

Research Article

# Practical Teaching Model in Double Indicator Titration: Influences on Academic Achievement of Chemistry Students

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**Abstract:** The purpose of this study was to evaluate a practical model in teaching double indicator titration in chemistry in the senior high schools in Ghana. Research design for the study was Action research. The population was made up of chemistry teachers and students in four senior high schools with two schools located in the Kwaebibirim District and two senior high schools located in the Denkyembuo District of the Eastern Region of Ghana. Purposive and simple random sampling techniques were used to select the respondents for the study. The sample comprised of twenty-five (25) chemistry teachers and one hundred and fifty (150) students in the four Senior High schools. The study indicated that Chemistry teachers would improve upon the academic performance of chemistry students in double indicator titration when they use the developed practical teaching model (DEPTTEM) more. The main instruments used in this study were classroom observational checklists and questionnaires. Descriptive statistics (frequency, percentage, mean and standard deviation) were used to analyze the data gathered. Coding schemes were developed using Statistical Package for Social Sciences (SPSS) (version 21) to organize the data into meaningful and manageable categories. The study also revealed that the outcome of the post-test indicated that, the DEPTTEM impact differently on the academic performance of SHS male and female chemistry students in the Kwaebibirim and Denkyembuo Districts of the Eastern Region. It is recommended that the government and non-governmental organizations should collaborate with the Ministry of Education to sponsor in production of more of the developed practical model (DEPTTEM) for teaching chemistry lessons. This in a way would help improve the academic performance of chemistry students in the Kwaebibirim and Denkyembuo Districts of the Eastern Region and the nation at large. It is also recommended that chemistry teachers should consider teaching methods that would equally cater to both male and female chemistry students during chemistry lessons.

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## 1. Introduction

Chemistry is a practical oriented subject that occupies a prominent place in senior high school (SHS) science curriculum [1]. It is an experimental science that needs a high level of practical work for its understanding, development and application. Practical work enables students to understand scientific concepts in everyday life. It also assists them to apply the learned chemistry concepts and skills to social problems and understanding scientific and technological principles involved in household devices [2]. The original reasons for laboratory development lay in the need to produce skilled technicians for industry and highly competent workers for research laboratories. There are many espoused purposes for doing practical work [3]. The quality of practical work varies considerably

but there is strong evidence from this country and elsewhere that; when well-planned and effectively implemented, science education laboratory situates students' learning in varying levels of inquiry; requiring students to be both mentally and physically engaged in ways that are not possible in science education experiences.

A study conducted in the contents of the senior high chemistry curriculum that can inculcate entrepreneurial skills and concluded that there are many of such concepts in the SHS curriculum with quantitative analysis; Acid – base titrations recording the second highest mean and standard deviation of 3.81 and 0.29 respectively [4]. Real world applications of titration are in the field of developing new pharmaceuticals and determining unknown concentrations of analyte of interest in blood and urine. Practical activities are designed to make the students active participants; such methods are in their infancy in chemical education [5]. Some of the objectives of practical work are to:

- encourage accurate observation and description
- promote a logical reasoning and formulate hypothesis
- use knowledge and skills acquired in unfamiliar situations
- develop interpretation skills
- develop problem solving skills
- design simple experiments and to test hypothesis

Much effort has been made to identify the problems that are inherent in the teaching of chemistry in SHS. These factors influence the effective teaching of chemistry which in turn plays a vital role in the lives of the students as it affects their performance. These include physical class room and laboratory, In-service training, School management, Instructional arrangement or methodology and etc [7]. The physical classroom needs good ventilation, availability of good chalk board, enough chairs and tables, charts and clean environment. Other factors of the physical classroom include the presence of instructional materials in the laboratory such as apparatus and chemicals [8]. This implies that effective model that can be used to improve teaching and learning of double indicator titration is the developed practical teaching model (DEPTTEM) as compared to the teachers' method [9]. The school management is another vital factor that may be considered before anticipating a good result. Some of the responsibilities of the school management include provision of library, laboratory, and essential services such as light, food vendors, counsellor and first aid [8]. The SRC serves as teaching Centre and promotes practical work. The SRC has laboratory assistant, a coordinator and a budget to renew and buy the needed materials. Manuals as well as computers for practical work are available. The SRC also organizes workshop for teachers [10].

Despite these improvements in the training of the science teacher and his teaching capabilities, students' performance in chemistry practical continue to be low according to the West African examination council chief examiners report for senior high school certificate examination (2002-2007). The descending performance of chemistry students is due to the wrong way and manner teachers teach practical chemistry [11]. The poor performance of students in Chemistry is the methods used by the teachers. From the above discussion, it is clear that there is the need to improve on the methods of teaching chemistry practical to student [12]. For this reason, this research seeks to design practical teaching model based on constructivist approach in teaching the topic "double indicator titration involving HCl against  $\text{Na}_2\text{CO}_3/\text{NaOH}$  mixture".

### ***1.1. Inquiry-Based Science Learning***

Scientific inquiry has been a standard in most policy reform documents during the last two decades [13]. The National Science Education Standards define scientific inquiry as: "Multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to

gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results" [13]. Also, the National Research Council, has expanded their description of scientific inquiry activities to include laboratory experiences: "Laboratory experiences provide opportunities for students to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science" [13].

Inquiry has been used in science education in a number of ways, ranging from the simple description of knowledge gain through applying the scientific method in well-designed activities to the complex instructional approach where teachers act only as facilitators and students actively guide their own learning process [14]. Research has shown mounting evidence of the positive effects of integrating inquiry into science teaching and learning [15]. In their meta-analysis of inquiry-based science teaching, researchers compared and contrasted scientific inquiry in 37 studies published between 1996 and 2006 in terms of two dimensions: the cognitive dimension of inquiry and the guidance dimension of inquiry [15]. The cognitive dimension consisted of four domains: conceptual structures and cognitive processes that were used during scientific reasoning; epistemic frameworks used when scientific knowledge was developed and evaluated; social interactions that shaped how knowledge was communicated, represented, argued, and debated; and procedural domain that described the methods of asking scientifically oriented questions, designing experiments, executing procedures, and analysing data. The guidance dimension of inquiry identified the extent to which activities were guided by the teacher or student. The results of this meta-analysis indicated that engaging students in guided inquiry activities, specifically epistemic activities or the combination of procedural, epistemic, and social activities, has positive learning gains compared to traditional learning or unstructured student-led activities. The implementation of inquiry-based science teaching programme is posited to help motivate and engage students in science learning, improve their academic readiness and achievement and reduce their resistance behaviours toward science and technology [14, 16, 17].

Scientific investigations and hands-on activities play a distinctive role in inquiry-based science teaching and learning. During investigations and hands-on activities, students are required to use the scientific inquiry elements of questioning; stating a hypothesis; making a plan; conducting observations and experiments to generate artifacts; collecting information; drawing conclusions; and, communicating throughout the inquiry process [18]. The intended outcome of the scientific investigations and hands-on activities in this curriculum unit was that students develop a deeper understanding of scientific concepts, enhance their research and problem solving skills, develop positive attitudes toward science, and improve their academic achievement in science subjects [16, 18].

A research was conducted into the approaches that can be used to teach chemistry at senior high. The findings indicated that inquiry and guided discovery are the best approach with a mean of 3.33 and 3.70 respectively [4]. Even though laboratory activities breed interest in students' attitude to science education, it does not warrant realization of the goal of science teaching and learning, rather the combination of all the teaching and learning methods should be used due to the variation in the students [19]. Students need to be encouraged to become deeply involved in the laboratory work so as to develop their skills. Chief Examiners' Reports on SHS chemistry paper 3 in 2007 shows that most students have continued to perform poorly countrywide in comparison to paper 1 and 2. The Chief Examiners' Reports further pointed out that, it is clear from candidates' answers that only few schools follow a practical approach to the teaching of chemistry [20]. It has also been observed (by the researcher) that most practical activities in science (chemistry) education in most SHS in Kwaebibirim District of the Eastern Region is still a pipeline dream as few teachers are capable of teaching chemistry practical work; and many chemistry teachers still need assistance on how to involve students in meaningful practical activities. The purpose of this study was to use practical model to teach double indicator

titration in chemistry in the senior high schools in Ghana. The study sought to answer these research questions (1) How effective is the practical teaching model in teaching double indicator titration at the SHS? (2) In what ways does the use of the practical teaching model influences students' academic performance at SHS? (3) Is there any difference between male and female students' academic achievement of concepts in practical chemistry after being exposed to the practical teaching model?

## 2. Materials and Methods

Research design for the study was Action research. The study comprised the development and formative evaluation of the teacher support material (TSM) through group discussions and Collaborative/Cooperative learning. From these observations, a lesson plan (DEPTTEM) was designed to enhance the teaching and learning of double indicator titration under the following categories,

### 1. Break the topic into four parts

- a. HCl against NaOH using methyl orange and phenolphthalein indicator separately. These would help the student know the reactions taking place and also the volume of HCl required to neutralise the NaOH as well as the colour change at the end point.
  - b. HCl against  $\text{Na}_2\text{CO}_3$  using methyl orange and phenolphthalein indicator separately. These would help the student know the reactions taking place and also the volume of HCl required to neutralise the  $\text{Na}_2\text{CO}_3$  as well as the colour change at the end point. The student would learn that the reaction is half-way when using phenolphthalein indicator but that of methyl orange is a complete reaction. Knowing these two titrations, the student would have an idea of equations of reaction taking place, colour change at various endpoints and total volumes of HCl required to neutralise all  $\text{Na}_2\text{CO}_3$  and NaOH when given a mixture of the two.
  - c. HCl against  $\text{Na}_2\text{CO}_3/\text{NaOH}$  mixture using methyl orange and phenolphthalein indicator separately (discontinuous method). At these stage the student brings the knowledge acquired in titration a and b . The student has all the knowledge of what is going to happen before performing the practical.
  - d. HCl against  $\text{Na}_2\text{CO}_3/\text{NaOH}$  mixture using phenolphthalein followed by methyl orange indicator (continuous method). This stage the student brings the knowledge acquired in titration c. The student knows that, at the phenolphthalein end point all the NaOH and half of the  $\text{Na}_2\text{CO}_3$  have been used leaving half of the  $\text{Na}_2\text{CO}_3$  in solution for the methyl orange titration.
2. **Grouping of students.** Students should be put into groups of five members instead of working in isolation. These would help reduce the problem of inadequacy of apparatus, it will bring about discussing and also improve collaborative learning which will intern enhance performance of girls. Girls are more comfortable with discussing and collaborative learning.
  3. **Thirdly,** the design of the lesson should be in the form of discussion, questioning and answering while the practical is ongoing. With the above mentioned category, the researchers came up with the lesson design (DEPTTEM) as shown.

### 2.1. Developed Practical Teaching Model for Double Indicator Titration (HCL Against $\text{Na}_2\text{CO}_3/\text{NaOH}$ Mixture)

#### 2.1.1. Topic

## Double Indicator Titration ( $\text{Na}_2\text{CO}_3/\text{NaOH}$ Mixture)

### 2.1.2. Subtopics

- Titration of HCl against NaOH using a single indicator (phenolphthalein or methyl orange).
- Titration of HCl against  $\text{Na}_2\text{CO}_3$  using a single indicator (phenolphthalein or methyl orange).
- Titration of HCl against  $\text{Na}_2\text{CO}_3$  using double indicator method (phenolphthalein and methyl orange).
- Titration of HCl against  $\text{Na}_2\text{CO}_3/\text{NaOH}$  mixture using a single indicator (phenolphthalein or methyl orange).
- Titration of HCl against  $\text{Na}_2\text{CO}_3/\text{NaOH}$  mixture using double indicator method (phenolphthalein and methyl orange).

### 2.1.3. Objectives

Today we are going to perform titration using two different indicators to determine the exact concentrations of two substances ( $\text{Na}_2\text{CO}_3$  and NaOH) in a given mixture.

### 2.1.4. Anticipatory Set

- What is the colour change at the end of titration between HCl & NaOH using methyl orange indicator?
- What is the colour change at the end of titration between HCl &  $\text{Na}_2\text{CO}_3$  using methyl orange indicator?
- What is the colour change at the end of titration between HCl & NaOH using phenolphthalein indicator?
- What is the colour change at the end of titration between HCl &  $\text{Na}_2\text{CO}_3$  using phenolphthalein indicator?

Write the balanced chemical equations of the following reactions

- Hydrochloric acid + Sodium hydroxide  $\rightarrow$  Sodium chloride + Water
- Hydrochloric acid + Sodium trioxocarbonate(IV)  $\rightarrow$  Sodium chloride + Carbon dioxide + Water
- Hydrochloric acid + Sodium trioxocarbonate(IV)  $\rightarrow$  Sodium chloride + Sodium hydrogen trioxocarbonate(IV)

### 2.1.5. Collaborative/Cooperative Activity 1

Teacher divides the whole class into six groups of five members each. The groups are labeled **A B C D E F**.

Teacher classifies groups **A B C** as the **methyl orange group** and groups **D E F** as the **phenolphthalein group**.

Teacher supplies each of the groups with the following materials

- Retort stand and clamp
- Burette
- Pipette
- Funnel
- White tiles
- Conical flask
- Acid-base indicator
- An acid solution ( HCl)
- A base solution ( NaOH)

The acid-base indicator supplied to groups **A B** and **C** should be methyl orange and that supplied to groups **D E** and **F** should be phenolphthalein.

Teacher gives the following instructions to students.

- Put the HCl into the burette and titrate against 25cm<sup>3</sup> portions of the NaOH solution using two or three drops of the given indicator.
- Repeat the titration until consistent titre values are obtained.
- Tabulate your results and calculate the average volume of acid used
- The average volume of acid used for the methyl orange groups should be V<sub>a</sub>, V<sub>b</sub> and V<sub>c</sub> respectively.
- The average volume of acid used for the phenolphthalein groups should be V<sub>d</sub>, V<sub>e</sub> and V<sub>f</sub> respectively
- The methyl orange indicator groups should calculate their overall average volume of acid used as:

$$V_a + V_b + V_c / 3 = V_0$$

The phenolphthalein indicator groups should calculate their overall average volume of acid used as:

$$V_d + V_e + V_f / 3 = V_1$$

### 2.1.6. Discussions 1

Teacher asks the following questions after the activity Teacher asks students the following questions:

- What is the difference between V<sub>0</sub> and V<sub>1</sub>.
- Why is it that V<sub>0</sub> = V<sub>1</sub>.
- What is the reaction equation between HCl and NaOH when the indicator used is methyl orange?
- What is the reaction equation between HCl and NaOH when the indicator used is phenolphthalein?
- What can you say about the volume of HCl used in the methyl orange group and in the phenolphthalein titrations?
- Then we can say that volume of HCl ≡ NaOH in the methyl orange titration is.....
- Then we can say that volume of HCl ≡ NaOH in the phenolphthalein titration is.....

### 2.1.7. Collaborative/Cooperative Activity 2

Teacher maintains the same groupings **A B C** as the methyl orange group and **D E F** as the phenolphthalein group.

Teacher supplies all the materials for titration as indicated above with exception of the NaOH solution to each of the groups. In place of NaOH, teacher supplies Na<sub>2</sub>CO<sub>3</sub> solution.

Teacher maintains the indicators supplied to each groups. That is teacher gives groups **A B C** methyl orange indicator and groups **D E F** phenolphthalein indicator.

Teacher gives the following instructions to students.

- Put the HCl into the burette and titrate against 25cm<sup>3</sup> portions of the Na<sub>2</sub>CO<sub>3</sub> solution using two or three drops of the given indicator.
- Repeat the titration until consistent titre values are obtained.
- Tabulate your results and calculate the average volume of acid used
- The average volume of acid used for the methyl orange groups should be V<sub>a</sub>, V<sub>b</sub> and V<sub>c</sub> respectively.
- The average volume of acid used for the phenolphthalein groups should be V<sub>d</sub>, V<sub>e</sub> and V<sub>f</sub> respectively
- The methyl orange indicator groups should calculate their overall average volume of acid used as:

$$V_a + V_b + V_c / 3 = V_2$$

The phenolphthalein indicator groups should calculate their overall average volume of acid used as:

$$V_d + V_e + V_f / 3 = V_3$$

### 2.1.8. Discussions 2

Teacher asks the following questions after the activity

- What is the difference between  $V_2$  and  $V_3$
- Why is it that  $V_3 = 1/2 V_2$
- What is the reaction equation between HCl and  $\text{Na}_2\text{CO}_3$  when the indicator used is methyl orange?
- What is the reaction equation between HCl and  $\text{Na}_2\text{CO}_3$  when the indicator used is phenolphthalein?
- What can you say about the volume of HCl used in the methyl orange group and in the phenolphthalein titrations?
- Then we can say that volume of HCl  $\equiv$   $\text{Na}_2\text{CO}_3$  in the methyl orange titration is.....
- Then we can say that volume of HCl  $\equiv$   $1/2 \text{Na}_2\text{CO}_3 \equiv \text{NaHCO}_3$  in the phenolphthalein titration is.....
- Can the  $\text{NaHCO}_3$  produced at the end of phenolphthalein titration be titrated against HCl using methyl orange indicator?

### 2.1.9. Collaborative/Cooperative Activity 3

Teacher maintains the same groupings **A B C D E** and **F**.

Teacher supplies all materials for titration as indicated in activity 2. In this case, teacher supplies both methyl orange and phenolphthalein indicators to all the groups.

Teacher gives the following instructions to students.

- Put the HCl into the burette and titrate against  $25\text{cm}^3$  portions of the  $\text{Na}_2\text{CO}_3$  solution using phenolphthalein as indicator to the point. Do not discard the contents in the flask. Record the titre value.
- Add two drops of methyl orange indicator to the contents of the flask and continue the titration with the HCl until the end point. Record the titre value.
- Repeat the exercise until consistent titre values are obtained.
- Tabulate your results
- Calculate the average volume of HCl used at the phenolphthalein end point.
- Calculate the average volume of HCl used at the methyl orange end point.
- Groups **A B C** should calculate their overall average volume of HCl used at methyl orange and phenolphthalein end points as  $V_4$  and  $V_5$  respectively.
- Groups **D E F** should calculate their overall average volume of HCl used at methyl orange and phenolphthalein end points as  $V_6$  and  $V_7$  respectively.

### 2.1.10. Discussions 3

Teacher asks the following questions after the activity

- What is the difference between  $V_4$  and  $V_5$
- What is the difference between  $V_6$  and  $V_7$
- Why is that  $V_4 = V_5 = V_6 = V_7 = V_3$
- Why is it that  $V_4 + V_5 = V_2$
- Why is it that  $V_6 + V_7 = V_2$
- What is the reaction equation between HCl and  $\text{Na}_2\text{CO}_3$  in the first titration when the indicator used is phenolphthalein?

- What is the reaction equation between HCl and Na<sub>2</sub>CO<sub>3</sub> in the second titration when methyl orange indicator was added to the resulting solution obtained in the
- first titration?
- Then we can say that volume of HCl  $\equiv$  1/2 Na<sub>2</sub>CO<sub>3</sub> in the phenolphthalein titration (first titration) is.....
- Then we can say that volume of HCl  $\equiv$  NaHCO<sub>3</sub> in the methyl orange titration (second titration) is.....

#### 2.1.11. Collaborative/Cooperative Activity 4

Teacher maintains the same groupings **A B C** as the methyl orange groups and **D E F** as the phenolphthalein groups.

Teacher supplies all the materials for titration as indicated above with the exception of the base solution to each of the groups. In place of the base solution, teacher supplies Na<sub>2</sub>CO<sub>3</sub>/NaOH mixture solution to each group.

Teacher maintains the indicators supplied to each groups. That is teacher gives groups **A B C** methyl orange indicator and groups **D E F** phenolphthalein indicator.

Teacher gives the following instructions to students.

- Put the HCl into the burette and titrate against 25cm<sup>3</sup> portions of the Na<sub>2</sub>CO<sub>3</sub>/NaOH solution using two or three drops of the given indicator.
- Repeat the titration until consistent titre values are obtained.
- Tabulate your results and calculate the average volume of acid used.
- Groups **A B C** should calculate their overall average volume of HCl used as V<sub>8</sub>
- Groups **D E F** should calculate their overall average volume of HCl used as V<sub>9</sub>

#### 2.1.12. Discussions 4

Teacher asks the following questions after the activity

- What is the difference between V<sub>8</sub> and V<sub>9</sub>
- Calculate V<sub>0</sub> + V<sub>2</sub> and compare it with V<sub>8</sub>. What do you realise.
- Calculate V<sub>1</sub> + V<sub>3</sub> and compare it with V<sub>9</sub>. What do you realise.
- Why is it that V<sub>8</sub> > V<sub>9</sub>
- What are the reaction equations between HCl and Na<sub>2</sub>CO<sub>3</sub>/NaOH when the indicator used is methyl orange?
- What are the reaction equations between HCl and Na<sub>2</sub>CO<sub>3</sub>/NaOH when the indicator used is phenolphthalein?
- Then we can say that volume of HCl  $\equiv$  Na<sub>2</sub>CO<sub>3</sub> + NaOH in the methyl orange titration is.....
- Then we can say that volume of HCl  $\equiv$  1/2 Na<sub>2</sub>CO<sub>3</sub> + NaOH in the phenolphthalein titration is.....
- Can the NaHCO<sub>3</sub> produced at the end of phenolphthalein titration be titrated against HCl using methyl orange indicator?

#### 2.1.13. Collaborative/Cooperative Activity 5

Teacher maintains the same groupings **A B C D E** and **F**.

Teacher supplies all materials for titration as indicated in activity 2. In this case, teacher supplies both methyl orange and phenolphthalein indicators to all the groups.

Teacher gives the following instructions to students.

- Put the HCl into the burette and titrate against 25cm<sup>3</sup> portions of the Na<sub>2</sub>CO<sub>3</sub> solution using phenolphthalein as indicator to the point. Do not discard the contents in the flask. Record the titre value.

- Add two drops of methyl orange indicator to the contents of the flask and continue the titration with the HCl until the end point. Record the titre value.
- Repeat the exercise until consistent titre values are obtained.
- Tabulate your results
- Calculate the average volume of HCl used at the phenolphthalein end point.
- Calculate the average volume of HCl used at the methyl orange end point.
- Groups **A B C** should calculate their overall average volume of HCl used at phenolphthalein and methyl orange end points as  $V_{10}$  and  $V_{11}$  respectively.
- Groups **D E F** should calculate their overall average volume of HCl used at phenolphthalein and methyl orange end points as  $V_{12}$  and  $V_{13}$  respectively.

#### 2.1.14. Discussions 5

- What is the difference between  $V_{10}$  and  $V_{12}$
- What is the difference between  $V_{11}$  and  $V_{13}$
- Compare  $V_1 + V_3$  and  $V_{10}$
- Compare  $V_1 + V_3$  and  $V_{12}$
- Why is that  $V_4 = V_5 = V_6 = V_7 = V_{11} = V_{13} = V_3$
- Then we can say that volume of HCl  $\equiv 1/2 \text{ Na}_2\text{CO}_3 + \text{NaOH}$  in the phenolphthalein titration (first titration) is.....
- Then we can say that volume of HCl  $\equiv \text{NaHCO}_3$  in the methyl orange titration (second titration) is.....

After the lesson plan had been made, it was applied in the teaching and learning of double indicator titration in research school two and subjected to criticisms. the following criticisms were made;

1. The size of the group was large; these will make some of the students lazy and would not take part in the practical. The classroom would be too mechanistic, thus the number of students in a group was reduced to three.
2. The model is time consuming. With this criticism, the researcher explained that, teachers could arrange with students and meet on weekends.
3. The number of teachers during the lesson should be two not one because, the model comes with an observational check list. The researcher explained that, the presence of the laboratory assistant makes the number of teachers two. Thus both can supervise the practical section.

Modifications were made to arrive at a final version (version B), with real evidence of its practicality obtained.

The third stage involves testing the developed practical teaching model. A pre-test, post-test, quasi-experimental/control group design was used. Two groups of students participated in the study i.e. the Experimental and Control groups. A pre-test was administered to the two groups in order to determine the equivalence of the groups' ability in double indicator titration before the commencement of the treatment. The experimental group was given the treatment i.e. they were taught the concepts in Practical Chemistry using the DEPTM. The control group was taught the same chemistry practical concepts using the lecture method or the teachers' method.

Furthermore, the regular chemistry class teachers were used for the study in both experimental and control groups. Training was given to the chemistry teacher who took the experimental group on the application of the DEPTM while the chemistry teacher who took the control group used the conventional method. Since intact stream was used. The experimental stream teacher was given notes of lesson prepared by the researcher

while the researcher vetted the lesson plan prepared by the chemistry teacher in the control group to ensure that the teacher did not deviate from the procedures of instructions commonly used by chemistry teachers. DITAST was used for both pre-test and post-test. The treatments consist of teaching a selected chemistry topic: Double Indicator Titration ( $\text{Na}_2\text{CO}_3/\text{NaOH}$  Mixture against  $\text{HCl}$ ). The control group was taught the same topic using lecture method. Lesson plans for both the treatment and control group were the same in terms of contents, basic instructional objectives, length of time for teaching and mode of evaluation except for practical activities in the treatment group. The classroom observational checklist was used to check the teaching activities of both the experimental and control groups.

At the end of the five lessons periods, the researchers administered the post-test (after reshuffling of the items) to the subjects in the two groups using the DITAST. The scripts from both pre-test and post-test of the two groups were marked and scored using the marking guide. The data collected from the pre-test and post-test of DITAST were analyzed using mean and standard deviation for answering the research questions and the results were shown in [Table 1](#).

Observations were made on how teachers use the TSMs, followed with questionnaire to find out how they felt using the TSMs. In addition, ten students of each of the selected SHS were given questionnaire after the use of the TSMs, to get their impressions and to find out whether their learning of double indicator titration by using the DEPTTEM-based TSMs was enhanced. The purpose of the observation and the questionnaire for both teachers and students was to collect quantitative data to answer research questions 3, 4 and 5. The analyses of the quantitative data were in the form of description of trends and interpretation of relationship of responses given by the chemistry teachers and students in the questionnaire.

The study sought to identify the characteristics of teacher support materials that can support the teachers to teach double indicator titration in senior high schools. To be able to identify the characteristics, it was necessary to provide descriptive information on the teachers' views about the TSMs through interviews. In addition, it sought to show how the chemistry teachers used the DEPTTEM-based TSMs to teach double indicator titration in the senior high schools. In other to do this, observational data of the teachers were gathered while they used the TSMs to interpret the competences exhibited so as to make generalizations about how the TSMs were used.

However, there was the need to gather quantitative information from teachers and students about their experiences in the teaching process and learning gains when the approach was used. This is to know the effect that the use of DEPTTEM-based TSMs had on the teachers' teaching and students' learning of double indicator titration in the senior high schools.

The population was made up of chemistry teachers and students. in four senior high schools with two schools located in the Kwaebibirim District and two senior high schools located in the Denkyembuo District of the Eastern Region of Ghana. Purposive and simple random sampling techniques were used to select the respondents for the study. The sample consisted of twenty-five (25) chemistry teachers and one hundred and fifty (150) in the four SHS which were coded as Research School 1 (RS 1), Research School 2 (RS 2), Research School 3 (RS 3) and Research School 4 (RS 4). The distribution of the number of students in each class of the selected schools is presented in [Table 1](#).

**Table 1. Result of sampling for this study**

Selected SHS	Number of Chemistry Students	Number of Chemistry Teachers
Research School 1 (RS 1)	30 (out of 60)	6 (out of 8)
Research School 2 (RS 2)	30 (out of 72)	5 (out of 7)
Research School 3 (RS 3)	30 (out of 56)	4 (out of 6)
Research School 4 (RS 4)	60 (out of 85)	10 (out of 15)
<b>Total</b>	<b>150</b>	<b>25</b>

*Source: Field data*

The main instruments used in this study were classroom observational checklist and questionnaire. The classroom observational checklist of this study was made up of varying number of sets of action statements which was based on the design of each DEPTTEM-based lesson plan. The observational checklist was divided into four sections: lesson introduction; lesson development; lesson application; and lesson closure. It contains only two columns: the Yes and No columns. Classroom observational checklist was used as an instrument because it helped the researcher to check the effectiveness of the teaching methods employed by the chemistry teachers in the sampled schools. Semi-structured questionnaire was used to supplement the classroom observational checklist. Questionnaire was selected because all the participants were literate, and therefore could read and respond to the items. Both sets of questionnaires were designed to contain open-ended and close-ended items. Thirty-five (35) minutes was given to participants to respond to the questionnaires. To ensure a 100 per cent return rate, the researcher collected the questionnaire on the same day after participants had responded to them. Out of the 175 questionnaires distributed to participants, all of them were retrieved (25 for chemistry teachers and 150 for chemistry students). Therefore, the response rate for this study was 100%.

Descriptive statistics (frequency, percentage, mean and standard deviation) were the tools used in analysing the data gathered. Coding schemes were developed using Statistical

Package for Social Sciences (SPSS) (version 21) to organize the data into meaningful and manageable categories. These involve the data obtained from the classroom observational checklist, questionnaires and pre and post – test. The categorized data were converted into frequency counts, simple percentages, means and standard deviations and were used to answer the research questions in this study. Portions of the data were subjected to narrative description. The use of descriptive statistical tools in the analysis of the data resulted from.

### 3. Results and Discussion

This section presents results and discussion for the study. The first research question was: “How effective is the developed practical model in teaching double indicator titration at the SHS?” The questionnaire for both students and teachers were used to answer this question and the results were shown in Tables 2, 3, 4 and 5.

**Table 2. Results of chemistry students on the effectiveness of DEPTTEM in teaching double indicator titration**

	Frequency	Percent
Students' preference DEPTTEM	134	89
Teachers' method	16	11

*Source: Field data, 2016. (Total number of chemistry students=150)*

Result from Table 2 showed that, most of the chemistry students (134, representing 89%) preferred the DEPTTEM as compared to their teachers' method (16, representing 11%). This result therefore suggest that, chemistry students had better understanding and were able to retain the knowledge gained when the DEPTTEM was used as compared to their teachers' method; hence, the model was effective.

**Table 3. Results of chemistry teachers on the effectiveness of DEPTTEM in teaching double indicator titration**

	Frequency	Percent
Students' preference DEPTTEM	19	76
Teachers' method	6	24

*Source: Field data, 2016. (Total number of chemistry teachers=25)*

From Table 3, majority of the teachers (19, representing 76%) were of the view that, they preferred the DEPTTEM in relation to their own teaching method (6, representing 24%). This implies that chemistry teachers were able to achieve their lesson objectives when the DEPTTEM was used more than their won teaching method.

**Table 4. Result of chemistry students on the effectiveness of DEPTTEM in teaching double indicator titration**

	DEPTTEM		Teachers' method	
	f	%	f	%
Clarity of procedures	142	95	8	5
Time allocation	137	91	13	9
Group work	141	94	9	6
Explanations	128	85	22	15
Interactiveness	145	97	5	3

*Source: Field data (Total number of chemistry students=150)*

Result from Table 4. indicates that, in using the DEPTTEM, most of the teachers and students (145, representing 97%) got more opportunity to interact than in using the teachers' method (5, representing 3%). Also, majority of the students were of the view that, the use of DEPTTEM help their teachers to clarify procedures (142, representing 95%) more than using the teachers' method (9, representing 6%). Similarly, 141 (94%) chemistry students were of the view that, the use of DEPTTEM help them in group work as compared to the teachers' method (9, representing 6%). Lastly, 137 (91%) chemistry students attest to the fact that, the use of DEPTTEM help in times allocation in relation to their teachers' method (13, representing 9%). This result therefore suggest that, the use of DEPTTEM help chemistry students to improve upon their knowledge and skills in chemistry lessons as compared to the teachers' method; therefore, the DEPTTEM was effective in teaching and learning of double indicator titration. Next is the result by the chemistry teachers.

**Table 5. Result of chemistry teachers on the effectiveness of DEPTTEM in teaching double indicator titration**

	DEPTTEM		Teachers' method	
	f	%	f	%
Clarity of procedures	16	64	9	36
Time allocation	18	72	7	28
Group work	13	52	12	48
Explanations	20	80	5	20
Interactiveness	21	84	4	16

*Source: Field data, 2016. (Total number of chemistry teachers=25)*

The result from [Table 5](#) indicates that, most of the teachers (21, representing 84%) were of the view that DEPTTEM helps them to interact with students during teaching and learning as compared to teachers' method (4, representing 16%), followed by explanations (20, representing 80%) compared to teachers' method (5, representing 20%), time allocation (18, representing 72%) compared to teachers' method (7, representing 28%), clarity of procedures (16, representing 64%) as compared to teachers' method (9, representing 36%) and group work (13, representing 52%) as compared to teachers' method (12, representing 48%). It was therefore concluded based on these results from [Tables 2-5](#) that, DEPTTEM was an effective developed practical model in teaching double indicator titration at the SHS as compared to the teachers' method.

Findings of this study correspond with earlier research into the approaches that can be used to teach chemistry at Senior High schools. The findings indicated that inquiry and guided discovery are the best approach with a mean of 3.33 and 3.70 respectively [\[4\]](#). Furthermore, findings of this study concur previous study that interactions between the teacher and the learners and between the learners themselves are a hallmark of a successful lesson or practical and learner centered teaching [\[21\]](#).

An earlier research posits that even though laboratory activities breed interest in students' attitude to science education, it does not warrant realization of the goal of science teaching and learning, rather the combination of all the teaching and learning methods should be used due to the variation in the students. Findings of that study further revealed that students need to be encouraged to become deeply involved in the laboratory work so as to develop their skills [\[19\]](#). Moreover, a researcher conducted a study on student knowledge retention and the findings showed that, students retain 10% of what they read; 26% of what they hear; 30% of what they see; 50% of what they see and hear; 70% of what they say and 90% of something they say while performing a task [\[22\]](#).

The research question two (2) "In what ways does the use of the developed model influences students' academic performance at SHS?" The researcher explained the nature of the tasks (instruments) to the chemistry teachers. The sampled students were administered with the DITAST pre-test before the treatment strategy to the experimental group. The test which lasted 45 minutes was supervised by the researcher and the chemistry teachers. DITAST post-test in the form of class test was conducted at the end of administration of the teaching model and was supervised by the researcher and chemistry teachers. Students' scores obtained from pre- test and post-test were also recorded and analyzed and the results were shown in [Table 6](#).

**Table 6. Results of mean and standard deviation for the experimental and control groups**

Groups	N	Pre-test		Post-test		Mean
		Mean	Std. Deviation	Mean	Std. Deviation	Achievement Gain
Treatment	50	8.1463	2.91171	17.3659	2.74551	9.22
Control	100	7.1571	2.31339	10.6714	2.67420	3.51
Mean Diff.		.9892		6.69445		

*Source: Field data (Total number of chemistry students=150)*

Result from Table 6 shows that, the experimental pre-test and post-test mean scores were 8.1463 and 17.3659 with standard deviation scores of 2.91171 and of 2.74551 respectively. However, the control group has pre-test and post-test mean scores of 7.1571 and 10.6714 with standard deviations scores of 2.31339 and 2.67420 respectively. As shown in Table 6, the mean achievement gain for the treatment group is 9.22 while the mean gain in the control group is 3.51 indicating the superiority of treatment group over the control group in using the developed model.

The results therefore suggest that, the chemistry students in the experimental group had a higher mean score in double indicator titration ( $\text{Na}_2\text{CO}_3/\text{NaOH}$  mixture) compared to their control group counterparts. This finding implies that method of instruction helped the chemistry students to acquire the necessary knowledge and skills better. Thus, the active involvement of chemistry students in practical activities has given rise to efficient learning, which accounted for the reported significant effect in acquisition of knowledge and skills. It was therefore concluded that, the developed model influenced SHS chemistry students' academic performance positively.

The findings of this study therefore suggest that participation of the students in the class aids retention and makes the lesson more meaningful. This is because as the chemistry students participate and manipulate equipment/materials, they apply their five senses and other skills to their lessons more than when they would have learned in abstraction or remained less active in the class. The findings of this study also imply that chemistry teachers should adopt practical activity method of teaching (student-centered method).

The reason had been that students learn better when they are involved in the activity. Thus, activity-based methods enhance understanding of chemistry concepts and increase the ability to acquire science process skills by the learner. Findings of this study suggest that curriculum planners are expected to plan for conceptual change over period of years. This is because learning involves the restructuring of prior knowledge to gain new ones for effective learning to take place. Therefore, since the use of practical activities enhances students acquisition of knowledge and skills, it follows that curriculum planners can create the awareness of this method in teachers by including it in the chemistry curricula. Also, they should include within the existing subjects' contents of the chemistry curriculum, some corresponding indigenous knowledge. They can do this by re-examining the existing units of the subject matter taught in Senior High schools and identifying their corresponding indigenous knowledge and instructional material. This could make the teaching of chemistry more interesting and meaningful to the students.

Findings of this study were in line with the views of previous researchers that active participation of the students gave rise to more meaningful and effective learning [23, 24-25]. A study investigated the effects of students' achievement of new teaching material developed for the unit "acids and bases". Also, the students' attitudes towards chemistry were explored. The new materials included work sheets base on conceptual instructional method, the sample consisted of thirty-eight students. The findings from the post-test indicated that, the students in the experimental group taught with the new teaching material showed significantly greater achievement in the unit acids and bases than did the students in the control group. In addition, the experimental group had a significantly higher score

than the control group, with regard to their attitudes towards chemistry [26]. This shows that the implementation of the new material produced better results both in terms of achievement and attitudes.

The third research question sought to investigate if there was a difference between male and female students' academic achievement of concepts in practical chemistry after being exposed to the practical teaching model. To answer this research question, pre-test and post-test were conducted for male and female chemistry students after they have been classified into experimental and control groups. Descriptive statistics (mean and standard deviations) scores were recorded after the pre-test and post-test and the result was presented in Table 7.

**Table 7. Mean and standard deviation results for experimental and control groups across the sex**

Groups	Sex	N	Pre-test		Post-test		Mean
			Mean	SD	Mean	SD	Achievement Gains
Treatment	Male	45	8.2174	2.6450	17.521	2.7281	9.30
	Female	10	8.0556	3.2982	17.166	2.8336	9.11
	Mean Diff.		0.1618		0.3550		
Control	Male	78	6.8378	2.2300	10.891	2.1315	4.05
	Female	17	7.5152	2.3864	10.424	3.1920	2.91
	Mean Diff.		1.3226		.4677		

*Source: Field data. (Total number of chemistry students=150)*

Result from Table 7 shows that, the pre-test means scores and standard deviation score for the experimental male and female were 8.2174 and 2.6450; 8.0556 and 3.29835 respectively. Similarly, the post-test means scores and standard deviation scores for the experimental male and female groups were 17.5217 and 2.72813; 17.1667 and 2.83362 respectively. Also, the pre-test means scores and standard deviation scores for the control male and female were 6.8378 and 2.23002; 7.5152 and 2.38644 respectively. Also, the post-test means scores and standard deviation score for the control male and female were 10.8919 and 2.13156; 10.4242 and 3.19208 respectively. The mean achievement gains for males and females in the treatment group are 9.30 and 9.11 respectively. In the control group, the gains were 4.05 and 2.91 respectively for males and females.

These results therefore suggest that, there was a difference between male and female students' academic achievement of concepts in practical chemistry after been exposed to the practical teaching model. This finding was not in agreement with the findings of Ibe, who found no difference between instructional method and gender on performance. This reason for the differences in the findings could be that, the other studies, was conducted in Nigeria which has different cultural background as compared to Ghana [25]. The DEPTM is a collaborative approach to learning which makes it more comfortable for females. Collaborative learning has been observed to enhance achievement of female and African American students [27]. However, the difference in the performance of male and female could also be that, the lesson is a laboratory activity which did not favour females. Most women are not in science due to the laboratory activities [28].

#### 4. Conclusion and Recommendations

The study indicated that Chemistry teachers would improve upon the academic performance of chemistry students in double indicator titration when they use the developed

practical model (DEPTTEM) more. The study also revealed that the outcome of the post-test indicated that, the DEPTTEM impact differently on the academic performance of SHS male and female chemistry students in the Kwaebibirim and Denkyembuo Districts of the Eastern Region. It is recommended that the government and non-governmental organizations should collaborate with the Ministry of Education to sponsor in producing more of the developed practical model (DEPTTEM) for teaching chemistry lessons. This in a way would help improve the academic performance of chemistry students in the Kwaebibirim District of the Eastern Region and the nation at large. It is also recommended that chemistry teachers should consider teaching methods that would equally cater for both male and female chemistry students during chemistry lessons. This would help prevent them from been bias in their lesson delivery; hence, catering for gender differences.

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