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ORIGINAL ARTICLE

Impact of Research- and Assessment-based Instructional Modes on the Achievement of Senior High School Students in Selected Chemistry Topics

Johnson Ayodele Opateye[1]*, Daniel Raphael Ejike Ewim[2]

[1]Department of Educational Foundations, National Open University of Nigeria, Jabi, Abuja, [2]Department of Mechanical Engineering, Durban University of Technology, Durban, South Africa

***Corresponding Author:** jopateye@noun.edu.ng

ABSTRACT

This research focused on the impact of research- and assessment-based instruction on senior high school students' achievement in selected chemistry topics. A 3 × 2 × 2 pre-test and post-test control group in a quasi-experimental research design was used on a population of Grade 11 chemistry students in Ojo Local Government Area of Lagos state. Two schools (one public and one private) were randomly assigned to each of the treatments. A sample of 240 chemistry students was used. Three research questions were answered and five hypotheses were tested. The reliability coefficient of the "Chemistry achievement test" was found to be 0.770 using the Kuder–Richardson Formula 20. Research-based, assessment-based, and conventional instruction manuals were also developed. The data collected were analyzed using descriptive statistics and analysis of covariance. It was found that the impact of assessment- and research-based instruction on senior high school students' achievement in the selected topics was significant ($F(2,227) = 49.214$, $p < 0.050$). It was also found that the students exposed to the assessment-based instructional mode had a higher achievement than those in the research-based and conventional groups. Male chemistry students were found to benefit more than the female students after being exposed to research- and assessment-based instructional modes. It is, therefore, recommended that assessment- and research-based instructional modes be used to teach the selected chemistry topics to enhance effective learning.

KEY WORDS: Research-based instruction; assessment-based instruction; selected topics; chemistry students; gender; type of school

INTRODUCTION

Chemistry plays a key role as a science subject, with its potential to lead to technological breakthroughs (Lv et al., 2018). It is the pivot on which the wheel of science rotates. Chemistry is part of the development that is taking place in the fields of medicine, agriculture, transportation, housing, and industries. Chemical products such as fabrics, drugs, cosmetics, paints, soap, fertilizers, and so forth lead to improved quality of life. Students' knowledge of chemistry helps them to explore various careers in the health sector, food processing industries, extractive industries, engineering, agriculture, pharmaceuticals, petroleum, and petrochemical industries, among others.

Sesen and Tarhan (2010) argue that if active learning modes are used to teach chemistry, it would result in positive increases in four areas: Interest in chemistry lessons, comprehending and learning chemistry, the importance of chemistry in life, and chemistry and professional choice. Research on difficult topics in Nigerian Grade 11 chemistry has established that types of chemical reactions, redox reactions, balancing redox reactions, electrode potential and electrochemical cells, laws of electrolysis, chemical equilibrium, reversible reactions, solubility, sulfur and its compounds, IUPAC nomenclature of organic compounds, and alkynes are extremely difficult to learn (Adzape, 1995 and Gongden et al., 2011). These concepts are difficult for students to learn due to students' insufficient understanding of mole concepts, low numerical abilities, and non-practicability of the concepts (Opateye, 2012b). These topics are challenging due to their quantitative nature and their less obvious application to real life. Such topics involve deep understanding before they can be applied, other than the ordinary "cram and pour" nature of other chemistry topics.

Several techniques have been used in the recent past to teach chemistry in Nigerian secondary schools. Such techniques include interactive lectures, which make the teacher the only source of information in the class; problem solving, which makes the learners ponder on the concepts before coming to a conclusion (Abd-El-Khalick, 2012); laboratory activities, which help the students to learn first-hand about chemistry concepts through experimentation (Tenaw, 2014); and cooperative learning, which promotes interactivity among the learners (Ogunleye, 2011). The applications of these techniques to chemistry teaching have not yielded positive results on students' understanding of the chemical concepts, hence, the need to explore other techniques such as research- and assessment-based strategies to complement the teaching and learning of chemistry in secondary schools.

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In recent years, increasing attention has been given to the centrality of assessment for learning. Among those researchers on assessment who have made key contributions in this area are Black and Wiliam (2009). Black and Wiliam performed an extensive review of related research and argue that assessment for learning should be used to enhance educational standards. They went on to report that assessment was based on learning modes that are used to apply various learning targets in academic programs in higher institutions. It is therefore essential to make assessment focus on learning outcomes that would develop competencies and the necessary values for learners. The greatest factor that affects a teacher's effectiveness may be their ability to use varying and engaging modes to deliver knowledge and skills to the students in the classroom. According to the Smith and Ingersoll (2004), instructional modes are one of a variety of ways in which a teacher is able to deliver instruction to students to achieve learning objectives and positively impact on students' achievement. In planning for instruction, teachers should first identify learning goals and decide on the assessment measures to be used. By focusing first on what students should learn and how it will be assessed, teachers can then select instructional modes that engage students and assist in attaining the specified learning goals. Teachers can easily access a variety of teaching resources using appropriate instructional modes through collaboration with colleagues, internet searches, experience, professional journals, and books (Hock and Mellard, 2011). Greenstein (2010) points out that assessments can be used to improve learning because they give the teachers defined goals, create rigors for students, enhance students' motivation, increase engagement, foster feedback, and encourage personalized learning. When teachers' classroom assessments become an integral part of the instructional process, students learn better in a chemistry class. Fox (2014) points out that research-based instruction contains tools and modes to gather, structure, and analyze classroom observation data. Case studies, sample data sets, findings and conclusions drawn from sample data tables, and a step-by-step process for collecting the data are all components of research-based instruction. Eberly Center for Teaching Excellence (2014) identified one of the principles of using research-based instruction as recognizing that students' previous knowledge can enhance or disturb learning. When students are motivated, effective learning is sustained, determined, and directed to productive application of attained knowledge. Furthermore, how students learn and organize knowledge influence how they apply what they know, the level of mastery developed, and how they acquire competent skills and practice how to fit them into new learning situations. Motivated students apply what they have learned, goal-directed practice coupled with targeted feedback enhances the quality of students' learning, and students' present level of development interacts with the social, emotional, and intellectual climate of the course to impact learning and helps them to become self-directed learners. Students must learn to monitor and evaluate their approaches to learning. Research-based instruction involves starting with review, presenting new material, thinking aloud, guided practice, stating the objective, using a graphic organizer, concept sorting, checking understanding, and providing feedback (Rosenshine, 2012).

Learning modes tailor the classroom instruction to bringing chemical concepts to the focus of the learners. If appropriately applied, they illuminate the higher learning of the children. Modes that make students learn help them to remember what they have assimilated. Active learning modes in chemistry allow students to put the main information into their own words, make mental images and pictures of new information, ask questions and make predictions about the new information, and recognize unknown words by seeking out their meaning. Teachers make use of many insights in their classrooms but lack the ability to ascertain which is best for all students. According to the Niederhauser and Stoddart (2001), educational research helps to identify which instructional mode is effective for teachers to use to bring the best methods of instruction into their classes. The evidence obtained from cognitive research results in the development of instructional methods based on the experience of teachers to apply such findings. Teachers are central to the application of educational research findings in the classroom (Rockoff, 2004) and the extent of their experience in the classroom provides researchers with valuable information about how students act and react to instructional methods and content.

Assessment of students' learning is central to effective instruction in the classroom. In education, assessment consists of methods or tools that teachers use to evaluate, measure, and document the academic readiness, learning progress, skill acquisition, learning attitudes, or educational needs of students. According to the O'Kaine (2014), educational assessment is the process of documenting, usually using specific and measurable terms of knowledge, skills, attitudes, values, and beliefs. It is a means of obtaining information from tests, examinations, projects, assignments, or other means about the performance or abilities of individuals. Assessment focuses on the individual learner, the learning environment (class, laboratory, workshop, field, or other organized learning environment), the institution, or the educational system of a society. Assessment practices in education rely on the theoretical framework of the practitioners and researchers, assumptions, and beliefs about the nature of human mind, the origin of knowledge, and how they learn. Assessment is often divided into formative and summative categories for the purpose of considering different objectives for assessment practices (Hamilton, 2010). Placement assessment is used to position students according to the prior achievement or personal characteristics at the most appropriate point in an instructional sequence, in a unique instructional mode, or with a suitable teacher conducted through placement testing formative assessment. This is an educational assessment that is used to enhance learning. Summative assessment is generally carried out at the end of a course or project, while diagnostic assessment focuses on the difficulties that occur during the learning process (Dixson and Worrell, 2016).

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Performance assessment uses tools that provide the framework for students' to work more independently and to make them to pay closer attention to the quality of their academic work (Pellegrino, 1999). This is a series of assessments given to students that also helps the teacher to effectively provide students with information on the strengths and weaknesses of their work. In creating a performance assessment, teachers provide direct instructions for what students need to assimilate and how to apply their ability. The outcome of this is that teachers can be more consistent and fairer when evaluating and grading student work. The information obtained from the results of performance task assessment also helps students to set learning goals and thus helps teachers to focus on using the appropriate instruction (Czerniak and Lumpe, 1996 and Elwood, 2006). Parents can also use assessment lists to scrutinize their children's work in school and to help follow the progress they are making even when at home.

Gender, in most cases, is confused with sex (Maccoby, 2003). Maccoby argues that gender is a person's psychological experience of being a man or a woman and it consists of other features such as personality, self-concept, and making distinction of one's nature and abilities, while sex only distinguishes between male and female biological characteristics. Joel and Aride (2006) reported that boys performed better and dominate in social studies, chemistry, physics, mathematics, and environmental studies classes, while most girls go into studying languages and the arts. They also pointed out that a higher scale score indicated that the students perceived learning chemistry as easy. Nnamani and Oyibe (2016) highlighted that boys perceived chemistry learning to be considerably easier than their female fellow students did and concluded that there was a significant difference between the gender of students and ease of learning chemistry. School type, whether public or private, plays a significant role in the academic success of learners. It was discovered that students who attended private high schools performed better than their colleagues who attended public high schools and that there is significant difference in students' academic performance in social studies based on school type (Okon and Archibong, 2015).

Bedi and Garg (2000) revealed a significant difference in science performance between private and public high school students, with private school students achieving better. Furthermore, Opateye (2012a) established that school type contributes significantly to students' achievement in electrochemistry. Hence, the type of school, whether public or private, can influence students' achievement in chemistry when research- and assessment-based instructional strategies are used. Consequently, this study focused on the impact of research- and assessment-based instruction on Grade 11 students' achievement in chemistry. It also established the significant main and interaction impacts of gender and school type and type of instruction on students' achievement in chemistry.

Statement of the Problem

Based on the previous student comments, this study's researchers have identified challenging topics in the high school chemistry curriculum such as electrochemistry, chemical equilibrium, chemical reaction rates, and solubility, as well as redox reactions. Over the years, different instructional modes such as concept mapping, direct discussion, panel discussion, and role playing have been used and proved to be beneficial to students' learning of chemistry, but these have not helped in alleviating the difficulty levels of these topics. Furthermore, little attention has been paid to using assessment- and research-based instructional modes to teach chemistry in high schools. It was therefore the purpose of this study to investigate the impact research- and assessment-based instruction would have on Grade 11 students' achievement in historically challenging chemistry topics.

Research Questions

The following research questions were investigated in this study:

1. How do Nigerian Grade 11 students achieve in difficult chemistry topics before and after being exposed to assessment- and research-based instruction?
2. How does the achievement of male and female Nigerian Grade 11 students in difficult chemistry topics before and after exposure to assessment- and research-based instruction compare?
3. How does the achievement of public and private Grade 11 students in difficult chemistry topics before and after being taught through assessment- and research-based instruction compare?

Hypothesis

1. Research- and assessment-based instruction will not have a significant impact on Grade 11 students' achievement in difficult chemistry difficult topics
2. Gender will not have a significant impact on Grade 11 students' achievement in difficult chemistry topics
3. School type will not have a significant impact on Grade 11 students' achievement in difficult chemistry topics
4. The interaction effect of type of instruction and gender on Grade 11 students' achievement in difficult chemistry topics will not be significant
5. The interaction effect of type of instruction and school type on Grade 11 students' achievement in difficult chemistry topics will not be significant.

METHODOLOGY

The study adopted a 3 × 2 × 2 pre-test and post-test control group in a quasi-experimental design type and was designed to investigate research- and assessment-based instructional modes in chemistry in senior high school in Nigeria. The target population covered all Grade 11 chemistry students in the Ojo Local Government Area (LGA) of Lagos state. Three out of 21 public senior high schools and three private senior high schools out of 38 in the LGA were selected using the simple random

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sampling method. The total student sample used consisted of 240 students from the three public and three private schools in Ojo LGA. The type of instruction was randomly assigned to schools, with one public and one private school assigned to the research-based group, one public and one private school assigned to the assessment-based group, and the control group had one public and one private school assigned to it. An intact chemistry class from each school was used. The response instrument was the "Chemistry achievement test" (CAT) (Appendix 1). Section A contains students' biodata, while Section B has 30 multiple-choice items with each item having alternatives from A to D. The questions covered five difficult topics in chemistry: IUPAC nomenclature, Faraday laws, redox series, balancing of half-cell reactions, chemical equilibrium, solubility, and reaction rates. The instrument was trial-tested to validate the items using the Kuder–Richardson formula 20. Its reliability coefficient was 0.77. Three instruction manuals, which were stimulus instruments, were produced. The first was the assessment-based instruction manual; the second was the research-based instructional manual, while the third was the conventional chemistry instruction manual. The assessment-based instruction manual contains a series of formative assessment questions on each of the identified difficult topics, while the research-based instruction manual contains procedures for students' research on each of the topics being used for teaching. The conventional chemistry instructional manual consists of frequently used lesson plans given as lectures by the teacher.

Permission was sought and obtained from the school administrators/proprietors to include their schools. Chemistry teachers for each of the selected six schools were used to undertake the teaching using the research-based, assessment-based, and conventional modes after training. As noted, each of the types of instruction was randomly assigned to two schools, one public and one private school. The intact chemistry classes of each school were used, therefore, having three groups. Chemistry students in Group A were exposed to research-based teaching, those in Group B were exposed to assessment-based teaching, and Group C used the conventional mode. The exposure of the students to these types of instruction took 6 weeks. The 1st week was used to train the teachers and for the administration of the pre-test. The remaining 5 weeks were used to teach students identified difficult chemistry topics using the different types of instruction, after which the students were given a post-test. Data collected were subjected to analysis using relevant statistical tools according to the research questions raised and hypotheses tested. The study took 6 weeks, in which chemistry teachers for each of the schools were trained on how to use the instruction manuals based on each treatment assigned to them. The CAT was pre-tested to each group before the application of the treatments. After the groups were exposed to treatments, a post-test was administered to the students. Descriptive statistics were used to answer research questions 1–3. Analysis of covariance (ANCOVA) with Scheffe *post hoc* was utilized to test hypotheses 15. The pre-test was used as the covariate. All hypotheses were tested at a 0.05 level of significance.

RESULTS

The results of the study are presented following.

Research Question One

How do Nigerian Grade 11 students achieve in difficult chemistry topics before and after being exposed to assessment- and research-based instruction?

Table 1 reveals that the pre-test mean chemistry score for students in the research-based instructional group was 12.501, with a post-test mean score of 17.825. Furthermore, for the assessment-based group, students' pre-test mean score was 14.282 and the post-test mean score was 19.990. Students who were exposed to the conventional mode of instruction had a pre-test mean score of 14.506, with a post-test score of 17.156. In all the groups, the post-test mean scores were higher than the pre-test mean scores. However, students exposed to assessment-based instruction had the highest post-test mean scores, followed by those in the research-based group and then the conventional group. Students in the research-based group also had the highest mean gain of 5.708, followed by the assessment-based group with a mean gain of 5.324, while those in the conventional group had the lowest mean gain of 2.650. Therefore, the assessment-based instructional mode is more effective in teaching difficult chemistry topics than both research-based and conventional modes, although the research-based method is better than the conventional method.

Research Question Two

How does the achievement of male and female Nigerian Grade 11 students in difficult chemistry topics before and after exposure to assessment- and research-based modes of instruction compare?

As shown in Table 2, the male students' pre-test mean score was 14.390, with a post-test mean score of 17.960. Female students' mean pre-test score in chemistry was 14.160, with a mean post-test score of 18.710. Although female chemistry students had a higher post-test mean score, male students had a slightly higher mean gain than their female counterparts, of 4.570 compared to 4.550. Therefore, male chemistry students benefited more than the female students after being exposed to research- and assessment-based instructional modes.

Research Question Three

How does the achievement of Nigerian Grade 11 students in public and private school in difficult chemistry topics before and after being taught use assessment- and research-based modes of instruction compare?

Table 3 shows that the pre-test achievement score in chemistry by public school students was 14.257 and the post-test mean score was 18.764; for private senior high school students, the mean pre-test score was 13.274 and 17.883 was the post-test mean score. Both public and private senior high school students

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had higher post-test scores, although that of public school students was better. Private school students had a higher mean gain (4.609) than those in public school with a gain of 4.507.

Hypothesis 1 (Ho_1)

Research- and assessment-based instructional modes will not have a significant impact on Nigerian Grade 11 students' achievement in difficult chemistry topics.

From Table 4, the treatment had a significant impact on students' achievement in chemistry in Grade 11. The F value of 49.214 at degrees of freedom of (2,227) with p = 0.000 that is < 0.050 depicts significant main of treatments. Type of instruction also contributed 30.20% to changes observed in students' achievement in chemistry, since the partial eta value was 0.302. Therefore, the impact of assessment- and research-based instruction on senior high school students' achievement in difficult chemistry topics was significant.

Table 5 shows a significant difference between students in the research-based and assessment-based groups, with p = 0.003. Furthermore, there was a significant difference in achievement in difficult chemistry topics between assessment-based students and those in the conventional group, with p = 0.000.

Hypothesis 2 (Ho_2)

Gender will not have a significant impact on Nigerian Grade 11 students' achievement in difficult chemistry topics.

From Table 2, it was discovered that male Grade 11 students benefited more in achievement in chemistry than their female counterparts after exposure to research-based and assessment-

Table 1: Description of students' achievement in chemistry based on treatment

Treatment	Pre-test			Post-test			Mean gain
	Mean	Std. devn.	Std. error	Mean	Std. devn.	Std. error	
Research-based	12.501	3.614	0.088	17.825	4.687	0.136	5.324
Assessment-based	14.282	2.556	0.086	19.990	3.351	0.057	5.708
Conventional method	14.506	3.738	0.060	17.156	3.878	0.058	2.650

Table 2: Description of students' achievement in difficult chemistry topics by gender

Gender	n	Pre-test			Post-test			Mean gain
		Mean	Std. devn.	Std. error	Mean	Std. devn.	Std. error	
Male	124	14.390	3.577	0.036	17.960	4.178	0.038	4.570
Female	116	14.160	3.277	0.030	18.710	3.878	0.049	4.550

Table 3: Description of students' achievement in difficult chemistry topics by school type

Type of school	n	Pre-test			Post-test			Mean gain
		Mean	Std. devn.	Std. error	Mean	Std. devn.	Std. error	
Public	120	14.257	3.379	0.077	18.764	3.968	0.114	4.507
Private	120	13.274	3.463	0.055	17.883	4.341	0.051	4.609

Table 4: Analysis of covariance of students' achievement in chemistry by type of instruction, gender, and school type

Source	Type III Sum of square	Df	Mean square	F	p	Partial eta squared
Corrected model	3247.090	12	270.591	67.115	0.000	0.780
Intercept	187.636	1	187.636	46.540	0.000	0.170
Pre-test	2572.675	1	2572.675	638.105	0.000	0.738
Treatment	396.834	2	198.417	49.214	0.000	0.302
Gender	2.280	1	2.280	0.566	0.453ns	0.002
School type	0.505	1	0.505	0.125	0.724ns	0.001
Type of instruction * gender	0.374	2	0.187	0.046	0.955ns	0.000
Type of instruction * school type	15.578	2	7.788	1.932	0.047	0.017
Gender * school type	1.241	1	1.241	0.308	0.580ns	0.001
Type of instruction * gender * school type	3.842	2	1.921	0.476	0.622ns	0.004
Error	915.206	227	4.032			
Total	84719.00	240				
Corrected total	4162.296	239				

R-squared=0.780; Adjusted R-squared=0.768

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Table 5: Scheffe multiple complications of students' achievement in difficult chemistry topics by type of instruction

Treatment (I)	Treatment (J)	Mean diff (I - J)	Std. Error	p-value
Research-based	Assessment-based	–2.160*	0.618	0.003
	Conventional	0.670	0.618	0.552
Assessment–based	Research-based	2.161*	0.618	0.003
	Conventional	2.841*	0.618	0.000
Conventional	Research-based	–0.670	0.618	0.552
	Assessment-based	–2.840*	0.618	0.000

based instructional modes. Table 4 shows that the F-value of 0.566 at degrees of freedom (1,227) was not significant, since the value of P was 0.453, that is, greater than 0.050. Therefore, the impact of gender on Grade 11 students' achievement in difficult chemistry topics was not significant. Hypothesis two is not rejected.

Hypothesis 3 (Ho_3)

School type will not have a significant impact on Nigerian Grade 11 students' achievement in difficult chemistry topics.

It was shown from Table 3 that Grade 11 students from private senior high schools benefited more after exposure to research-based and assessment-based instruction than those in the public schools. Table 4, therefore, revealed that school type's impact on students' achievement in difficult chemistry topics was not significant ($F(1,227) = 0.125$, $p > 0.050$). Hypothesis three is, therefore, not rejected.

Hypothesis 4 (Ho_4)

The interaction effect of type of instruction and gender on Nigerian Grade 11 students' achievement in difficult chemistry topics will not be significant.

From Table 4, the ANCOVA result shows that the interaction effect of type of instruction and gender on students' achievement in difficult chemistry topics was significant ($F(2,227) = 0.046$, $p > 0.050$). This shows that the use of research-based and assessment-based instruction modes is not sensitive to whether a student is male or female.

Hypothesis 5 (Ho_5)

The interaction effect of type of instruction and school type on Nigerian Grade 11 students' achievement in difficult chemistry topics will not be significant.

Table 4 reveals that the interaction of the treatment and school on students' achievement in chemistry ($F(2,227) = 1.932$, $p < 0.050$) was significant. This means that the use of research- and assessment-based instructional modes is sensitive to the type of school, whether private or public. This is in line with results in Table 3, which showed that while public-school students had a higher performance in chemistry, private school students benefitted more when exposed to these treatments. Therefore, there is a significant interaction effect of research- and assessment-based instruction and school type on senior high school students' achievement in difficult chemistry topics.

DISCUSSION OF FINDINGS

The findings presented reveal that assessment-based instruction is more effective in teaching difficult chemistry topics compared to research-based instruction. Students exposed to assessment-based instruction had the highest post-test mean scores, followed by those in the assessment-based group and then the conventional group. Therefore, the assessment-based instructional mode was more effective in teaching chemistry than both the research-based and conventional modes. This is in accordance with the findings of Carless (2005) that implementation of assessment-based learning correlates with the cognitive enhancement of science students. Research-based instruction enables students to carry out investigations better than conventional instruction. When students were asked to do research while carrying out a task, they learnt a great deal more and faster. This was similar to self-discovery whereby whatsoever was discovered in the course could be utilized effectively without any aid. It also helped students to learn with little or no supervision, widening their scope of learning, and helping improve their self-esteem in the subject matter. Therefore, the research-based instruction was more effective in teaching difficult chemistry topics than conventional instruction.

Female students seemed to benefit less than their male counterparts after being exposed to assessment-based and research-based instruction. This trend will be a subject of the future investigation.

Assessment- and research-based instruction in private schools yielded a higher achievement than that of students in public schools. Private schools have adequate facilities to empower and enhance students. Where there are enough chemistry textbooks, backup generators, and internet facilities, the tasks will be more appealing to the students. Students from private senior high school benefited more after exposure to research-based and assessment-based instruction than those in the public schools. This finding corroborates those of Rockoff (2004), who asserted that type of school influences students' achievement in science based on the instructional approach used to teach the subject.

Assessment-based instruction was the most effective in teaching difficult chemistry topics. It helped students to develop their understanding of the subject. The research shows that male chemistry students gained more value than their female counterparts from being exposed to assessment- and research-based instruction. In other words, male students performed better than their female counterparts. This research also shows that school type had an impact on students' achievement: The difference between public and private senior high school Grade 11 students' achievement in difficult chemistry topics was significant, and the students in private schools have a higher mean gain than their counterparts in public school.

Students in the two types of schools have the same background knowledge but the private school students perform better after they are exposed to non-conventional instruction. Sesen and Tarhan (2010) and Lynn (2002) also reported that chemistry students in private schools are more sensitive to innovative teaching than their public-school counterparts.

Several factors could have accounted for this difference. One possible reason is infrastructure: Looking at some private schools, they have good infrastructure for effective teaching and learning, they have well-equipped laboratories and constant power supply, and most of the classrooms are well furnished and well equipped with air conditioners and fans, which all create an environment conducive to learning. All these will facilitate effective teaching and learning, unlike in public schools who do not have well-equipped laboratories or zero proper classroom furniture; learners have to learn in an environment that is not conducive and this affects their performance.

RECOMMENDATIONS

The following recommendations were made from the findings of the study:

1. The government should organize seminars and training for the in-service chemistry teachers on the effective design and implementation of research-based instruction and assessment-based instruction to enhance the learning of difficult topics in senior high school chemistry
2. Female chemistry students should be encouraged to participate more effectively in both assessment- and research-based instruction
3. Assessment-based instruction should be used often in both private and public schools, as it has the most impact on students' performance in difficult chemistry topics
4. Public schools should adopt more research-based instruction to widen the scope of learning of the difficult chemistry topics among students and to help them focus their attention on those topics.

CONCLUSION

The study revealed that assessment-based instruction was most effective to teach difficult topics in chemistry when compared to both research-based and conventional instruction, although the research-based method was better than the conventional method. Furthermore, male private school chemistry students benefited more than the female students after being exposed to research-based and assessment-based instruction. Assessment-based and research-based instruction enhances students' achievement in difficult chemistry topics to a greater extent than conventional instruction.

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APPENDIX 1

Chemistry Achievement Test (CAT)

Instruction: Answer all the questions by cycling (O) the correct option from options A–D for each of the question. Each question carries equal marks. Please note that this test is meant for research purpose only and it does not add to your performance in the subject for the present term.

1. $Zn+H_2SO_4 \rightarrow ZnSO_4+H_2$

In the above reaction, how much zinc will be left undissolved if 2.00 g of zinc is treated with 10 cm^3 of 1.0 M of H_2SO_4? (Zn=65; S=32; O=16, and H=1)

A. 1.35 g
B. 1.00 g
C. 0.70 g
D. 0.65 g

2. When sodium dioxonitrate (III) ($NaNO_2$) dissolves in water, ΔH is positive. The process of dissolution is

A. Exothermic
B. Endothermic
C. Isomeric
D. Hygroscopic

3. The equilibrium reaction between copper (I) chloride and chlorine at 250°C and 1 atmosphere is represented by the equation: $2CuCl+Cl_2 \rightarrow 2CuCl_2$, ΔH=–166kJ. Which of the following statements is TRUE for the reaction, pressure remaining constant?

A. More $CuCl_2$ is formed at 400°C
B. More $CuCl_2$ is formed at 10°C
C. Less $CuCl_2$ is formed at 10°C
D. There is no change in the amount of $CuCl_2$ formed at 40°C and 10°C

4. $Zn+2HCl \rightarrow ZnCl_2+H_2$. The rate of the above reaction will greatly increase if

A. The zinc is in the powdered form
B. A greater volume of the acid is used
C. A smaller volume of the acid used
D. The zinc is in the form of pellets

5. 3.06 g of a sample of potassium trioxochlorate(V) was required to make a saturated solution with 10 cm^3 of water at 25°C. The solubility of the salt at 25°C is (K=39, Cl=35.5, 0=16).

A. 5.0 moles dm^3
B. 3.0 moles dm^3
C. 0.5 moles dm^3
D. 2.0 dm^3

6. In the reactions

(I) $H_2(g)+½O_2(g) \rightarrow H_2O$ ΔH=–286kJ
(II) $C(s)+O_2(g) \rightarrow CO_2$; ΔH=–406 kJ

The equations imply that

A. More heat is absorbed in (I)
B. More heat is absorbed in (II)
C. Less heat is evolved in (I)
D. Reaction (II) proceeds faster than (I)

7. Which of these metals, Mg, Fe, Pb, and Cu will dissolve HCl?

A. All the metals
B. Mg, Fe, and Cu
C. Mg, Fe, and Pb
D. Mg and Fe only

8. Increasing the pressure of a gas

A. Lowers the average kinetic energy of the molecules
B. Decreases the density of the gas
C. Decreases the temperature of the gas
D. Increases the density of the gas

9. Which of the following happens during the electrolysis of molten sodium chloride?

A. Sodium ion loses an electron
B. Chlorine ion gains an electron
C. Its ions dissolve readily in water
D. Sodium ion is oxidized

10. In the reaction $Fe+Cu^{2+} \rightarrow Fe^{2+}+Cu$, iron displaces copper ions to form copper. This is because

A. Iron is in the metallic form while the copper is in the ionic form
B. The atomic weight of copper is greater than that of iron
C. Iron is higher in the electrochemical series than copper
D. Iron is inert metal

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11. In which of the following processes is iron being oxidized?
1. $Fe+H_2SO_4 \rightarrow FeSO_4+H_2$
2. $FeSO_4+H_2S \rightarrow FeS+H_2SO_4$
3. $2FeCl_2+Cl_2 \rightarrow 2FeCl_3$

A. 1 and 3
B. 2 and 3
C. 2 only
D. 3 only

12. The product formed at cathode during the electrolysis of sodium chloride solution with carb on electrodes is
A. Sodium
B. Chlorine
C. Hydrogen
D. Sodium hydroxide

13. In the reaction $N_2(g)+O_2(g) \rightarrow 2NO(g)$ an increase in the pressure will
A. Have no effect
B. Cause more nitric oxide to be produced in the equilibrium mixture
C. Cause less nitric acid to be produced in the equilibrium mixture
D. Cause more oxygen to be produced in the equilibrium

14. The I.U.PA.C name for the compound, CH_3-$C(CH_3)Cl$-CH_2-CH_3 is
A. 2-cloro-isopentane
B. 1-chloro-2-ethylpentane
C. 2-chloro-2-methylbutane
D. 1-chloro-2-ethylpropane

15. In the chemical reaction, $W+X \leftrightarrow Y+Z$, more of Z is formed
A. If the concentration of X is reduced
B. If Y is continuously removed from the reaction mixture If the concentration of Y is reduced
C. If the concentration of X is kept constant
D. If the concentration of W is reduced

16. Which of the following statement is correct during the electrolysis of a caustic soda solution using platinum electrodes?
A. Oxygen gas is given off at the cathode
B. Hydrogen gas is given off at the anode
C. Sodium metal is deposited at the anode
D. Alkalinity at the cathode increases

17. Which of the following combinations of conditions may increase the rate of a chemical reaction?
A. Decrease in temperature and increase in concentration of the reactants
B. Increase in temperature, addition of a catalyst, and decrease in the surface areas of the reactants
C. Increase in temperature, increase in concentration, addition of catalyst, and increase in the surface area of the reactants
D. Addition of a catalyst and in the absence of light

18. The IUPAC name of CH_3-$CH(CH_3)$-CH_2-CH_3
A. 1-methylpentane
B. 3-methylbuatane
C. 2-methylpentane
D. 2-methylbutane

19. Which of the following is NOT a true statement of the Kinetic theory of gases?
A. The molecules move at random
B. The size of molecules is negligible as compared with the volume of gas
C. The molecular collisions are perfectly elastic
D. Every molecule has the same kinetic energy at a particular temperature

20. 5 cm^3 of a saturated solution of sodium chloride at 30°C gave on careful evaporation, 1.95 g of solid salt. The solubility of sodium chloride at 30°C is (Na=23, Cl=35.5).
A. 5.00 mole dm^{-3}
B. 5.67 mole dm^{-3}
C. 6.00 mole dm^{-3}
D. 6.67 mole gm^{-3}

21. The oxidation state of chlorine in potassium chlorate is
A. +1
B. +2
C. +3
D. +5

22. Which of the following cannot displace hydrogen from water or steam?
A. Copper
B. Calcium
C. Iron
D. Magnesium

23. The IUPAC names of the compounds CH_3COOH and $CH_2=CH_2$ are respectively
A. Acetic acid and ethane
B. Ethanoic acid and ethane
C. Methanoic acid and ethylene
D. Ethanol and ethylene

24. Consider the following exothermic reaction, $2S(s)+O_2(g) \leftrightarrow 2SO_2(g)$. If the temperature of the reaction is reduced from 800°C to 500°C, and no other change takes place, then
A. The reaction rate increases
B. Concentration of SO_2 decreases
C. Concentration of SO_2 increases
D. SO_2 gas becomes unreactive

25. The oxidation state of manganese in potassium permanganate is
A. +7
B. +5
C. +3
D. +2

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26. The reaction of zinc with copper (II) ions in aqueous solution can be represented as follows: $Cu^{2+}(aq)+Zn(s)\leftrightarrow Cu(s)+Zn^{2+}(aq)$. Which of the following is the most complete description of this reaction?
A. Copper (II) ions are being reduced
B. Zinc is being oxidized
C. Copper (II) ion and zinc are being reduced
D. Copper (II) ions are being reduced and zinc oxidized

27. The following reactions are stages in important industrial processes:
I. $N_2(g)+3H_2(g)\leftrightarrow 2NH_3(g)$ ΔH is negative
II. $2SO_2(g)+O_2(g)\leftrightarrow 2SO_2(g)$ ΔH is negative
III. $N_2(g)+O_2(g)\leftrightarrow 2NO(g)$ ΔH is positive.
Which of the above forward reactions are favored by (i) a decrease in the concentration of the pressure and (ii) an increase in temperature?
A. I
B. II
C. III
D. I and II

28. 0.1 Faraday of electricity was passed through a solution of copper (II) tetraoxosulfate (VI). The maximum weight of copper deposited on the cathode would be
A. 64.0 g
B. 32.0 g
C. 6.4 g
D. 3.2 g

29. In the redox reaction $2Fe^{2+}+Cl_2\rightarrow 2Fe^{3+}+2Cl^-$
A. Cl_2 is reduced because it has lost electrons
B. Cl_2 is reduced because its molecules are changed to two ions
C. Cl_2 is reduced because its oxidation number has decreased
D. Fe^{2+} is reduced because it has lost electrons

30. The reaction $3C(s)+2Fe_2O_3(s)=4Fe(s)+3CO_2(g)$; $\Delta H=46.0$ kJ is
A. adiabatic
B. isobaric
C. endothermic
D. isothermic

MARKING MEMORANDUM FOR CAT

1. A	2. B	3. B	4. A	5. D	6. C	7. D	8. D	9. B	10. C
11. A	12. C	13. A	14. C	15. B	16. D	17. C	18. C	19. D	20. D
21. D	22. A	23. B	24. C	25. A	26. D	27. C	28. D	29. C	30. C