ISSN 2348-3156 (Print)
International Journal of Social Science and Humanities Research ISSN 2348-3164 (online)
Vol. 7, Issue 1, pp: (367-376), Month: January - March 2019, Available at: www.researchpublish.com

EFFECTS OF INQUIRY-BASED LEARNING STRATEGIES ON SENIOR SECONDARY SCHOOL STUDENTS' CONCEPTUAL AND COMPUTATIONAL KNOWLEDGE IN CHEMISTRY

IKEOLUWA FOLASADE ADEOYE

SCHOOL OF SCIENCE, EMMANUEL ALAYANDE COLLEGE OF EDUCATION, OYO, OYO STATE, NIGERIA
EMAIL: ikeoluboye@yahoo.com & ikeoluwaadeoye@gmail.com
MOBILE NUMBER: + 2348038235302

Abstract: **The effects Investigate-Discuss (ID), Predict-Discuss-Investigate-Discuss (PDID) and Teacher Demonstration (TD) on conceptual and computational knowledge of 359 (214 male and 145 female) senior secondary school two (SS2) chemistry students were investigated. The influence of students' mathematical ability and gender were examined on students' conceptual and computational knowledge. A quasi experimental research design of pre-test post-test control group was employed. The subjects were randomly sampled from nine secondary schools in two Education Districts in Lagos State, Nigeria and were assigned to experimental and control groups. The students were engaged in eight weeks of practical activities on contents of electrolysis, chemical kinetics, chemical equilibrium and redox reactions using operational guides of ID, PDID and TD as applicable to each school. Three validated and reliable research instruments were used; Mathematical Ability Test (MAT), Conceptual Knowledge Test (CKT) and Computational Ability Test. The MAT was used to classify the students into low, medium and high mathematical ability levels while CKT and CAT assessed students' conceptual and computational knowledge, respectively. The instruments were pre and post administered to the students two days after the treatment. The findings showed main significant effect of treatment on ID for conceptual knowledge and PDID for computational knowledge. There were significant main effects of students' mathematical ability, gender and interaction effect of treatment and mathematical ability on computational knowledge. The use of ID and PDID modes of inquiry-based learning are recommended for chemistry learning in secondary schools to promote conceptual and computational knowledge.**

Keywords: **Inquiry-based Learning, Gender, Mathematical Ability, Conceptual knowledge, Computational knowledge.**

1. INTRODUCTION

Inquiry as mode of instruction is credited to Bruner (1961) who originated discovery learning in the 1960s argued that ‘‘practice in discovering for oneself teaches one to acquire information in a way that makes that information more readily viable in problem solving’’ (Bruner 1961, p. 26). Bruner's ideas were similar to Dewey (1949) who emphasised learning by doing. Discovery occurs in problem solving situations where learners draw on their prior knowledge to make connections with the new knowledge by interacting with the materials to be learnt, exploring, manipulating objects, raising questions and performing experiments to find the answers (Grauer, 2016).

Inquiry takes variety of instructional techniques. Inquiry may be to verify ideas or and solve problems with the teacher guidance (guided inquiry) or without his \ her guidance (open inquiry) by Ajeyalemi (2011) and Adeoye (2016). The guided-inquiry learning approach is recommended for learning the sciences at senior secondary school in Nigeria. This is aimed at and providing students with the knowledge and understanding of the complexities of the world in which they live and producing manpower for national development (Federal Republic of Nigeria, FRN, 2011).

There are four different ways in which practical activities may be designed in the guided inquiry type. These are teacher-demonstration, class-assisted demonstration, detailed worksheet and loosely structured problem-solving (Ajeyalemi, 2011). Each form of organisation describes different levels of guidance that are involved. The teacher-demonstration is the process by which a teacher shows to a student or group of students to illustrate a concept, principle or skill to the students so as to verify facts and /or aid understanding of the concept or principle. In teacher-demonstration, usually the teacher does all the work in describing the procedure, manipulating equipment, describing observations and possibly recording and interpreting the data. The students are just mere observers and passive listeners but may ask some questions.

The class-assisted demonstration is a team approach in which students assist the teacher in the demonstration. The students play a more active role than they do in the teacher-demonstration. The students may be involved in suggesting the procedure, manipulating, collecting and interpreting data. The purpose is not only to illustrate a point or to verify some facts and principles but also to encourage inquiry. The students' involvement in the teaching and learning process encourages the students to think and to acquire the concepts and principles involved in the demonstration. The approach is also likely to make the students to be more attentive and develop positive attitudes to science as they like to watch some of their peers performing (Ajeyalemi, 2011).

The detailed worksheet type of practical activities is symptomatic of a higher level of students' involvement than observed for the teacher or class- assisted demonstration. The aim of the practical work is often pre-determined by the teacher whether students are working individually or in groups. In addition, the students are provided with all the necessary equipment, materials and detailed instructions on the series of steps to take in accomplishing the objectives of the practical class. The advantage of this form of organisation is that students, at least, have the opportunity of practicing some of the skills of scientists such as observing, measuring, manipulating equipment and materials, collecting data, recording and interpreting data, inferring and concluding from data. However, because this is a highly structured type of organisation, it would ordinarily not allow for much initiative on the part of the students.

The loosely-structured problem-solving type of practical work, often puts students in a problem-solving situation and encourages the students to solve the problem on their own, with minimum guidance from the teacher. The important of this approach is that students may participate in the formulation of the problem and are responsible for designing the experimental procedure, determining the necessary equipment and materials for solving the problem, collecting and interpreting the data, and making conclusion(s). This type of practical work is described as problem-based by Millar (2009). The approach is more student-centred, provides opportunities for students to engage in authentic investigative and higher-order thinking processes. However, it is often time consuming and costly and very demanding on teachers and students. Whatever the type of organisation adopted, the quality of practical experiences to which students are exposed to also matter, if they are to develop formal thinking abilities as well. The integration of detailed work-sheet and loosely structured problem solving types of guided-inquiry were employed in designing learning packages used for this study.

The aims and objectives of practical activities are not being achieved in Nigerian school system as result of poor learning environment and science teachers adhering mainly to lecture-recitation pattern of instruction (Ajeyalemi, 2009). These may be one of the reasons for high rate failure of secondary school chemistry students as observed in the analysis of students' results in the West African Examination Council (WEAC) between 2002 and 2012. The results indicate that less than 50 % of the candidates who sat for SSCE obtained credit grades and above (A1 to C6) in chemistry except for year 2010 with 53.59 %. This observation is not limited to Nigeria only, Barker (2012) reported that most Louisiana's high school science teachers use traditional methods of instruction that are characterised by lecturing, regular note taking usage of textbooks. Also, Drake and Long (2009) and Furtado (2010) reported that in many classrooms across the United States, science instruction science has taught by these methods do not support the need for developing student scientists.

There are reports on the importance of inquiry-based learning. Aydeniz, Cihaki, Graham and Restinger (2012) and Chairan, Klahan and Coll (2015) reported that using inquiry-based learning facilitates students' understanding of facts, applying science concepts to real life problems. Surif, Ibrahim and Dalim (2014) and Holme, Luxford and Brandriet

(2015) showed that conceptual understanding is necessary for chemistry students to be successful in quantitative problems solving. However, Adeoye (2012) and Gultepe, Celik and Kilic (2013) showed that majority of the chemistry students often solve quantitative problems using algorithmic to problems without adequate knowledge of the concepts underlying these problems.

Other factors that may influence students' achievement in chemistry include attitude to learning, students' mathematical ability, students' gender and inadequate learning facilities. Hashim, Ababkr and Eljack (2015) and Sever and Guven (2015) indicated that inquiry learning fosters students' achievement and attitude to chemistry learning. Hashim, et al. also reported a significant difference in the achievement of male and female students exposed to inquiry in favour of male students while Anyafulude (2013) found female students significantly achieved than male in both problem and discovery-based learning strategies in chemistry. Adigwe (2012) and Potter (2014) reported that mathematical knowledge and cognitive reasoning ability of students have influence on students' achievement in chemistry. However, there is need to examine Nigeria chemistry students' achievement in conceptual and computational knowledge using inquiry-based learning strategies of Investigate-Discuss (ID), Predict-Discuss-Investigate-Discuss (PDID) and Teacher Demonstration (TD). What would be the achievement of chemistry students on conceptual and computational knowledge with different mathematical ability levels, gender and inquiry-based learning strategies?

Purpose of the Study

The objectives of this study were to determine (i) effects of three inquiry-based learning strategies (ID, PDID and TD) on senior secondary school chemistry students' achievement in conceptual and computational knowledge (ii) effects of learning strategies, gender and mathematical ability on students' achievement in conceptual and computational knowledge.

The following research questions were raised for the study:

1. What are the effects of three inquiry-based learning strategies on chemistry students' achievement in conceptual knowledge and computational knowledge?

2. How does mathematical ability influence chemistry students' achievement in conceptual knowledge and computational knowledge?

3. What is the influence of gender on chemistry students' achievement in conceptual knowledge and computational knowledge?

2. RESEARCH HYPOTHESES

The following null research hypotheses were formulated for the study:

H_0^1 There is no significant main effect of treatment on chemistry students' achievement in conceptual knowledge and computational knowledge.

H_0^2 There is no significant effect of mathematical ability on chemistry students' achievement in conceptual knowledge and computational knowledge.

H_0^3 There is no significant effect of gender on chemistry students' achievement in conceptual knowledge and computational knowledge.

H_0^4 There is no significant interaction effect of treatment and mathematical ability on chemistry students' achievement in conceptual knowledge and computational knowledge.

H_0^5 There is no significant interaction effect of treatment and gender on chemistry students' achievement in conceptual knowledge and computational knowledge.

H_0^6 There is no significant interaction effect of mathematical ability and gender on chemistry students' achievement in conceptual knowledge and computational knowledge

H_0^7 There is no significant interaction effect of treatment, mathematical ability and gender on students' achievement in conceptual knowledge and computational knowledge.

3. METHODOLOGY

A quasi experimental research design of pre-test post-test control group was used to determine the effects of three inquiry-based learning of four perceived difficult chemistry topics: chemical kinetics, chemical equilibrium, electrolysis and redox reactions in conceptual and computational knowledge. The study randomly sampled 359 senior secondary school two chemistry students, consisted of 214 male students and 145 female students in nine secondary schools in two Education Districts, Lagos State, Nigeria. The sampled schools were randomly assigned to the experimental (ID and PDID) and control (TD) groups. The chemistry students in their intact classes were randomly sampled for the study.

Three learning packages: operational guides for the ID, PDID and TD learning strategies consisted of eight practical activities, developed by researcher to engage the sampled students in learning process for eight weeks of 80 minutes per week. The operational guides had the same contents but different procedures for their implementations. The chemistry teachers in the sampled schools were trained for three weeks on the implementation of the guides in the classrooms.

The students in ID and PDID learning strategies learnt in small discussion groups of 5 to 6 members of different academic abilities. The students appointed leader and recorder for the group and these roles were rotated per week. The ID and PDID were student-centred approaches where students carried out the practical activities co-operatively using the operational guides and the findings of the investigations were discussed. Each student presented reports on the activities. The PDID learning strategy differed from ID learning strategy in that the students in the group made predictions and discussed the predictions of the outcomes investigations before they carried out the investigations. The TD was teacher-centred. The teacher carried out the practical activities with little or no assistance from the students. The teachers discussed the underlying principles in the demonstrated activities to the students.

The Mathematical Ability Test (MAT), Conceptual Knowledge Test (CKT) and Computational Ability Test (CAT) were the research instruments. The MAT, CKT and CAT were validated by three experienced chemistry teachers and the reliability determined. The reliability coefficient values of 0.72 for MAT using Kuder-Richardson formula 20 (KR20), 0.85 and 0.73 for CKT and CAT, respectively obtained with Pearson Product Moment Correlation method. The MAT contained 20 items logarithms, probability, statistics, proportionality, knowledge of which is required for understanding some chemistry concepts. The CKT had eight easy questions on the chemistry topics that measured students' conceptual understanding. The CAT also consisted of eight quantitative questions that required students' conceptual understanding to successfully solve the problems. The MAT, CKT and CAT were administered to the students prior to treatment. The students' scores on MAT were used to classify the students to mathematical ability levels: low, medium and high using interquartile range. The CKT and CAT were re-administered to the students two days after the treatment. The pre-test and post-test scores on CKT and CAT were subjected to statistical analysis using mean, standard deviations and analysis of covariance (ANCOVA).

4. RESULTS

The students' responses to pre-test and post-test in conceptual knowledge and computational ability were analysed and results are shown on Table 1.

Table 1: Pre-test and Post-test Mean Scores on Learning Outcomes by Treatment Groups

Treatment	N	Learning Outcomes	Mean ($\bar{x}$) and Standard Deviation (SD) Scores Pre-test		Post-test		Mean Gain
			($\bar{x}$)	(SD)	($\bar{x}$)	(SD)	
ID	114	CKT	26.70	9.12	45.14	5.91	18.44
		CAT	13.16	9.30	26.32	5.82	13.16
PDID	123	CKT	29.20	10.35	43.98	7.86	14.78
		CAT	17.07	7.85	27.16	5.43	10.09
TD	122	CKT	28.63	10.42	40.85	5.45	12.22
		CAT	9.32	5.14	18.67	4.91	9.35

The ID had the highest mean gain score of 18.44 followed by the PDID with 14.78 while the TD had the least mean gain score of 12.22 in CKT. The ID also had the highest mean gain score of 13.16, the PDID higher with 10.09 and then the ID with least score of 9.35 in CAT.

ISSN 2348-3156 (Print)
International Journal of Social Science and Humanities Research ISSN 2348-3164 (online)
Vol. 7, Issue 1, pp: (367-376), Month: January - March 2019, Available at: www.researchpublish.com

Table 2: Students Mean and Standard Error Scores on Conceptual and Computational Knowledge by Treatment, Mathematical Ability and Gender

Category of Post CKT		N	CKT Mean	CKT Std. Error	CAT Mean	CAT Std. Error
Treatment	ID	114	44.76	.828	25.89	.531
	PDID	123	42.48	1.034	24.92	.819
	TD	122	41.22	.901	20.20	.781
Mathematical Ability	Low	92	42.62	.873	22.20	.686
	Medium	226	43.40	.454	24.43	.354
	High	41	42.42	1.259	24.38	.968
Gender	Male	214	43.59	.638	24.941	.557
	Female	145	42.05	.852	22.395	.609

Results on Table 2 show students' mean achievement on post CKT by treatment, gender and mathematical ability indicated ID > PDID > TD, Medium > Low > High and Male > Female while the patterns of students' achievement for CAT are ID > PDID > ID, Medium $\geq$ High > Low and Male > Female.

Answer to Research Questions:

Research Question 1: What are the effects of the three inquiry-based learning strategies on chemistry students' achievement in conceptual knowledge and computational knowledge?

Results shown on Table 2 indicate that students in the ID had mean score of 44.76 while those in PDID and TD had mean scores of 42.48 and 41.22, respectively. The students in ID had the highest mean score, followed by PDID and then TD. The students in the ID had the highest score of 25.89 while the PDID and TD groups were 24.92 and 20.20, respectively.

Research Question 2: What is the influence of mathematical ability on chemistry students' achievement in conceptual knowledge and computational knowledge?

The medium mathematical ability students had the highest score of 43.40 followed by low mathematical ability and then high in conceptual knowledge while high and medium mathematical ability students had equal achievement in computational knowledge with 24.38 and 24.43, respectively. The low mathematical ability students had the least score.

Research Question 3: What is the effect of gender on chemistry students' achievement in conceptual knowledge and computational knowledge?

The results on Table 2 show that male students achieved higher than the female counterparts in conceptual knowledge test with mean achievements of 43.59 and 42.05, respectively. The male students also achieved higher, 24.94 in computational ability test than female students with mean achievement of 22.40. The results indicate that male students outperformed their female counterparts on conceptual and computational knowledge.

Test of Research Hypothesis:

The data were further subjected to statistical analysis using ANCOVA.

Research Hypothesis H_0^1 : There is no significant main effect of treatment on the chemistry students' achievement in conceptual knowledge and computational knowledge.

Table 3: Summary of ANCOVA of Students Conceptual Knowledge by Treatment, Gender and Mathematical Ability

Source	Type III Sum of Squares	Df	Mean Square	Partial Eta Squared	F	Sig.
Corrected Model	1928.817	18	107.156	.119	2.546	.001
Intercept	18268.687	1	18268.687	.561	434.064	.000
PRECKT	58.287	1	58.287	.004	1.385	.240
Treatment	359.344	2	179.672	.024	4.269	.015*
Gender	89.138	1	89.138	.006	2.118	.147
Math. Ability	41.386	2	20.693	.003	.492	.612

ISSN 2348-3156 (Print)
International Journal of Social Science and Humanities Research ISSN 2348-3164 (online)
Vol. 7, Issue 1, pp: (367-376), Month: January - March 2019, Available at: www.researchpublish.com

Treatment*Gender	80.839	2	40.419	.006	.960	.384
Treatment*Math. Ability	111.554	4	27.888	.008	.663	.618
Gender*Math. Ability	10.351	2	5.176	.001	.123	.884
Treatment*Gender*Math.Abil	181.038	4	45.259	.012	1.075	.369
Error	14309.768	340	42.088			
Total	688744.00	359				
Corrected Total	16238.585	358				

R = .119; R^2 = .072 * Significant at < .05

Source: Adeoye (2016)

The results on Table 3 showed significant main effect of treatment on students' achievement on conceptual knowledge indicate that $F_{(2,340)} = 4.269$; $p < .05$.

Table 4: Scheffe Post Hoc Tests of Conceptual Knowledge Achievement by Treatment Group

(I) Treatment	N	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.
ID	114	PDID	1.17	846	.383
		TD	4.29	.847	.000*
PDID	123	ID	-1.17	.846	383
		TD	3.12	.831	.001*
TD	122	ID	-4.29	.847	.000*
		PDID	-3.12	.831	.001*

*Pairs of groups significantly different at p <.05.

Scheffe post hoc tests showed on Table 4 indicate that the ID and PDID treatment groups are significantly different from the TD treatment group in conceptual knowledge.

Table 5: Summary of ANCOVA by Treatment, Gender and Mathematical Ability in Computational Ability Test

Source	Type III Sum of Squares	Df	Mean Square	F	Partial Squared	EtaSig.
Corrected Model	6830.544	18	379.475	14.664	.437	.000
Intercept	24417.582	1	24417.582	943.580	.735	.000
PRECAT	814.492	1	814.492	31.475	.085	.000
Treatment	952.628	2	476.314	18.406	.098	.000*
Gender	246.386	1	246.386	9.521	.027	.002*
Math.Ability	220.654	2	110.327	4.263	.024	.015*
Treatment*Gender	115.267	2	57.633	2.227	.013	.109
Treatment*Math.Ability	251.544	4	62.886	2.430	.028	.047*
Gender*Math.Ability	96.599	2	48.299	1.866	.011	.156
Treatment*Gender*Math.Ability	184.357	4	46.089	1.781	.021	.132
Error	8798.386	340	25.878			
Total	222653.000	359				
Corrected Total	15628.930	358				

R = .437 R^2 = .407 *Significant at p < .05

Source: Adeoye (2016)

The results of ANCOVA on computational ability test show $F_{(2,340)} = 18.406$; $P < .05$ on Table 5 indicate a significant main effect of treatment on computational knowledge. Hence, the null hypothesis H_0^1 is rejected. Scheffe post hoc tests were used to determine the direction of significant difference and results are presented in Table 6.

Table 6: Scheffe Post Hoc Tests of Computational Knowledge across Treatment Groups

(I) Treatment	N	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.
ID	114	PDID	- .85	.701	.483
		TD	7.63	.702	.000*
PDID	123	ID	.85	.701	.483
		TD	8.47	.689	.000*
TD	122	ID	-7.63	.702	.000*
		PDID	-8.47	.689	.000*

*Pairs of groups significantly different at p <.05.

Results on Table 6 show no significant difference in the achievement of the students in the PDID and ID learning strategies in computational knowledge but the ID and the PDID are significantly different from the TD learning strategy in computational knowledge.

Research Hypothesis H_0^2 : There is no significant influence of mathematical ability on chemistry students' achievement in conceptual knowledge and computational knowledge.

The results of ANCOVA of effect of mathematical ability on students' achievement in conceptual knowledge presented on Table 3 show that ($F_{(2,340)} = .492$; $p > .05$) hence no significant effect of mathematical ability of students on conceptual knowledge but exists on computational knowledge since the $F_{(2,340)} = 4.263$; $p < .05$ as shown on Table 5.

Research Hypothesis H_0^3: There is no significant effect of gender on the chemistry students' achievement in conceptual knowledge and computational knowledge.

There is no significant difference in the achievement of male and female students in conceptual knowledge as indicated on Table 3 ($F_{(1,340)} = 2.118$; $p > .05$) but male students significantly achieved higher than female in computational knowledge as shown on Table 5 since $F_{(1,340)} = 4.484$, $p < .05$. Hence, there is significant effect of gender on computational knowledge but not significant for conceptual knowledge.

Research HypothesisH_0^4 : There is no significant interaction effect of treatment and mathematical ability on chemistry students' achievement in conceptual knowledge and computational knowledge.

The results on Table 3 showed no significant interaction effect of treatment and mathematical ability on conceptual knowledge ($F_{(4,340)} = .663$; $p > .05$) but there is significant interaction effect of treatment and mathematical ability for computational knowledge ($F_{(4,340)} = 2.430$; $p < .05$) as shown on Table 5. The line graphs shown in Figure 1 indicated the interactions of treatment; ID, PDID and TD at various mathematical ability levels to influence students' achievement in computational knowledge.

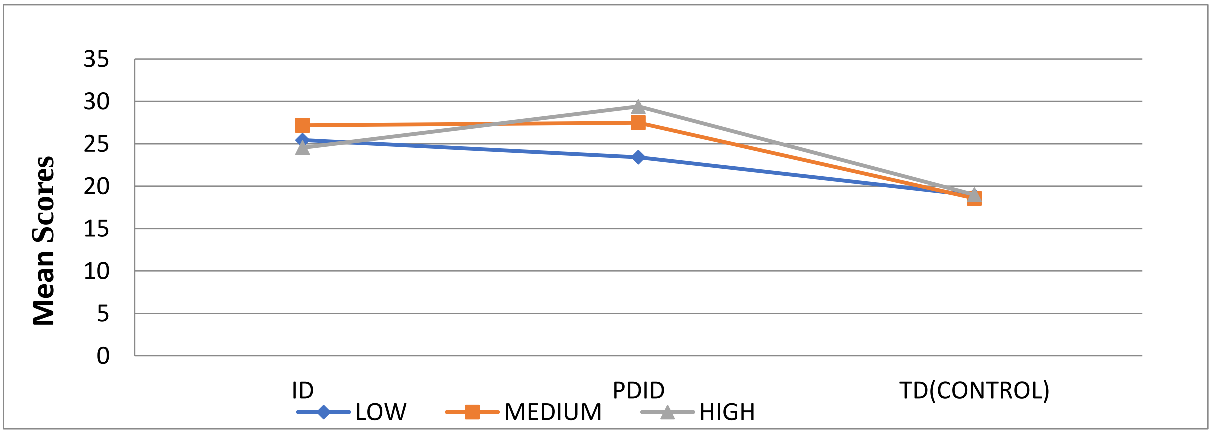

Figure 1: Interaction of Treatment and Mathematical Ability on Computational Knowledge

Research HypothesisH_0^5**:** There is no significant interaction effect of treatment and gender on chemistry students' achievement in conceptual and computational knowledge.

There is no significant interaction effect of the treatment and gender on students' conceptual knowledge ($F_{(2,340)}$ = .960; p > .05) and computational knowledge ($F_{(2,340)}$ = 2.227; p > .05) as shown Tables 3 and 5, respectively. Hence, the null hypothesis H_0^5 is not rejected.

Research HypothesisH_0^6 : There is no significant interaction effect of mathematical ability and gender on the chemistry students' conceptual knowledge and computational knowledge.

Results on Tables 3 and 5 show no significant interaction effect of mathematical ability and gender on the chemistry students' conceptual knowledge ($F_{(2,340)}$ = .123; p > .05) and computational knowledge ($F_{(2,340)}$ = 1.866; p > .05) since P > .05. The null hypothesis H_0^6 is not rejected.

Research HypothesisH_0^7: There is no significant interaction effect of treatment, mathematical ability and gender on the chemistry students' conceptual knowledge and computational knowledge.

There is no significant interaction of treatment, mathematical ability and gender on the chemistry students' conceptual knowledge, $F_{(4,340)}$ = 1.075; p > .05 in Table 3 and computational knowledge $F_{(4,340)}$ = 1.781; p > .05 in Tables 5. Hence, the null hypothesis H_0^7 is not rejected.

5. DISCUSSIONS OF THE FINDINGS

Students' active involvement in inquiry-based learning promotes conceptual and computational knowledge. This is indicated in the findings of this study where students in the ID and PDID learning strategies significantly performed higher than the students in TD where students were passive listeners. The chemistry teacher in the TD group dominated the teaching and learning process. The ID inquiry-based learning strategy did not allow the students to explore, collect, analyse data and solve problems with the learning materials. The reasoning skills are limited to what they had been told by the teachers, hence the students learnt by memorising scientific facts. This finding is supported by Hashim, et al. (2015) and Sever, et al. (2015) who found inquiry-based learning strategy to be significantly more effective than traditional methods on students' achievement in chemistry.

The students in the ID and PDID learning strategies actively involved themselves in the learning process by carrying investigations, exploring the learning environment, explaining the findings of the investigation, elaborating and evaluating the new knowledge acquired from the new situation to solve related problems. The discussions of the findings of their investigations with their counterparts promote meaningful learning as the misconceptions would be clarified. The students actively constructed knowledge from the experience using process skills, reflected and conceptualised the understanding of chemistry concepts and task process. The processes encourage the students to make connections of new knowledge with prior knowledge hence students possess adequate conceptual knowledge in chemistry necessary to solving quantitative problems in the subject. The studies of Surif et al. (2014), Chairan et al. (2015), Adeoye (2016) and Adeoye and Ajeyalemi (2016) were in agreement that inquiry learning enhanced conceptual understanding.

The results of the study also indicated that gender has significant effect on computational knowledge. Chemistry is mathematical in nature and most female students have phobia for any subject that is mathematical. This may be one of the reasons for female poor achievement in chemistry. The finding further indicated that students' mathematical ability influences chemistry students achievement in computational knowledge and this is in agreement with Adigwe (2012) and Potter (2014).

There is significant interaction effect of treatment and mathematical ability on computational knowledge of the chemistry students but this was not observed on conceptual knowledge. The implication of this is that, the PDID learning strategy if effectively implemented with students' adequate mathematical ability would promote high achievement in computational knowledge. Learning strategies and students' mathematical ability are essential for computational knowledge in chemistry.

Implications

The traditional methods of instruction are inadequate to effect meaningful learning in conceptual and computational knowledge in chemistry however active learning strategies do. Mathematical ability is a requirement to boost chemistry students quantitative knowledge in the subject. One of the major reasons why female students shy away from chemistry is mathematical knowledge requires in the subject. Female students should be encouraged to put more effort in mathematics to encourage effective learning of chemistry.

6. RECOMMENDATION AND CONCLUSION

The implication of this study is that if ID and PDID learning strategies are effectively implemented in Nigerian senior secondary schools for teaching chemistry over a long period of time would enhance students' achievement in both internal and external examinations. The use of ID and PDID learning strategies are therefore recommended for the teaching of chemistry in senior secondary schools for better attainment of conceptual and computational knowledge. Government should equip chemistry laboratories with chemicals and equipment and ensure effective implementation of guided inquiry in the teaching of science subject as recommended in the curricular through regular visits to schools by educational monitoring team.

In conclusion the ID and PDID inquiry-based learning strategies have greater potential in the development of students' conceptual and computational knowledge in science than the traditional lecture and teacher demonstration.

REFERENCES

[1] Adeoye, I. F. (2012): Secondary school students' conceptual and computational knowledge in electrochemistry. *Oyo State Journal of Mathematical Association of Nigeria*, 3(2), 96-106.

[2] Adeoye, I. F. (2016): *Effects of inquiry-based learning strategies on senior secondary school students' learning outcomes in chemistry.* Ph. D Thesis submitted to School of Postgraduate Studies, University of Lagos, Lagos State, Nigeria.

[3] Adeoye, I. F. and Ajeyalemi, D. (2016): Effect of Learning in Inquiry Context on Chemistry Students' Conceptual Knowledge at Three Levels of Representation in Redox Reaction and Electrolysis. *Lagos Education Review (A Journal of Studies in Education)*, 16(2), 133-142

[4] Adigwe, J. C. (2012): Effects of mathematical reasoning skills on students' achievement in chemical stoichiometry. *Review of Education, Institute of Educational Journal*, 23(1), 1-22.

[5] Ajeyalemi, D. (2009): Education for scientific values. In U. M. O. Ivowi, (ed). *Education for value.* Lagos: Foremost Educational Services Ltd.

[6] Ajeyalemi, D. (2011): Practical work in school science Are the aims and objectives being achieved? 2011 *Memorial Lecture, 52nd Annual Conference Proceedings of the Science Teachers Association of Nigeria.*

[7] Anyafulude, J. C. (2013): Effects of problem-based and discovery-based instruction strategies on chemistry achievement. *Journal of Educational and Social Research*, 3(6), 105-111.

[8] Aydeniz, M., Cihak, D., Graham, S. and Retinger, L. (2012): Using inquiry-based instruction for teaching science to students with learning disabilities. *International Journal of Special Education*, 27(2), 189-206.

[9] Barker, J. G. (2012): *Effect of instructional methodologies on students achievement; Modeling instruction vs. traditional instruction*. A Thesis submitted to Faculty of Louisiana State University, Louisiana.

[10] Bruner, J. S. (1961): *The act of discovery*. Harvard Educational Review. 31(1), 21-32.

[11] Chairan, S., Klahan, N. and Coll, R. K. (2015): Exploring secondary students of chemical kinetics through inquiry-based learning activities. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(5), 937-956.

[12] Dewey, J. (1949): *Knowing and the known*. Boston: Beacon Press.

[13] Drake, K. and Long, D. (2009): Rebecca's in the dark. A comparative study of problem-based learning and direct instruction \ experiential learning in two 4th-grade classroom. *Journal of Elementary Science Education*, 21(1), 1-16.

[14] Federal Republic of Nigeria (2011): *National Policy on Education*. Abuja: NERDC Press.

[15] Furtado, L. (2010): Kindergarten teachers' perceptions of an inquiry-based science teaching and learning professional development intervention. *New Horizons in Education*, 58(2),104-120.

[16] Grauer, S. (2016): *Fearless Teaching*. Roslyn, New York: AERO

[17] Gultepe, N., Celik, A. Y. and Kilic, Z. (2013): Exploring effects of high school students mathematical processing skills and conceptual understanding of chemical concepts on algorithmic problem solving. *Australian Journal of Teacher Education*, 36(10), 106-122.

[18] Hashim, A., Ababkr, T. E. and Eljack, N. S. (2015): Effects of inquiry based teaching on junior secondary school students academic achievements: A case study in Hadejia Zonal Education Area of Jigawa State, Nigeria. *SUST Journal of Humanities*, 16(1), 156-170.

[19] Holme, T. A., Luxford, C. J. and Brandriet, A. (2015): Defining conceptual understanding in general chemistry. *Journal of Chemical Education*, 92(9), 1477-1483.

[20] Millar, R. (2009): *Analysing practical activities to assess and improve effectiveness: The Practical Activity Analysis Inventory (PAAI).* York: Centre for Innovation and Research in Science Education, University of York.

[21] Potter, N. (2014): *Researching into the development of problem solving skills in undergraduate students and the cognitive factors on performance.* Ph.D. Thesis. Department of Chemistry, The University of Hull.

[22] Sever, D. and Guven, M. (2015): Effect of inquiry-based learning approach on student resistance in a science and technology courses. *Educational Science: Theory and Practice*, 14(4), 1601-1605.

[23] Surif, J., Ibrahim, N. H. and Dalim, S. F. (2014): Problem solving: Algorithms and conceptual and open-ended problems in chemistry. *Procedia-Social and Behavioural Sciences*, 116, 4955-4963.

[24] WAEC (2000-2012): *Analysis of senior secondary school examinations results*. Lagos: WAEC Press.