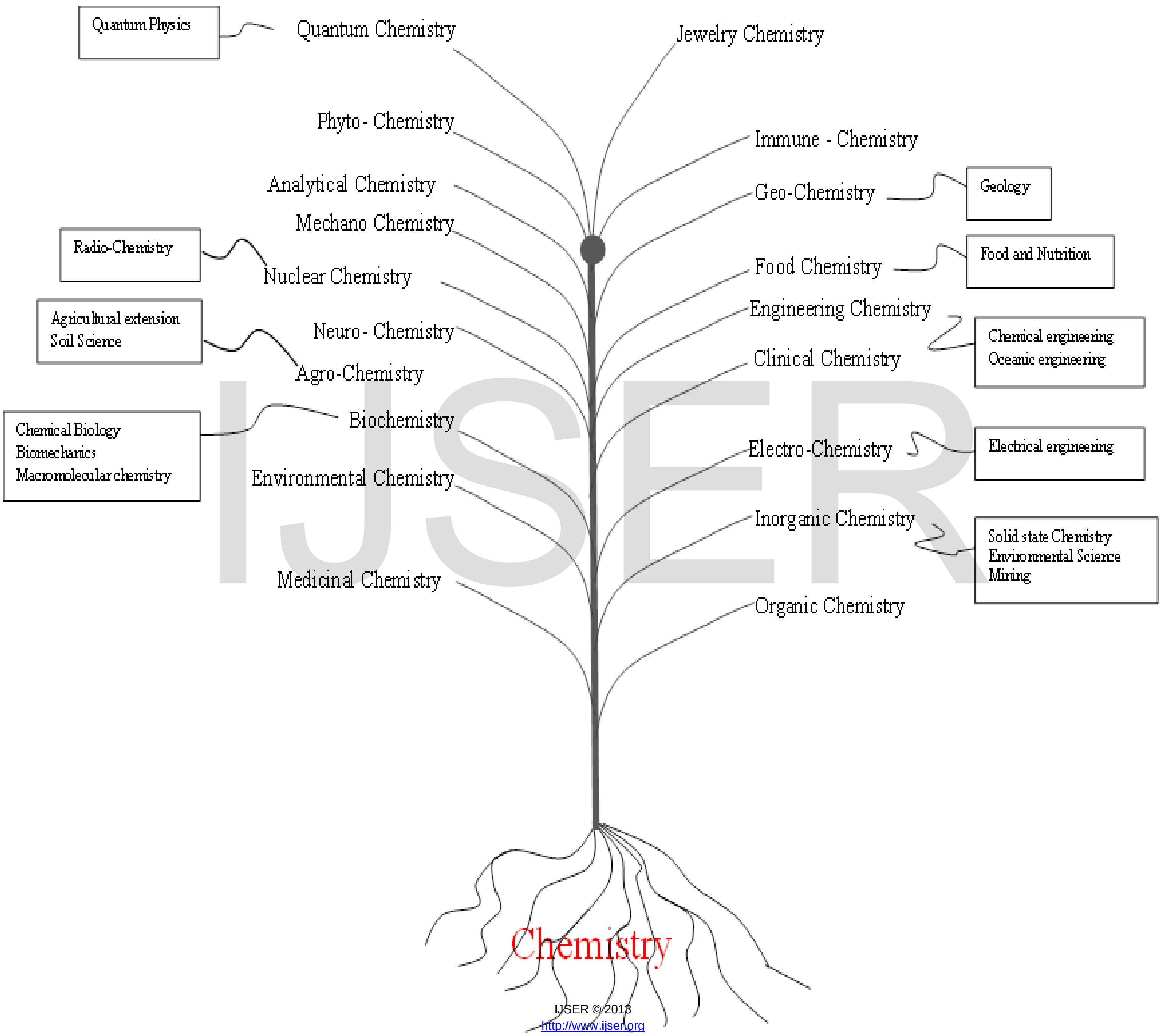
**Figure 1: Chemistry as Central Science** (Branches of Chemistry and some related disciplines)



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Analysis of results for six consecutive years as shown in the graphs below provides evidence of students' performance on the subject. In Kenya, the mean achievement scores of students in chemistry at the KSCE from 2005 to 2010 were 26.99, 24.78, 25.17, 22.50, 18.**9**9 and 24.71 respectively. In Nigeria, from 2005-2010 analysis of results of students who sat for WASSCE from 2005 to 2010**.** showed that 37.28%, 50.65%, 45.11%, 46.16%, 43.69**% and** 50.70% respectively passed at credit level

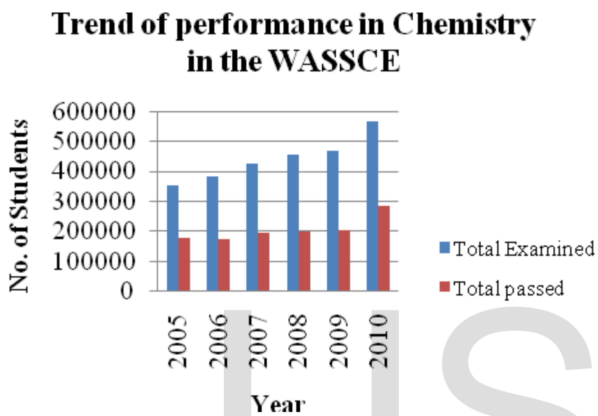


**Figure 1: Trend of performance in Chemistry in the WASSCE**

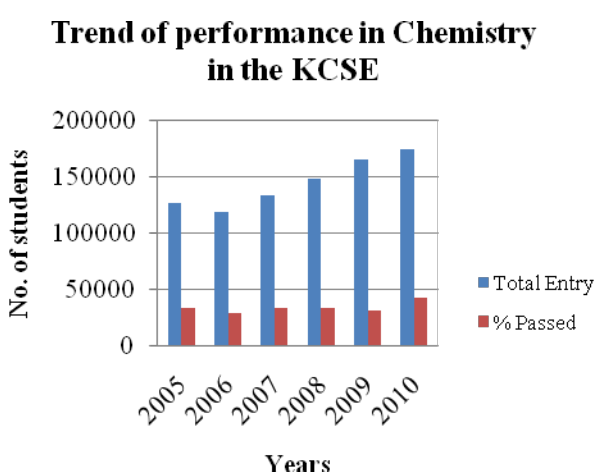


**Figure 3: Trend of performance in Chemistry in the KCSE**

This level of pass cannot foster global competitiveness or promote students' headway for admission into the Universities or Higher institutions for science related subjects that need chemistry as a prerequisite. Failure also shows that secondary school students are not being prepared for the global demands in the current era. A few studies proffered reasons for the persistent failure, [2]; [3] attributed the failure to lack of adequate teaching resources while [1] viewed students' attitude as a contributing factor. In a recent study carried out by [36] on Ethiopian University students, 82% and 80% of students respectively ascribed their lack of interest and motivation in chemistry to the teacher and teaching method. Similarly, [5] asserted that the poor performance was due to teachers' emphasis on content coverage and teachers' lack of interest to try new teaching methods.

In Kenya, concern about the persistent poor performance in science and mathematics led to the mounting of SMASSE (Strengthening Mathematics and Sciences in Secondary School Education) project. The project was organized by the Ministry of Education Science and Technology (MOEST) in collaboration with the Government of Japan through Japan International Cooperation Agency (JICA). The aim of the project was to provide in-service training for mathematics and science teachers to help them improve on their pedagogical content knowledge (PCK) and teaching methodology. Thus, the SMASSE initiative was based on the need for effective classroom practices and a shift from teacher-centered teaching methods to student-centered and activity-based methods. A similar trend to the Kenya experience was that in 2009 the Federal Government of Nigeria through the Minister for Information broadcasted the implementation of "re-branding" to be applied to all sectors of Government including education. The aim of re-branding was to adopt new and better ways of demonstrating responsible lifestyle that will foster the achievement of the country's vision 2020 in sustainable human development. In line with this, education reform agenda was campaigned with the aim of revamping science, technology and mathematics while imbedding innovative systems for ameliorating achievement, enterprise, development and economic growth [35]. In the view of [19] there was also a need to re-brand the country's education sector through teaching methods. One can therefore affirm that teaching methods remain a critical area of concern to be persistently addressed until success is achieved.

Studies have shown that about 51% of practicing teachers in Nigerian secondary schools are not professionally qualified to be in the classroom [30] and [26] found that a major defect in Nigerian science teaching is lack of application to real world. Further studies confirmed that most science teachers do not possess the prerequisite knowledge needed for

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activity-based learning [20]; [13]. Hence, the prevalent teaching method in Nigeria and Kenya is talk and chalk approach [17]; [15]; [9]: [10]. It is in the light of the evidence provided that this paper sought to design chemistry teaching models based on the learning theories to enhance teaching skills that may not only improve students' achievement if appropriately adopted in several innovative ways, but may well foster students' acquisition of 21st century competencies that could enable them face the challenges in a rapidly growing competitive world.

**1. Concept of Learning Theory and models:**

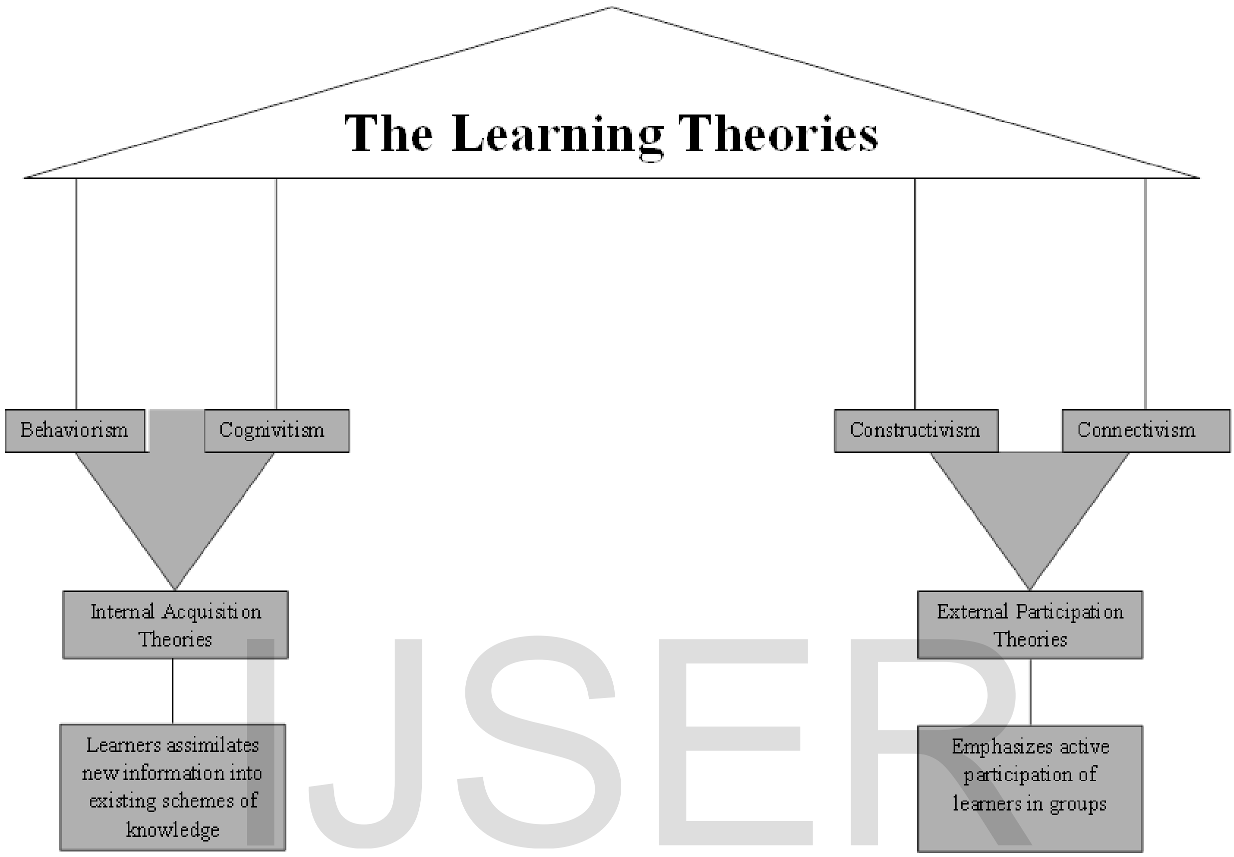
A learning theory endeavors to describe how children learn. A learning theory helps us understand the process of learning [18]. Learning theories play major role in instructional design models. Instructional design model conveys the entire idea of how to organize applicable instructional or pedagogical representation for achievement of instructional goals. Instructional models are strategies on which the styles or methods of teaching are based. According to [7] instructional models prescribe how combinations of teaching strategies should be incorporated to produce a structure of instruction. Models help learners to understand scientific concepts through visualization and the simplification of concepts or problems. Effective instructional models are based on the learning theories.

**2. The Learning Theories:** Four major schools of learning theories that exist to date are: Behaviorism, Cognitivism, Constructivism and Connectivism [18]. Behaviorism and cognitivism belong to internal or acquisition theories while contructivism and connectivism belongs to external or participation theories [31].

The internal acquisition theories have overtime advanced the idea that learning is a passive reception of information, to learning as an active search whereby learners build their schemas by assimilating new information into existing schemas of knowledge [21]; [38]. Participation theories on the hand give prominence to active participation of learners within a social group or context. This theory places strong emphasis on 'doing' and validates science as a process of doing. This paper deal with some aspects of the learning theories dealing with internal and external theories. [31] recommended that for effective teaching, a combination of the theories should be employed to take cognizance of students' diverse needs. Cognitive learning theory focus on the mental construct's and organizational patterns that an individual develops in the process of formation of new reasoning patterns in response to his/her inadequacy in using present reasoning patterns to cope with a demand [16]. In the course of the formation of new reasoning patterns, the individual actively engages his/her internal mental processes to combine new experiences with prior experiences and to generate logical operations.

Research has shown that knowledge is stored as a network of concepts in the brain of the leaner and that learners construct knowledge by making connections between new information and their conceptual network or mental structures [27]. The constructivist focuses on learners' construction of knowledge in their own understanding. From the standpoint of the constructivists, learners develop shared-meaning through the process of interaction with phenomenon, within a social context as they construct new knowledge. As far as the constructivist is concerned, learning is something that is done by the learner and not something imposed on him/her from outside, hence, the doing aspect of the external theories. In the view of [19] "learning can be thought about as a process of conceptual change in which faculty or incomplete models are repaired" p161. Conceptual change occurs during the process of dis-equilibration or cognitive conflict.

**Figure 4: The Learning Theories**



According to [26], accommodation which is the changing of one's own thinking in order to strive to equilibrium includes analysis of a situation to locate source of conflict and the formation of new hypothesis to plan an attack [11]. Prior to accommodation, the individual's mind was in a state of equilibrium but with the assimilation of new data the mental structures become inadequate to tackle the new situation and so must undergo process of change. Change in thought unit also gives rise to change in organizational pattern. The process of organization further entails changing the original mental structures. The end result of equilibration is increase of knowledge and a deeper understanding of experience encountered or of content in the area of science under investigation.

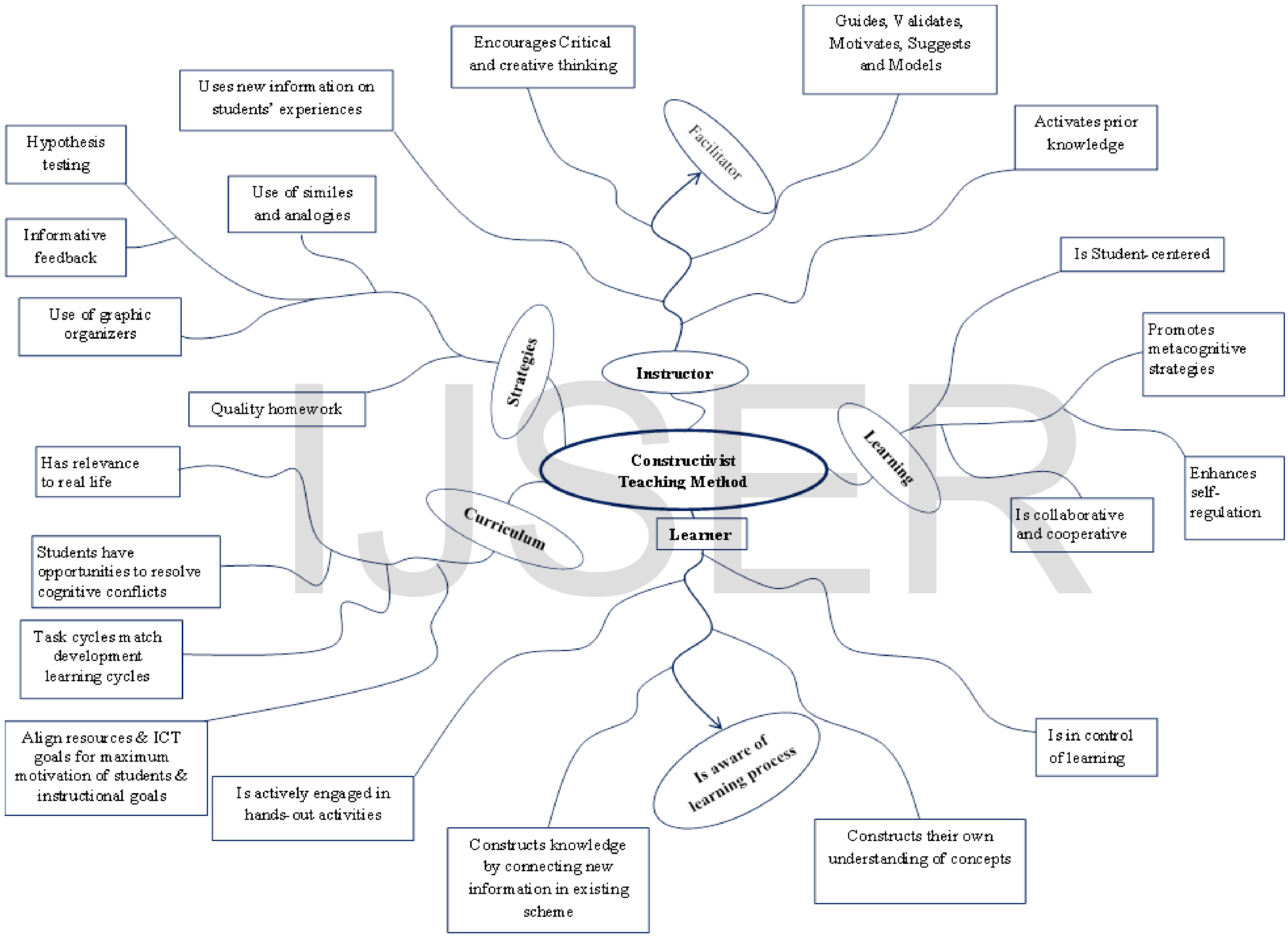
Social constructivism is established on the work of [26], [35], Bartlette, Bruner, Rodoff and Gestalt psychologists, who theorized that learners' understanding is both individual and social [39]. Two broad areas of constructivism exist: they are psychological and social constructivism. Social constructivism which is of social learning is deep-rooted in Vygotsky's theory. Social constructivism emphasizes the importance of relationship between students; the student and the instructor in the learning process. The role of learners' active participation as a team, shared responsibility [39] and social interaction in fostering critical and creative thinking and understanding of science concepts has eminence in social constructivism. Interaction in groups while carrying on hands-on activities provide learners opportunity for negotiation of meaning and arriving at consensus- an important mechanism in the equilibration of discrepancy and disagreement. [35] also believed that learning cannot be separated from the social and cultural settings in which it takes place.

**Schema Theory:** An attempt to explain how new information is encoded in the long term memory is the realm of the schema theory. Schema theorists opine that concepts are best understood after foundation of concrete and relevant information has been established [32]. The theory suggests that prior knowledge can expedite transfer of a learning task. Hence, for students to gain understanding and perform tasks in chemistry effectively, their prior knowledge must be provoked. Information processing model-elaboration processing strategy stresses the links between the information stored in long term memory and the new information. Therefore, the awareness of the relationship between concepts is very significant to cognitive teaching and learning in the classroom [13]. For meaningful learning to occur, students must be able to relate new knowledge (concepts or propositions) to what they know already. Meaningful learning implies that the learner fully comprehends the concept being learned and that the individual knows how that specific concept, ideas or facts relate to other stored facts [4]. Meaningful learning which the learning theories tend to achieve leads to deeper learning. Deeper learning is vital strategy through which students find meaning and understanding from course material and experiences [37]. With deeper learning students gain the competence to transfer knowledge to real life situations.

**Traditional Teaching and Modern Teaching Methods**

The traditional teaching methods which comprise expository, discussion and demonstration approaches are teacher-centered. Expository instruction has been criticized for placing little emphasis on thinking. It has been described as a "cookbook" nature of learning. Traditional instruction which is heavily driven by 'teacher-talk' involves the transmission of knowledge by the teacher to passive listeners. In science classroom where the traditional approaches dominate, little learning takes place [35] as the learner's goal is to regurgitate the information or procedure as prearranged by the teacher [8]. A supposition which is fundamental in the teaching method is that students are 'empty urns' into whom teacher is expected to pour knowledge. The teacher determines the outcome of the learning process and the learner is not challenged to create or critically contest teacher's results. The design in traditional approaches is such that learners spend more time in finding correct answers rather than critically thinking out how to construct their own meaning of scientific concepts. With emphasis on content coverage learners have little or no time for resolution of cognitive conflict and for interaction in groups where they can explain their own position on the learning process as they explore, elaborate and carry out hands-on activities. Several studies that compared the traditional teaching methods (TTMs) with constructivist methods tended to prefer the latter for stimulating conceptual change and meaningful/deeper learning [34]; [6]; [9], [30]. Figures 5 and 6 show the features of Traditional Teaching Methods and Constructivists Teaching Methods**.**

**Figure 5: Characteristics of Constructivist Teaching Method**



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**Model founded on Piaget's and Vygotsky's Theory**

**Figure 7: 5E Piagetian Model: Illustration of a typical lesson**

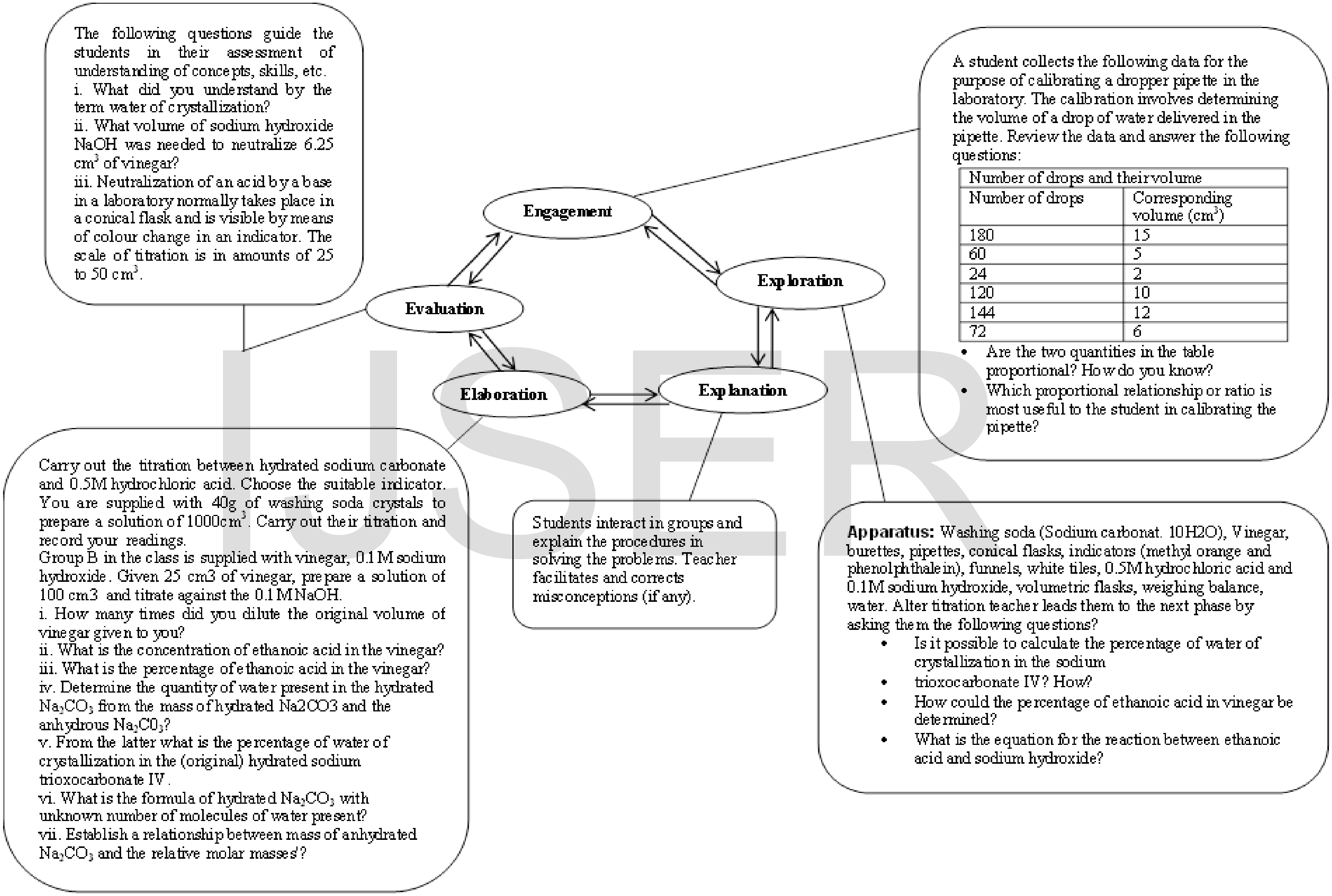
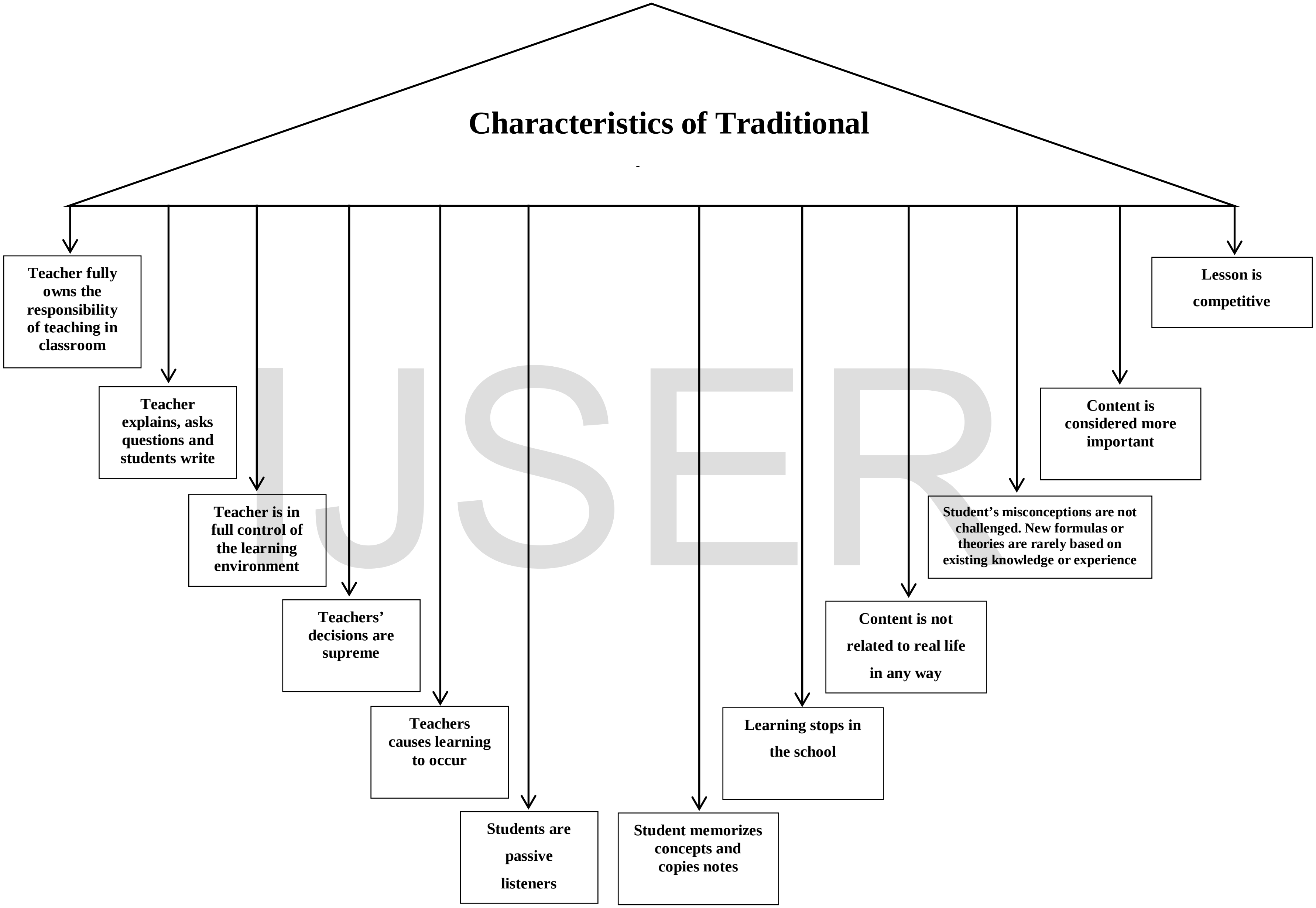


**Figure 6: Characteristics of Traditional Teaching Method**



**Instructional Design Model:** An instructional design model is a framework on which teachers can base their instruction in order to improve on the learning process to foster student's understanding of scientific concepts. Instructional research models can also make difficult science concepts easier to conceptualize. It is possible to design several models based on the learning theories but this paper designed models based on [26] and [35] theories, that is, the inquiry model and another based on the schema theory (information processing model).

**Information Processing Model**: Information processing model has its foundation on the schema theory. [11] translated the model into an instructional design constituting phases of learning.

**Gagne's** (1985) **Phases of Learning**

**Table 1: Instructional Design Model**

| **Internal process** | **Instructional event** | **Action example** |
|---|---|---|
| Reception expectancy | 1. Gaining attention<br>2. Informing learners of the objective | • Use abrupt stimulus change<br>• Tell learners what they will be able to do after learning |
| Retrieval working memory | 3. Stimulating recall of prior learning | Ask for recall of previously learned knowledge or skills |
| Selective perception | 4. Presenting the stimulus | Display the content and distinctive features |
| Semantic encoding | 5. Providing learning guidance | Suggest meaningful learning |
| Responding, reinforcement and retrieval. | 6. Eliciting performance<br>7. Providing feedback<br>8. Assessing performance | Requires additional learner performance with feedback |
| Retrieval and generalization | 9. Enhancing retention transfer | Provides varied practice and space |

Seeing that students have for many years registered poor performance in chemistry despite the research efforts aimed at improving students performance, it has become imperative for teachers to adopt models that are based on sound and tested theories. This study therefore examines the extent to which the models given in this study will impact on student's performance in chemistry.

**Research Questions:** To what extent will the application of models based on the learning theories affect student's performance in chemistry as against those taught using the traditional methods?

How does gender impact on students' performance in chemistry using models founded on the learning theories and students taught using traditional methods?

**Research Hypotheses:** The mean performance scores of students taught using models founded on the learning theories and those taught using the traditional approaches will not differ significantly.

**Research Design:** The study was a quasi-experimental pre-test posttest design. The non-equivalent control group design was used because intact classes were involved. When administrative decisions such as such school regulations prevent random assignment of subjects to treatment and control groups it is advisable to use non-equivalent control group design.

**Target Population:** The population comprised all chemistry students in Senior Secondary Class II of two Special Science Schools in Anambra State, Nigeria.

**Method:** The study sample comprised two hundred and twenty four (224) SS II students from one male and one female Special Science Schools in Anambra State - Nigeria. Purposive sampling was used to select all the students in SSII class because chemistry is a compulsory subject for all students in Special Science Schools. These schools were double streamed. Thus, four intact classroom groups were randomly assigned to different classes of the same school. The treatment group was made of 112 subjects (56 boys and 58 girls). The control group comprised (56 boys and 57 girls). Simple random sampling was used to select the responses of 56 boys and 56 girls for the treatment and control groups respectively to ensure equal replication of subjects. The sample for which data was complete was 224 subjects (112 female and 112 male) for the treatment and control groups respectively.

**Instrument** The instrument for the study was Chemistry Achievement Test (CAT) based on syllabus for SS class II with additional tests on the relevance of chemistry, topics precluded in the syllabus. The test was a 20-item objective question on organic chemistry and quantitative chemistry.

**Reliability of the instrument:** The instrument was subjected to trial testing using 40 chemistry

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students in a school different from the Special Science Schools used in the study. The scorer reliability estimate using Pearson- Product moment correlation was found to be 0.84.

**Instructional Procedure (Experimental Group): The** following instructional event designed for teaching a topic in organic chemistry is a model from the schema theory based on Gagne's phases of instructional model. The method used was the creation of typical lesson intended to implement the principles of the learning theory depicting the information processing model. The teacher's role was that of a facilitator whose duty it was to provoke students to think, create and take responsibility for the learning process. The reception expectancy stage informed students of what was expected of them by the end of the activities. At the retrieval working memory phase, questions were posed that elicited recall from the memory of learners' previous knowledge. The ability of learners to select material based on concepts under study was tested. Activities in the semantic encoding stage were an attempt to encrypt new knowledge with previous knowledge so that knowledge can be stored both in the short term and long term memory. Activities merged chemistry concepts under study and leaner's natural setting. Responding retrieval linked evaluation, further explanation, exploration and homework task that support lifelong learning cycle that will enhance retrieval and sustainable education.

**Table 2: Instructional Event: Lesson on polymerization**

| | |
|---|---|
| Reception Expectancy | Specific objective: By the end of the lesson students should be able to explain: (i) the terms monomer, polymer and polymerization.<br>(ii) Mention types of polymerization.<br>(iii) Make a list of products of polymerization.<br>(iv) Apply knowledge to environmental issues. |
| Retrieval Working Memory | (i) What is a molecule? (ii) Give example of a small and large molecule in nature. (iii) What does term *poly* mean? Now proffer one word to depict a large molecule. (iv).What type of reaction do unsaturated hydrocarbons undergo? (v). Mention 4 unsaturated compounds that exist in nature. |
| Selective Perception | Teacher had prepared nicely and delicious pot of indomie for experiment, the left over will be consumed by learners after the lesson. Small portions were put in plates for each group (four students/group) of students. The experiment (i). Disentangle the indomie and attempt to draw (a) one piece (b) untangled whole. |
| Semantic Encoding | One piece can be regarded as a single monomer while untangled whole indomie can represent a macromolecule or polymer. (iii) (a) what is the mass of 1 mole of $H_2O$? (b) What is the mass of 1 mole of $C_{17}H_{35}COOH$? (c) How big is a mole? (d) If you acquired 100 Kenya shillings in one second, how long will it take you to acquire 2 million Kenya shillings? (iv) Write down the chemical formulae of ethane and ethene and draw their structures (v) Which of these undergo addition reaction to form a large molecule. |
| Responding Reinforcement Retrieval | Now, draw the structure of butene, octene… and continue to repeat the structure on both ends severally. This is a polymer. Attempt to define the term, polymer.<br>Using the clay balls and toothpicks of broom sticks you were asked to bring (i) In your groups, form three dimensional structures separately. (ii) Link all of them to form one structure. Now, construct your own definition of the term polymerization. Homework: There are two types of polymerization. Find out what they are and the difference between them. Use natural beads to form polymers of different sizes. |
| Retrieval Generalization | We have natural and synthetic polymers (i). Attempt to classify the following products under natural or synthetic polymer. Wool, nylon, plastic containers, rubbers, hair, weavon, cellulose, eggs. (ii) What is a polymer? (iii) What are the uses of rubbers and plastics? (iv) What are the disadvantages of excessive use of plastics today? Take example of plastic littering, polythene bags and explain why they are a menace to the environment. (v) suggest ways of disposing them<br>Research (i) Cost of cleaning up litter has impact on our economy. |

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| | |
|---|---|
| | Discuss. (vi) How can litter cause serious health problems? (v). Paper and plastics represent a huge threat to the environment and interfere with the ecosystems. Describe a typical scenario of what happens on a very rainy flood day as per highways, farms, gutters and drainages. |

The traditional group was taught using talk-chalk method and teacher demonstration as students' listened copied notes and followed the teacher's step-by-step procedure.

**Data Presentation**

The Test of Assumption Between the Analysis of Variance (ANOVA) – the normality between the dependent variables is shown in Figure 8 below.

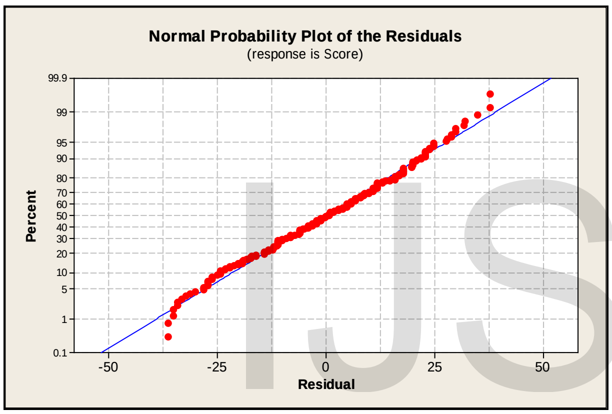



**Figure 8: Test of Assumption between the Analysis of Variance (ANOVA) – the normality between the dependent variables**

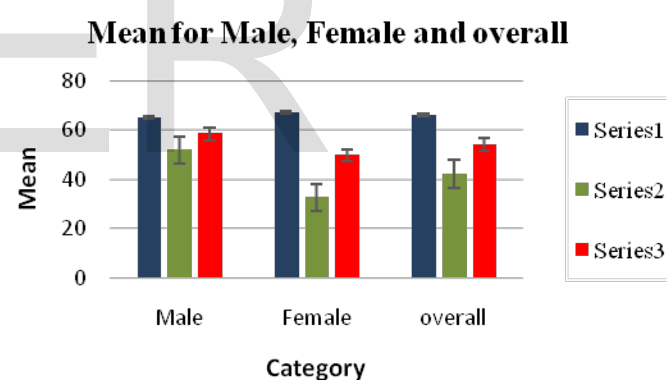
The graph shows that the data follows a normal distribution.

Research Question 1: To what extent will the application of models based on the learning theories affect students' performance in chemistry as against those taught by traditional methods?

**The table 3: Means and standard deviation of students' scores in post-treatment CAT (by treatment by Gender).**

| | | **Gender** | | |
|---|---|---|---|---|
| | | **M** | **F** | **Overall** |
| Experimental | Mean | 65.07 | 67.16 | 66.12 |
| | SD | 10.88 | 17.73 | 14.68 |
| | Sample size | 56 | 56 | 112 |
| Control | Mean | 51.86 | 32.59 | 42.22 |
| | SD | 11.43 | 19.57 | 18.66 |
| | Sample size | 56 | 56 | 112 |
| Overall | Mean | 58.46 | 49.87 | 54.17 |
| | SD | 12.94 | 25..44 | 20.59 |
| | Sample size | 112 | 112 | 224 |

The table shows that the mean performance score of the treatment group is 66.12 as against 42.22 for the control group. Thus, the experimental group has a




higher mean score than the control group.

**Figure 9: Showing the Mean Scores – Experimental and Control Groups; Gender Scores**

- Series 1 is Experimental group
- Series 2 is the control group
- Series 3 is the overall

To determine the level of significance of the mean scores ANOVA was carried out.

**Ho$_1$** The mean performance score of students taught using models founded on the learning theories and those taught using the traditional method will not differ significantly

**Table 4: One-way ANOVA: Score versus Group**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Group | 1 | 31969 | 31969 | 113.42 | 0.000 |
| Error | 222 | 62571 | 282 | | |
| Total | 223 | 94540 | | | |

S = 16.79 R-Sq = 33.82% R-Sq(adj) = 33.52%

The p-value is 0.000 which is less than 0.05. Therefore at 5% level of significance, the null hypothesis was rejected. Hence, teaching method had a significant effect on the mean score of students.

Individual 95% CIs for Mean Based on Pooled SD

**Table 5: Mean Scores and Standard Deviation of the Control and Experimental Groups**

| Level | N | Mean | SD |
|---|---|---|---|
| Control | 112 | 42.22 | 18.66 |
| Experimental | 112 | 66.12 | 14.68 |
| | 224 | 54.17 | 16.67 |

The mean score of the experimental group (66.12) was higher and significantly different from that of the control group (42.22).

To determine the significance of gender on the mean performance scores of students taught using the models**, Table** 6 below reveals the results**.**

Gender does not have a significant impact on students mean performance scores.

**One Way ANOVA: Scores versus Gender**
**Table 6: Determination of Significant Level of gender on the mean performance scores of students**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Gender | 1 | 4131 | 4131 | 10.14 | 0.002 |
| Error | 222 | 90408 | 407 | | |
| Total | 223 | 94540 | | | |

S = 20.18 R-Sq = 4.37% R-Sq (adj) = 3.94%

The p-value is 0.002 which is less than 0.05. Therefore at 5% level of significance, the null hypothesis was rejected. Therefore, gender had a significant effect in the mean score.

Individual 95% CIs for Mean Based on Pooled SD

**Table 7: Comparison of the performance (boys and girls) taught using the models (Mean and SD)**

| Level | N | Mean | SD |
|---|---|---|---|
| Boys | 112 | 58.46 | 12.94 |
| Girls | 112 | 49.87 | 25.44 |

Pooled SD = 20.18

The mean score of boys was better (58.46) and significantly different from that of girls (49.87).

**Discussion**

Evidence from the findings of this study showed that teaching that was based on the learning theories significantly impacted on students' performance in chemistry. The findings are in agreement with [33]; [6] who opined that constructivist methods fostered conceptual understanding more than the traditional methods. In addition, when students are involved in learning process, they develop competencies needed for knowledge transfer [36]. The stages in Gagne's steps of learning were meant to enhance the encoding of concepts in both short-term and long-term memory. That boy performed better than the girls seemed to agree with [24] who asserted that boys perform better than girls in the sciences. However, since girls in the experimental group had a higher mean score than girls in the control group, the teaching method enhanced the performance of both boys and girls.

**Conclusion**

In a world rapidly needing young people who are capable of decision-making through their capacity to use direct and inverse proportional reasoning, teaching methods which encourage memorization have become obsolete. Persistent failure in Chemistry among African chemistry students suggests that African leaders need to pay more attention on the quality and standard of education because educational achievement is the hallmark of any nation and the key to success of democracy and economy. The reality of this fact comes to light when students cannot gain entry into the Universities or institutions of higher learning for those disciplines which require chemistry as basic entry qualification. Finally, teachers must prepare students for the demands of the global business community which they must face after school – hence, the need to base teaching methods on sound evidence-based theories.

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