Senior Secondary School Students' Attitude to Inquiry-based learning in Chemistry

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Abstract- This study investigated 359 senior secondary school chemistry students' attitude to learning after being exposed to three inquiry-based learning strategies. The samples were randomly drawn from nine secondary schools in two Education Districts, Lagos State, Nigeria. The learning strategies were Investigate-Discuss (ID), Predict-Discuss-Investigate-Discuss (PDID) and Teacher Demonstration (TD) and sampled schools were assigned to the learning groups. The chemistry teachers in the sampled schools were trained on implementation of the learning strategies using the learning packages. Quasi experimental research design was used to determine the effects of the learning strategies on students' attitude to chemistry. The students' gender and mathematical ability and their interaction effects on chemistry students' attitude were also examined. The research instruments which were Mathematical Ability Test (MAT) and Chemistry Attitude Inventory (CAI) were validated and reliability coefficient values were high and positive. Both the MAT and CAI were pre-administered and CAI post-administered to the students after engaging them in eight weeks of practical activities. The students MAT scores were used to classify the students to low, medium and high mathematical ability levels. The data analysis using ANCOVA showed that there are significant main effects of treatment on students' attitude in favour of PDID. There are no significant main and interaction effects of gender and mathematical ability on attitudes. The study recommends the use of PDID strategy to promote students attitude in chemistry.

Index Terms- Inquiry learning, mathematical ability, gender, attitude, chemistry.

I. INTRODUCTION

Learning in science education involves more than students just listening and jotting down facts from the teacher. For students to meaningfully learn in science, especially chemistry, students must be motivated to actively engage, explore, gather information, analysis data, construct knowledge and solve problems in the learning environment. These activities are related to the three learning domains namely knowledge, skills and attitude which are goals of learning process (Bloom, 1956). Inquiry-based learning is adjudged as one of the methods of instruction for active learning because students are engaged in ''doing things and thinking about the things they are doing'' (Bonwell and Eison, 1991). Learners may be excited and developed interest in the learning if they are involvement in the learning process. However, the most common instruction mode in science and particularly in chemistry in Nigeria schools is lecture method which is often employed for easy coverage of syllabus. Sometimes, chemistry teachers employed teacher demonstration for quantitative analysis toward external examinations periods but this is hardly utilised in teaching chemistry. Consequently, the teacher demonstration and lecture methods do not promote students' achievement and attitude in chemistry (Adesoji, 2008; Cheung, 2009; Adeoye, 2016 and Adeoye, 2019).

Teacher's attitude, teaching method, students' gender and carrer interest have been reported to influence the students' attitude to learning and achievement in science (Adesoji, 2008; Cheung, 2009; Sesen and Tarhan, 2013 and Heng and Karpudewan, 2016). The studies of Cheung (2009) and Hashim, Ababkr and Eljack (2015) found positive relationship between chemistry students' attitude and achievement. Asabe (2013) investigated the relationship between science laboratory environment and students attitude. The study showed students positive attitude to science laboratory environment. Ibrahim and Karpudewan (2013) indicated that positive laboratory learning improved students' attitude in chemistry. The analysis of students' attitudes in chemistry in Chile by Montes, Ferreira and Rodriguez (2018) indicated that attitude towards were neither positive nor negative but showed significant effects of year group and chemistry achievement on attitude towards chemistry. The study indicated no effects of school type, gender or interaction between factors on students' attitude to chemistry. Their follow-up analyses revealed that as the students advance through schooling, their attitudes decline, but that the higher the chemistry scores, the more positive were their attitudes. This indicates that scoring high in chemistry could be a motivation to learning of chemistry. This can be effectively achieved if students are actively engaged in teaching and learning process (Adeoye, 2016; Delmang and Gongden, 2016; Adeoye, 2017; and 2019).

The abstract nature of chemistry and the students' learning difficulty necessitate the use of guided inquiry for teaching chemistry. The effects of the guided inquiry have been reported by many researchers in science. Inquiry was found to promote students scientific creativity, attitude, skills acquisition and achievement in chemistry (Yager and Akcay, 2010; Sesen and Tarhan, 2013 and Adeoye, 2019). However, in inquiry learning, Aktamis and Ergin found no significant difference on students' attitudes towards science but there were significant differences on students' scientific creativity, process skills and academic achievement. Yunus and Ali (2012) and Achor and Kalu (2014) revealed that majority of the students have positive attitude towards chemistry learning when they conducted experiments in

the laboratory. Yunus and Ali (2012) further showed that students have negative attitude because they lack interest towards chemistry and chemistry syllabus. Chairam, Klahan and Coll (2015) also found that inquiry-based learning strategies improved students' understanding of chemical concepts, The students also made significant progress in drawing concepts, identifying variables, designing experiments, presenting data, analysing results and drawing conclusions. Furthermore, the study found that the students in practical classes enjoyed practical activities and were interested in learning chemical concepts.

Chua and Karpudewan (2015) and Heng and Karpudewan (2016) found that gender and grade level have a significant effect on attitude towards chemistry learning. The findings further indicated that gender and grade level have a significant interaction effect on secondary school students' attitudes towards chemistry. Achor and Kalu (2014) also significant difference in mean attitude towards chemistry learning between experimental and control groups. However, there was no significant difference between the mean of attitude of boys and girls in chemistry practical. Zudonu and Njoku (2018) examined the effect of laboratory methods on students' attitudes in some chemistry concepts. Their results showed that both guided discovery and demonstration methods had higher gain mean rating for female students than male counterparts. The findings further indicated that male students had better positive attitude on lecture method than female in practical chemistry. Sakariyau, Taiwo and Ajagbe (2016) analysed students' attitude to science and found that was high proportion of students displayed positive attitude to science. However, the study showed no significant difference between the attitude of male and female towards science.

Besides the teacher teaching methods and students' gender, students' mathematical ability has been found to correlate with attitude and performance in chemistry Akinoso (2017). Mazana, Montero and Casmir (2019) investigated students' attitude towards learning mathematics. The findings indicated that initially the students exhibited a positive attitude towards mathematics but their attitude became less positive as the students moved to higher levels of education. Based on this finding, it is likely that those that are mathematical incline would have positive attitude in learning chemistry since chemistry is mathematically oriented.

1.2 Statement of Problem

The statistical analyses of May/June results showed that in 2017, the percentage of candidates with five credits and above including English language and Mathematics was 48.15 % while in 2018 it was 33.81 % (National Bureau of Statistics, 2019). The decline in the performance of the Nigeria Senior Secondary School Students in West African Examination Council was worrisome and there is need to investigate the causes. Students' attitude to learning, interest, mathematical ability, teacher methods of instruction, teachers' qualifications, adequacy of learning facilities and other may influence students' performance both in internal and external examinations. Attitude is one the keys that propel any individual to good success. Students' attitude to science learning is enhanced when students are active participants in teaching and learning (Yunus and Ali, 2013 and Zudonu and Njoku, 2018). There several studies and findings on students' and teachers' attitude to chemistry teaching and learning. However, limited studies exist on the attitude of students towards inquiry-based learning strategies. The study examined the attitude of chemistry students to inquiry-based learning strategies; Investigate-Discuss (ID), Predict-Discuss-Investigate-Discuss (PDID) and Teacher Demonstration (TD). The effect of students' gender and mathematical ability and their interactions with factors were further determined.

1.3 Purpose of the Study

The main purposes of this study was to determine (i) the effect of ID, PDID and TD learning strategies on senior secondary school students' attitudes and skills' acquisition in chemistry (ii) influence of gender and mathematical ability on senior secondary school chemistry students' attitudes and skills' acquisition and (iii) interaction effects of learning strategies, gender and mathematical ability on senior secondary school chemistry students' attitudes and skills' acquisition in inquiry-based learning.

1.4 Research Questions

The research questions for the study are as follows:

1. What are the effects of ID, PDID and TD learning strategies on senior secondary school chemistry students' attitude learning chemistry?
2. How does mathematical ability of senior secondary school chemistry influence students' attitude to learning chemistry?
3. What is the influence of gender on senior secondary school students' attitude to learning chemistry?

1.5 Research Hypotheses

The null research hypotheses for the study are:

H_0^1 There is no significant main effect of treatment on senior secondary school students' mean scores in chemistry attitudes inventory.

H_0^2 There is no significant effect of mathematical ability on senior secondary school students' mean scores in chemistry attitudes inventory.

H_0^3 There is no significant effect of gender on senior secondary school students' mean scores in chemistry attitude inventory.

H_0^4 There is no significant interaction effect of treatment and mathematical ability on senior secondary school students' mean scores in chemistry attitude inventory.

H_0^5 There is no significant interaction effect of treatment and gender on senior secondary school students' mean scores in chemistry attitude inventory.

H_0^6 There is no significant interaction effect of mathematical ability and gender on senior secondary school students' mean scores in chemistry attitude inventory.

H_0^7 There is no significant interaction effect of treatment, mathematical ability and gender on senior secondary school students' mean scores in chemistry attitude inventory.

1.6 Methodology

Quasi experimental research of pre-test post-test was used for the study. The samples were the Senior Secondary School (SSS) form two chemistry students that were randomly sampled in their intact classes in two education districts in Lagos State, Nigeria. The total samples comprised of male and female students were three hundred and fifty nine (359) of which male students were 214 and 145 female students.

Three approaches to inquiry-based learning were used to engage the sampled students in six weeks of practical activities in concepts of redox, chemical kinetics, equilibrium and electrolysis. These were Investigate-Discuss (ID), Predict-Discuss-Investigate-Discuss (PDID) and Teacher Demonstration (TD). In the ID approach, the students were actively engaged in practical activities, discussions and solving problems related to the practical activities in small groups. The ID and PDIP were student-centred learning approaches. The PDID differs from ID in that the students made predictions and discuss the predictions before carried out the investigations. This allowed the students to modify their misconceptions on the concepts for meaningful learning. The TD strategy is teacher-dominated, where the teacher carried out the practical activities and discusses the underlying principles and concepts related to the demonstrated activities. The trained chemistry teachers in the various sampled school who were certified to have the competency of the teaching strategies before engaged the students in practical activities.

The Mathematical Ability Test (MAT) contained twenty (20) items which were structured on logarithms, probability, simple percentages, mean, median and modes topics. The knowledge of these topics is required for understanding some contents in chemistry. The instrument was administered to the students at the start of the research. The instrument was used to categorise the students into high, medium and low mathematical ability based on their scores.

The Chemistry Attitude Inventory (CAI) was to explore students' attitude to the teaching and learning of chemistry using the inquiry learning strategies. The instrument contained 20 attitudinal statements comprised 10 positive and 10 negative statements in order to discourage guess work. A 4 – point Likert type scale was attached to each of the statements: Strongly Agree (SA), Agree (A), Disagree (D) and Strongly Disagree (SD) and were scored on a four point scale (1 – 4). The research instruments and the learning packages were validated and they were found reliable for the study. The CAI was pre-post administered to the students to determine their attitudes before and after engaging them in inquiry learning strategies.

The collected data were analysed using mean and Analysis of Covariance (ANCOVA).

1.7 Result

The results of students' responses to CAI by treatment are presented on Table 1.

Table 1: Pre-test and Post-test Mean Scores in CAI by Treatment

Treatment	N	Learning Outcome	Mean ($\bar{x}$) and Standard Deviation (SD)				Mean Gain
			Pre-test		Post-test		
			($\bar{x}$)	(SD)	($\bar{x}$)	(SD)	
ID	114	CAI	51.66	5.74	62.28	6.91	10.62
PDID	123	CAI	53.47	6.03	67.98	6.67	14.51
TD	122	CAI	56.02	5.91	58.31	6.81	2.29

The students in PDID had the highest mean score (14.51) in CAI followed by ID (10.62) and then TD (2.29) with the pattern of PDID > ID > TD. Results of further analysis are presented in Table 2 using mean and standard error scores.

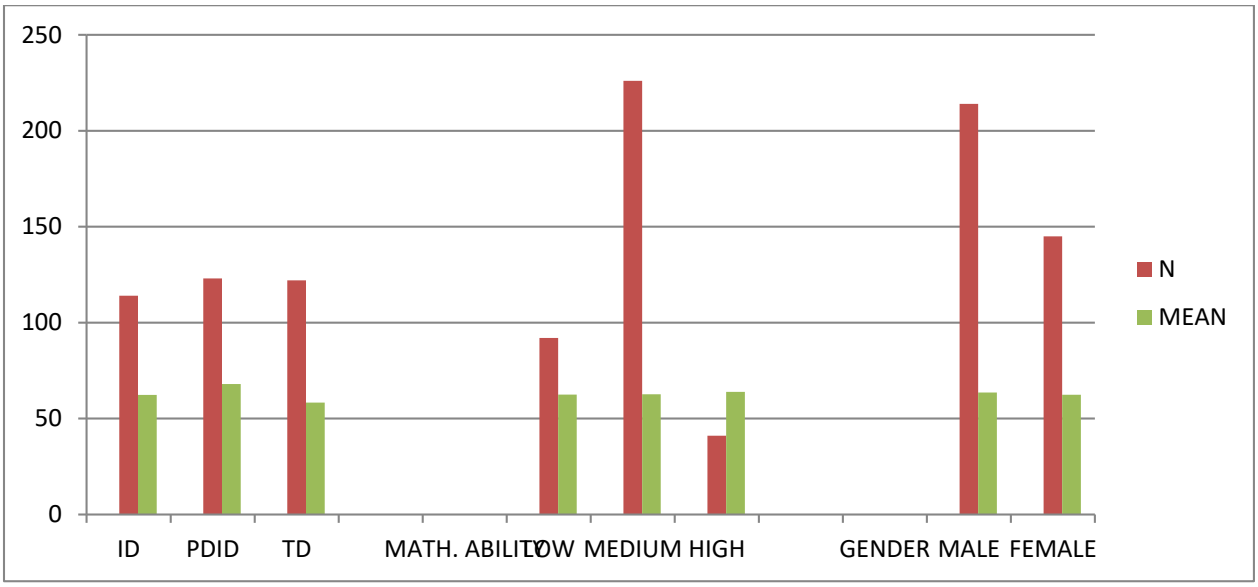
Table 2: Post Mean and Standard Error Scores in Chemistry Attitude Inventory by Treatment, Mathematical Ability and Gender.

Category		N	CAI	
			Mean	Std. Error
Treatment	ID	114	62.28	.636
	PDID	123	67.98	.613
	TD	122	58.31	.615
Mathematical Ability	Low	92	62.48	.922
	Medium	226	62.60	.481
	High	41	63.90	1.336
Gender	Male	214	63.58	.676
	Female	145	62.40	.909

Table 2 shows that students in the PDID had the highest score of 67.98 followed by ID, 62.28 and TD with the least of 58.31 score on chemistry attitude inventory.

The post mean scores of the students based on their mathematical ability as shown on Table 2 were slightly different from one another. The students with high mathematical ability had 63.90 while that of medium mathematical ability was 62.60 and 62.48 for low mathematical ability in attitude inventory. These are further explained with the use of bar chart in Figure 1.

Figure 1: The Descriptions of Treatment, Students' Mathematical Ability and Gender by Number Sampled and Mean Scores on Chemistry Attitude Inventory



ANCOVA was used to test for main significant effects of treatment, mathematical ability, gender and their interactions of students' scores in attitude inventory.

Table 3: Summary of ANCOVA on Attitude by Treatment, Gender and Mathematical Ability

Source	Type III Sum of Squares	Df	Mean Square	Partial Eta Squared	F	Sig.
Corrected Model	6197.668	18	344.315	.279	7.306	.000
Intercept	12694.499	1	12694.499	.442	269.364	.000
PRECAI	80.532	1	80.532	.005	1.709	.192
Treatment	1697.276	2	848.638	.096	18.007	.000*
Gender	50.884	1	50.884	.003	1.080	.300
Math. Ability	43.296	2	21.648	.003	.459	.632
Treatment*Gender	24.415	2	12.208	.002	.259	.772
Treatment*Math.Ability	49.880	4	12.470	.003	.265	.901
Gender*Math.Ability	7.425	2	3.713	.000	.079	.924
Treatment*Gender*Math. Abil	113.461	4	28.365	.007	.602	.662
Error	16023.419	340	47.128			
Total	1441805.000	359				
Corrected Total	22221.086	358				

$R = .279$; $R^2 = .241$ *Significant at $P < .05$ Sources: Adeoye (2016)

The results on Table 3 indicated only a significant effect of treatment on students attitude to chemistry learning ($F_{(2,340)} = 18.007$; $p < .05$). The direction of significant difference was determined using Scheffe post hoc tests and the results are presented on Table 4.

Table 4: Scheffe Post Hoc Tests of Attitude by Treatment Groups

(I) Treatment	N	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.
ID	114	PDID	-5.69	.883	.000*
		TD	3.97	.885	.000*
PDID	123	ID	5.69	.883	.000*
		TD	9.66	.868	.000*
TD	122	ID	-3.97	.885	.000*
		PDID	-9.66	.868	.000*

*Pairs of groups significantly different at P <.05 Source: Adeoye (2016).

The results show on Table 4 that the PDID learning strategy is significantly different from the ID and TD learning strategies and the ID also differ significantly from the TD learning strategy on the students' attitude towards chemistry learning.

1.8 Discussion of Result

The findings of the study show significant main effect of the treatment on students' attitude to chemistry learning. The pattern of students' attitude towards chemistry learning after treatment was the PDID > ID > TD. The students in the PDID differ significantly than those in the ID and the TD treatment groups in their attitude to chemistry learning. The ID students also differ significantly from those in the TD treatment group in attitude towards chemistry. The superiority of the Predict-Discuss-Investigate-Discuss learning strategy over the Investigate-Discuss and the Teacher Demonstration in promoting students attitude to chemistry learning may be as a result of the nature of the learning strategy which allowed the students to take total charge of the teaching and learning process. The characteristics nature of the PDID which include making predictions, confirmation of predictions by investigations, dialogue with peers, expression views and ideas, modification of ideas and active collaboration with peers and learning materials may have promoted the students' positive attitude in chemistry. The superiority of the Investigation-Discuss over the Teacher Demonstration may be due to the opportunity that the students in the ID learning group had in active participation in investigation, discussion of the underlying principles and collaboration with peers might prompted their positive attitude towards chemistry learning. The students' inactive participations, inability to question and reflect on the teacher's demonstration in the TD group might be the major reasons for the students' low attitude to chemistry learning. This finding is in support with significant effect of inquiry-based learning strategy on students' attitude to chemistry established by Cheung (2009), Sesen and Tarhan, (2013) and Zudonu and Njoku (2018). They showed significant effect of inquiry learning on students' attitude to chemistry learning.

The positive attitude to chemistry learning showed by high mathematical ability may be that their ability in mathematics motivated the students' interest in chemistry since the subject is mathematical in nature. The male students having better positive attitude to chemistry learning than female may be that the male students are more motivated in the inquiry than their female counterparts. However, significant effects of students' mathematical ability and gender do not exist in the study. Furthermore, treatment, mathematical ability and gender have no significant interactions on students' attitude to chemistry. This means that, the teaching strategies have great impact on students' attitude to chemistry learning. Active learning strategies such as PDID and ID are good motivators of students' attitude to learning of chemistry.

1.9 Implication of the Study

The implication of this study is that if inquiry-based learning strategies of PDID and ID are effectively implemented by chemistry teachers would promote students' positive attitude in the subject. Inquiry is scarcely used as learning method in science. This may be as a result of difficulties science teachers have in structuring inquiry learning. Time allotted for science teaching in most schools may not be sufficient for inquiry learning. The pressure of contents coverage for the purpose of both internal and external examinations may also be a factor. Inadequate laboratory materials may be another factor forlack of utilization of inquiry in Nigerian schools.

1.10 Conclusion

From the results of the study, it can be concluded that:

- PDID and ID learning strategies are effective in motivating students towards chemistry learning.
- Students' gender has no significant effect on students' attitude towards chemistry learning. However, students' good knowledge of basic mathematical knowledge may promote their attitude to chemistry learning.
- Students' mathematical ability has no significant effect on students' attitude towards chemistry learning. However, students' good knowledge of basic mathematical knowledge may promote their attitude to chemistry learning.
- There is no interaction effect of treatment, gender and mathematical ability on students' attitude in chemistry.

1.11 Recommendation

The inquiry-based learning of ID and PDID learning are strongly recommend for learning of chemistry. However, there must be learning facilities for implementation of inquiry-based learning strategies. Training and retraining of teachers are very important for inquiry to thrive in science classrooms. Science teachers should do away with conventional methods of lecture and demonstration of scientific concepts to the students to promote their interest in science. They should embrace learning by inquiry which allows students to observe phenomena, build a bridge between what they can see and handle rather than seeing phenomena as end.

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