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EFFECTS OF INQUIRY-BASED CHEMISTRY EXPERIMENTATION ON STUDENTS' ATTITUDES TOWARDS THE TEACHING AND LEARNING OF CHEMISTRY

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Abstract. *Students' attitude towards a subject is a key indicator of academic performance, therefore its enhancement is imperative for academic success. A sample of 328 grade eleven students was selected using cluster random sampling. Two different study groups; the experimental and control groups, were composed and exposed to the guided inquiry and demonstration methods of teaching chemistry experiments respectively. The Non-equivalent control group research design was employed with instruction lasting six weeks. Data on pre-test and post-test attitudes were collected using a 25-item attitude towards teaching and learning chemistry through experiment survey. Comparisons of mean attitude scores were made between the experimental and control groups, and between the pre-test and post-test for each group. The Mann-Whitney U test analyses indicated a higher mean attitude score for the control group. However, the difference in the mean scores was not statistically significant. The Wilcoxon Signed-Rank test analyses indicated statistically significant differences between the pre-test and post-test attitude mean scores for both independent groups. These outcomes show that both methods of teaching chemistry through experiments enhance students' attitudes to essentially the same extent. These findings imply that Liberian teachers can enhance students' attitudes through demonstrations.*

Keywords: *chemistry experiments, demonstration, guided inquiry, non-equivalent control group, students' attitude*

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Introduction

The attitudes of upper secondary school students towards science are fast becoming a growing concern to science educators. Empirical evidence indicates that there is a gradual dampening of learners' interest in chemistry due to wariness (McClary & Bretz, 2012; Potvin & Hasni, 2014). Said et al. (2016) have explained that this wariness can be due to the more abstract nature of the concepts in upper secondary school curriculums compared to the lower secondary schools, where objects discussed are easily seen. This loss of interest is reflected in the steady decline in the number of students opting to pursue studies in chemistry and other science disciplines (Halim et al., 2018; UNESCO, 2015).

The world may now be faced with an imminent threat of a reduction in the supply of science and technology professionals (Galama & Hosek, 2008), with grave implications for national and global scientific innovations in diverse areas of development. Thus, the pursuit of developing more positive attitudes towards learning science should be a crucial goal of science education worldwide (Gonzalez, 2016). Little wonder the last decade has witnessed an increase in the advocacy by education reformers for a shift towards a more learner-friendly science classroom environment that will enhance learners' positive attitudes to the subject.

Attitude is a measurable attribute that can be expressed through a continuum of answer alternatives on a survey instrument. It can be expressed through a person's opinions as a like or dislike or as an expression of the extent of like or dislike about an object or a process (Cheung, 2007). Research outcomes have suggested a direct correlation between learners' attitudes towards a subject and the academic performance thereof (Bassey et al., 2009). Also, innovative teaching strategies are linked to students' enthusiasm, motivation, and general attitudinal change towards science subjects in the research literature. If students show an inclination to or liking for a science subject in school, they tend to make an effort to learn and understand the meaning of concepts that they are taught (Akbas &

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Kan, 2006; Brandriet et al., 2011; Freedman, 1997; Salta &Tzougraki, 2004; Weinburgh, 1995). Teachers, therefore, have a responsibility to make lesson presentations appeal to learners; this may arouse their interests and extend their attention spans.

Notwithstanding, the research literature has revealed that students' attitudes towards learning chemistry largely depend on the techniques of teaching in the laboratory even though the relationship between experience in manipulation and skills in the laboratory and learning science has not been established. Lessons loaded with facts unconnected with their origins in science have been cited in the literature as responsible for the decline in learners' attitudes towards the natural sciences (De Vos et al., 2002). Attitudes, being multidimensional, seem to be affected by very many factors, which makes it imperative to explore the construct in different settings and contexts. Although the subject of students' attitudes has been widely discussed in the literature, it continues to attract more attention because it is an important indicator of learning.

A large number of studies of learners' attitudes towards science have been conducted in the past four decades. For instance, Zudonu and Njoku (2018) have used guided inquiry teaching, demonstration, and conventional teaching methods to study their effects on learners' attitudes towards teaching and learning chemistry in Nigeria. They found that the guided discovery led to significantly greater positive attitudes towards the teaching and learning of chemistry. This outcome is corroborated by that of Hoftein et al (2004), and Burnterm et al. (2014), who employed guided inquiry teaching versus structured inquiry methods of teaching experiments in Israel and Thailand respectively. However, in Cheung's (2009) study that involved students in Hong Kong, the students' positive attitudes towards chemistry were only marginal.

Kuo et al (2018) examined the effects of high and low achieving eight grade students' motivation toward science learning in Taiwan. The authors realized a significant jump in the outcome variables for the high achieving learners compared to the low achievers. In addition, while the high achievers made significant gains in their expectancy and learning strategies, low achievers enhanced their confidence, and value for science learning as well as achievement goals, learning strategies, and perception of the learning environment. However, these gains were not associated with statistical significance unlike those of the high achievers. The authors realized that the results could have been different if the intervention lasted longer than 6 weeks. These results indicate that inquiry-based instruction benefits learners differently, based on students' academic levels of achievement.

Research findings have also revealed that learners not only show different levels of attitudes towards chemistry (Hao, 2020) but that these attitudes are affected among other factors by the amount of subject matter content and teachers' approach to teaching (Méndez, 2006). According to Sata and Tzougraki (2004), the attitudes of eleventh-grade students in Greece regarding the difficulty of chemistry lessons were found to be related to concepts, symbols, and problem-solving. The students' attitudes regarding their interest in chemistry were neutral. The positive attitudes were traced to students' ability to relate the knowledge of chemistry to everyday application in real-life situations. However, only 4% of the students indicated motivation to continue studying chemistry for a career. Science and chemistry teachers need to be sufficiently trained in teaching techniques that will positively impact learners' attitudes and raise their levels of motivation to study chemistry.

Under virtual and real laboratory conditions, where high school students were exposed to an expository style of teaching in reaction kinetics, Winkelmann et al. (2014) reported that students' scores in the real and virtual settings were similar in attitudes. Although report writing was challenging for both groups, activity in the physical laboratory took longer to complete. The results showed that the presence of physical materials in science laboratories may not be necessary if virtual simulations of the experiments can be afforded. In another related study using online laboratory resources, open, guided, and structured levels of inquiry were experimented with in practical chemistry lessons in India (Nedungadi et al., 2015). In this study, significantly higher achievements were made in students' motivation and interests in science.

Nevertheless, in a systematic review of the literature that spanned between 2006 and 2016 on the effects of various didactic interventions on students' attitudes towards science, Aguilera and Perales-Palacios (2018) found a strong effect size of 0.54 associated with the context-based teaching, inquiry-based teaching, model-based teaching, project-based learning, and cooperative learning approaches. The authors found that these alternative teaching methods enhanced students' attitudes towards science, more greatly than the demonstration methods of teaching.

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Research Problem

Students' attitudes towards science teaching and learning have been identified as a determinant of their academic performance (Najdi, 2013). Upper-secondary school students' attitudes towards sciences also affect their decisions for enrolment into science disciplines or the choice of a career path (Hofstein & Naaman, 2011). In Liberia, evidence exists of unsatisfactory students' performances in the West African Senior Secondary Certificate Examination (WASSCE), since the end of the fifteen-year civil war, which ended in 2003 (Hinneh & Nenty, 2016; LSF, 2012; MOE, 2016). The West African Examinations Council's (WAEC) Chief Examiners' reports, which do not present statistical measures of candidates' performances, describe students' performance in chemistry variously as "very poor" WAEC (2017 p.65) and "below average" (WAEC, 2016 p.41).

A cumulative effect of the numerous challenges in the Liberian educational system on students' learning outcomes was realized in August 2013, when the Liberian Ministry of Education pronounced that all 25,000 candidates who sat for the University of Liberia's entrance examination failed (Chan et al., 2015; Gberie & Mosley, 2016). This level of challenge in the Liberian system of education probably means that Liberia has the weakest system of education in West Africa (Gberie & Mosley, 2016). The cause(s) for this decline has not yet been empirically studied (MOE, 2016), and there is no research output on upper secondary school students' attitudes towards science teaching and learning as a factor that could contribute to their academic achievements. It, therefore, seems imperative to study upper secondary school students' attitudes towards teaching and learning chemistry through experiments.

Research Focus

The aforementioned challenges in the education system have informed the decision to bridge the gap in knowledge by studying the effects of inquiry-based teaching on students' attitudes towards teaching and learning chemistry through experiments in Liberia. The preference for grade eleven in this study is on the basis that, being in the mid-secondary school, they truly represent the secondary school experience that was cardinal in this study. Besides, the teachers in the eleventh-grade class were more receptive to manipulation of the method of teaching than in the twelfth grade, where teachers were nervous about the completion of the WASSCE syllabus with their students in preparation for the high school leaving regional examinations. At the time of data collection, the tenth-grade students were just a few weeks old in their new classes.

Research Aim and Research Objectives

This research aims to determine the effect of inquiry-based chemistry laboratory teaching methods on the attitudes of grade eleven students towards teaching and learning chemistry. The following specific objectives guided and focused the study.

a) To compare the post-test mean scores of the experimental and control groups on the Attitudes towards the Teaching and Learning of Chemistry through Experiments (ATLCE).
b) To compare the experimental group's pre-test and post-test mean scores of the Attitudes towards Teaching and Learning Chemistry through Experiments (ATLCE).
c) To compare the control group's pre-test and post-test mean scores of the Attitudes towards Teaching and Learning Chemistry through Experiments (ATLCE).

These objectives lead to the following research questions

1. How do the experimental and control groups compare on attitudes toward teaching and learning chemistry?
2. How do the attitudes toward teaching and learning chemistry pre-test and post-test mean scores compare in the experimental group?
3. How do the attitudes toward teaching and learning chemistry pre-test and post-test mean scores compare in the control group?

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Research Methodology

General Background

The Non-equivalent Control Group Design, illustrated in Table 1 was used. This design is a form of the Quasi-experimental Design, which allows non-random assignment of subjects to study groups. A research permit to conduct a study in Bong County was granted by the Liberian Ministry of Education. Thereafter, a preliminary visitation of schools was made to acquaint the school's administrators with the research team (researcher and two research assistants) for subsequent interactions, and to make an assessment of the availability and ideality of the schools' facilities for the study, since it was laboratory-based. Thereafter, separate teacher training workshops were conducted for the Inquiry and demonstration methods teachers. This was followed by a pilot test of the instrument, and subsequent administration of the pre-test to experimental and control groups, which was done concurrently. Teaching lasted six weeks after the pre-test and was followed by the concurrent administration of the post-test in the seventh week.

Table 1
Non-equivalent Control Group Design

Group	Pre-test	Intervention (6 weeks)	Post-test (7th week)
Experimental	ATLCE	Inquiry-based experimentation	ATLCE
Control	ATLCE	Traditional demonstration	ATLCE

Study Participants

12 schools from a population of 30 upper secondary schools in Bong County were initially selected purposively based on the ideality and readiness for the experimentations. Therefore, the initial 12 schools had either the space or the materials needed for these experiments. Thereafter, using the Lottery method, the names of four schools were drawn to constitute the experimental group, followed by the second draw of a set of four schools to constitute the control group. A sample of 328 (170 males and 158 females) eleventh-grade students was drawn from a population of 1754. These students, whose average age was 17, represented those who are being taught using a newly implemented competency-based curriculum that came into effect in 2018. This sample size is considered statistically valid by the Morgan and Krajcik's (1970) Table of Required Sample Sizes calculated at a 95% confidence limit and .05 margin of error. All the grade eleven students of the selected eight upper secondary schools constituted the sample. Participating teachers and students signed informed consent before intervention.

Instrument and Procedures

The attitude towards teaching and learning chemistry through experimentation (ATLCE), adapted from Cheung (2009), comprised 25 items. It consisted of five subscales: students' motivation to learn chemistry by experimentation, students' preferences in chemistry experimentation, students' behavior in chemistry experimentation class, and students' anxiety in chemistry experimentation. Validities of the construct and content were determined by testing and evaluation professionals at the Cuttington University School of Graduate and Professional Studies in Liberia. The reliability and stability of the ATLCE were determined through the Cronbach Alpha coefficient computation in SPSS version 26.0. The value of 0.84 obtained indicated acceptable reliability (Fraenkel et al., 2012). Pre-tests and post-tests were administered to all sampled students concurrently under similar testing conditions.

The attitude surveys were administered to ascertain participants' attitudes before the intervention. Thereafter, in the intervention, the inquiry-based method of teaching for the experimental group on one hand, and the demonstration method for the control group, on the other hand, were implemented simultaneously. Three educational contact hours per week were maintained throughout for both groups. There were debriefing sessions with the inquiry-based methods teachers at the end of every week to allow the teachers to share their experiences

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in the intervention. Professional advice was given to the teachers on areas for improvement. This enhanced the teachers' experiences and the quality of lessons subsequently. At the closure of teaching, post-tests, which constituted reshuffled pre-test attitude subscales were administered to both groups of students. This partly helped to minimize threats to internal validity due to pre-test sensitization. Consistency in the instrument, the scorers, the test administrators, and the test administration procedures were strictly observed.

Guided Inquiry Lesson

The experimental and control groups were taught the same topic, Solutions and Solubility, from the eleventh-grade chemistry national curriculum. The only difference in the intervention between the two groups was the teaching methods. The inquiry lesson was characterized by the following teaching practices.

1. Students worked in small cooperative groups on the experiments
2. Students designed experiments and used a list of materials that were provided for the investigation.
3. Teachers stepped in to offer timely guidance
4. Teachers responded to questions with leading questions
5. Teachers allowed wait time, so students could process the information before voicing out the answer to a question.
6. Teachers circulated among the working groups to offer help

Therefore, it differed from the demonstration method of teaching, in which students merely watched the teacher do all the manipulation of the apparatus and ideas. Following are descriptions of the experiments that were conducted. Students' activity worksheets are found in Appendix A.

The Guided Inquiry Experimental Procedure

Every activity started with the teacher asking brainstorming questions to identify and determine learners' knowledge gaps and misunderstandings of the solutions and solubility. Therefore, using carefully crafted questions, the teacher elicited students' previous knowledge and understanding of the *Solutions and solubility* concept. It also served to reveal misconceptions. Students were instructed to ask scientific questions that would be answered by experimentation, design experiments diagrammatically in small cooperative groups, and follow the designs to experiment, analyze and discuss the results with peers in these groups, and in the larger group, with appropriate teacher guidance. The students' activities and cooperative group worksheets are presented in Appendices A and B respectively.

Data Analysis

Aggregated item scores were fed into Microsoft Excel and later copied into the Statistical Package for Social science Statistics (SPSS) version 26.0 to test for normality of the distributions of the scores. The outcome of this test determined the non-suitability of the use of parametric statistics for analysis, since the Shapiro-Wilks statistic is <.05. This implied that the test scores deviated from a normal distribution. Therefore, the Mann-Whitney *U* test, known to be a non-parametric equivalence of the independent samples *t*-test was used to compare the mean ranks of the experimental and control groups. Similarly, the Wilcoxon Signed-Rank test, the non-parametric equivalence of related (dependent) samples *t*-test was used to compare the mean ranks of the pre-test and post-test scores for each group, and to determine whether there were any significant differences between the groups' attitude scores. Effect sizes were calculated with the aid of an online effect size calculator using the formula;

Cohen's d = (M2 - M1) ⁄ SD (pooled)

SD (pooled) = √ ((SD12 + SD22) ⁄ 2)

Research Results

Following are the results of the statistical analysis conducted in this study, organized in tables.

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Table 2
Results of Descriptive Statistics of Study Participants

	Groups	*N*	*M*	*SD*	*Min*	*Max*
Post-test	Experimental	163	85.01	9.62	64.00	114.00
	Control	165	87.10	12.30	52.00	115.00

Table 2 shows a difference of approximately 2 points in the mean attitudes scores between the experimental and control groups. Also, a difference of approximately 2.5 was observed in the standard deviations between the two groups. This implies that there is only a slight variation in the individual attitude scores for both groups. Although the minimum scores are at a relatively larger variance, the maximum scores for both groups are also identical.

Table 3
Results of Comparison between the Experimental and Control Groups' ATLCE Post-test Scores

	Mann-Whitney U test			Test Statistic		
Group	*N*	Sum of Ranks	Mean Ranks	*U*	*t*	*p*
Experimental	163	26554.50	162.91	13188.50	26554.50	.763
Control	165	27401.50	166.07			
Total	328					

Considering the ATLCE scores in Table 3, the mean rank of 166.07 for the control group is higher than the experimental group (162.91). Also, a Mann-Whitney *U* test for significance indicated a $p > .05$, implying that the difference in the mean ranks is statistically insignificant at a .05 level of significance.

Table 4
Results of Descriptive Statistics for the Experimental Group's Pre-test and Post-test Scores

Group	*N*	*M*	*SD*	*Min*	*Max*
Pre-test	170	80.94	15.38	35.00	120.00
Post-test	163	86.34	11.26	60.00	115.00

Examination of Table 4 shows a higher post-test mean score than pre-test for the experimental group by a difference of 5.51 points. However, the standard deviation is higher for the pre-test scores than for the post-test one by 4.12 points. This means that the scores were more spread away from the mean at the pre-test than at the post-test. Also, although there is a relatively large difference between the minimum scores, the maximum scores were comparable. The Wilcoxon signed-rank test results shown in Table 5 indicate a higher positive mean rank than that for the post-test. The difference between the mean ranks of pre-test and post-test scores was indicated to be statistically significant by an indication of $p <. 05$.

Table 5
Wilcoxon Signed Rank Test Results for Comparing the Experimental ATLCE Group's Pre-test and Post-test Mean Scores

		N	Sum of Ranks	Mean Ranks	*p*
Post-test-pre-test	Negative Ranks	59	4104.00	69.56	.0001
	Positive Ranks	97	8142.00	83.94	
	Ties	7			
	Total	175			

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Table 5 shows a higher positive mean rank than negative rank. This means that the attitude post-test mean score for the experimental group was higher than that for the pre-test. Also, the difference between the mean ranks at an $\alpha = .05$ level of significance is indicated to be significant, by an indication of a $p < .05$.

Table 6
Results of Descriptive Statistics of the Control Group's Pre-test and Post-test Scores

Group	*N*	*M*	*SD*	*Min*	*Max*
Pre-test	165	85.68	12.27	53.00	115.00
Post-test	165	87.10	12.30	52.00	115.00

Table 6 shows a higher post-test attitude mean score than the pre-test. Also, the standard deviations of the pre-test and post-test scores are comparable. Besides, the minimum and maximum scores for pre-test and post-test are similar. The scores for the variables are comparable.

Table 7
Results of Comparison between the Experimental and Control groups' ATLCE Scores

		Wilcoxon Signed-Rank Test			Test Statistic
		N	Sum of Ranks	Mean Ranks	*p*
Post-test-pre-test	Negative Ranks	29	1103.00	69.56	.0001
	Positive Ranks	79	4783.00	83.94	
	Ties	57			
	Total	165			

Table 7 shows a higher positive mean rank than a negative rank, this shows that the post-test mean score was higher than that for the pre-test. Also, the difference between the mean scores is statistically significant at $\alpha = .05$.

Table 8
Effect Size of the Differences between Groups

Study group	*d*	*Δ*	*g*
Experimental group/control group	0.19	0.22	0.19
Experimental group – ATLCE (Pre-test/post-test)	0.40	0.35	0.40
Control group –ATLCE (Pre-test/post-test)	0.12	0.12	0.12

Table 8 indicates the effect size of the differences between the mean scores of the experimental and control groups, and that between the pre-test and post-test mean scores of both experimental and control groups. These results show that the effect sizes range between 0.12 and 0.40, which means that the effect sizes are very large (Cohen, 1988). Accordingly, these results indicate that the differences between the experimental and control groups, and between the pre-test and post-test mean scores for the experimental and control groups have considerably important practical relevance.

Discussion

A higher standard deviation of the pre-test than post-test scores of the experimental group indicates that students were more greatly diverse in their opinion before instruction but tended to agree more among themselves after the guided inquiry method of teaching. This implies students' significant change of opinion in the end, which

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can reasonably be attributed to the method of instruction. The range of pre-test scores (85) compared with that of the post-test (55) confirms that the students tended to agree more after teaching. A similar pattern of observation in the control group shows that the two groups may be similar in the variables of interest in this study.

Also, the wider variation of the control group's scores than that of the experimental group is a demonstration of a greater consensus among the experimental group concerning their opinion on the teaching and learning process. Nearly identical mean scores suggest that the two groups essentially converge in their expressed attitudes towards teaching and learning chemistry by experiments, despite the difference in the methods of teaching. The greater attitude demonstrated by the control group while unexpected, may not be unconnected with the challenges that are usually associated with inquiry-based teaching, where the task to construct scientific knowledge, and cultivate students' critical thinking is shifted more towards learners than their teachers. While experimentation is reputed for enhancing students' motivation and general attitudes towards science, it is reasonable to think that students' liking for the inquiry-based method of teaching may wane due to the rigorous mental exercise in figuring out experimental designs, and the right terminologies for explaining results. However, this effect may not have been of great relevance, since the difference in the attitudinal mean scores between the groups is statistically insignificant. Thus, it seems experimentation, whether conducted using an inquiry approach or not, will enhance students' attitudes. This outcome portrays the guided inquiry approach of science teaching as being essentially equal in potential to influence students' attitudes. Given that the majority of these students are not exposed to experiments in Bong County, the similarity in outcomes of attitudes may be attributed to the fact that experiments just excite and appeal to students, irrespective of the level of students' engagement, owing to the long anticipation of it. All they seem to appreciate is the experience of witnessing an experiment; either demonstrated by themselves or seeing it being demonstrated.

A better indicator of the effectiveness of the teaching methods may be the difference between the pre-test and post-test mean scores for each group. In this regard, a meaningful gain for both groups was found, which supports the earlier assertion that both methods of instruction tend to improve students' attitudes toward the teaching and learning of chemistry through experiments. Beyond the statistical interpretation of the difference between the pre-test and post-test mean scores, these differences also have practical relevance by indication of their effect sizes. The significance of the effect of both teaching approaches in this study is therefore both statistical and practical, and hence can be used to inform educational reform in Liberian science education programs.

Although the outcome of this study is in agreement with many others in the research literature, which claim the significant effect of both inquiry and traditional experimentation methods of teaching on learners' attitudes (Nedungadiet al, 2015; Zudonu & Njoku, 2018), it is also in disagreement with the findings of many quasi-experimental studies, which claim significant differences between inquiry and traditional teaching methods (Aguilera & Perales-Palacios, 2018; Kuo et al., 2018; Zudonu & Njoku, 2018). The results in this study imply that chemistry teachers in Bong County need to expose their students to experiments of some sort, to arouse their students' interest in, and liking for the subject. This assertion is predicated on the claim that students' interest in a subject is positively correlated with their academic performance (Kuo et al., 2018).

Conclusions and Implications

This study compares the effect of the guided inquiry and demonstration methods of teaching chemistry experiments on grade eleven learners' attitudes toward the teaching and learning of chemistry in Bong County, Liberia. Using the Non-equivalent control group design, this study demonstrates that after six weeks of teaching, the guided inquiry and demonstration approaches improve learners' attitudes towards the teaching and learning of chemistry through experiments to a comparable extent. The outcome of this study proves a point that practitioners and researchers should not give up on the demonstration of experiments in chemistry. It may also be reasonably inferred that the use of a blend of both approaches to instruction may enrich the practical science experience in upper secondary school by capitalizing on the strengths of each approach. The frequent and widespread use of experimentation in science classrooms stands to raise students' motivation and liking for the science disciplines and improve learning outcomes. Science teachers' main energies should be directed towards arousing students' interest in science through purposeful laboratory activities.

The regaining of students' interest in science will hence reduce the imminent threat of a reduction in science and technology professionals, whose contributions to national and global development cannot be underestimated. The outcome of this study adds to the growing amount of evidence of the effect of teaching approaches on learn-

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ers' attitudes towards science from the Liberian context. It, therefore, contributes to the global debate around the influence of inquiry-based instruction. These findings imply that teachers in Liberia and other countries that have resource-challenged science programs could effectively garner students' attitudes through traditional demonstration. However, one limitation of the study is that it did not relate students' attitudes to students' academic performances in chemistry. Further research needs to compare the effects of the comparison among the prevalent expository, demonstration, and inquiry-based teaching approaches on students' attitudes in Liberia.

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Declaration of Interest

The authors declare no competing interest.

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Appendix A: Experimental Activities

Activity 1: The effect of particle size of a solid on its solubility in a liquid
Students were provided with the following
4 cubes of sugar
6 test tubes
1 Wash bottles containing water
1 stopwatch
In this activity, students in their groups were given the following instruction.
In your respective group and using the materials provided,
1. Design an experimental procedure to determine the effect of the molecular size of sugar (solute) on its solubility in water (solvent).
2. Carry out the investigation, make keen observations and record your observations on a sheet. Data should include
a. time taken for the sugar samples to dissolve,
b. temperatures of the water
3. Note your observation
4. What is the practical everyday application of this investigation?

Activity 2: The effect of temperature on the solubility of a solid in a liquid
Students were provided with the following
4 Sugar cubes
1 Thermometer
3 beakers holding water at 3 different temperatures
6 Test tubes
In your respective group and using the materials provided,
1. Design an experimental procedure to determine the effect of temperature on the solubility of sugar (solute) in water (solvent).
2. Carry out the investigation, make keen observations and record your observations on a sheet. Data should include
a. the temperature of the water in the beakers just before pouring it.
a. time taken for the sugar samples to dissolve,
c. date and time, and
d. names of group members.
3. Note your observation
4. What is the practical everyday application of this investigation?

Activity 3: The effects of intermolecular forces on miscibility and solubility of one liquid in another
The materials provided were as follows;
6 test tubes
5 beakers, one each containing water, kerosene and vegetable oil, vinegar, green alcohol
3 test tube holders
In your respective group and using the one set of materials at a time,
1. Design an experimental procedure to determine the effect of intermolecular forces on the solubility of two liquids.
2. Carry out the investigation, make keen observations and record your observations on the activity sheet. Data should include responses to the following
a. which two liquids are miscible?
b. why are the two liquids miscible?
c. which liquids are immiscible
3. Note your observation
4. What is the practical everyday application of this investigation?

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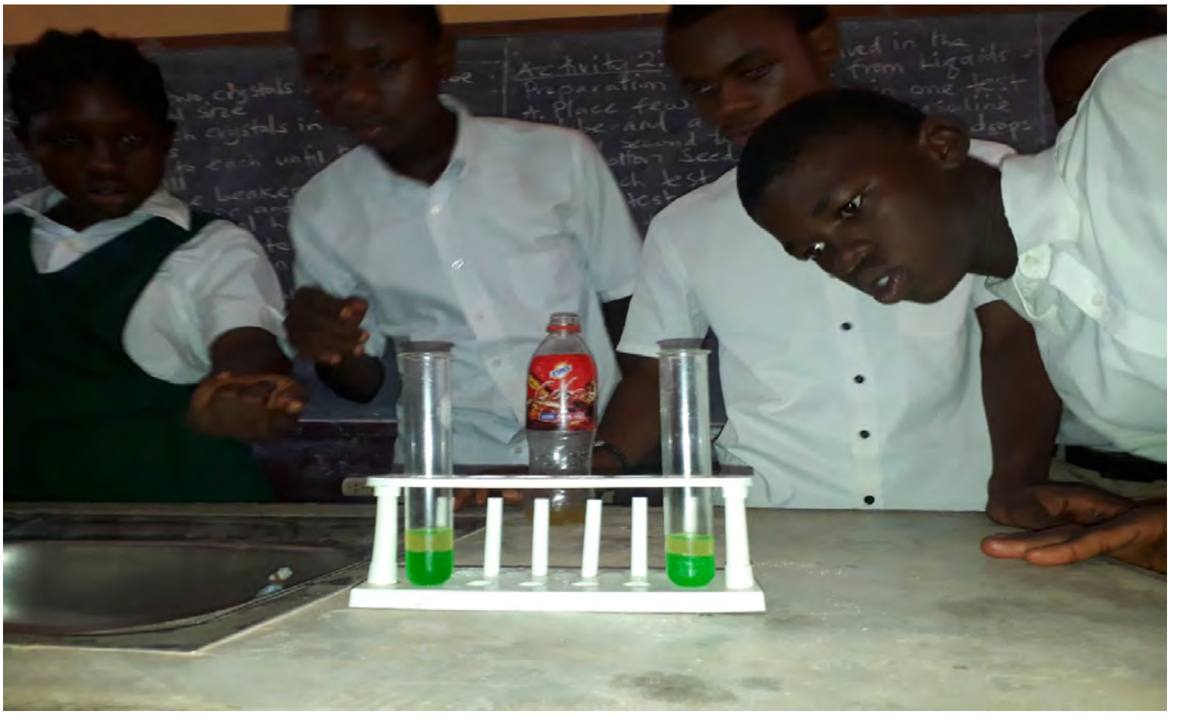
Appendix A: investigating the effect of intermolecular forces, and density on the solubility of liquids



Title of Activity 4: distinguishing between Solutions and Suspensions

The students were provided with the following
4 cubes of sugar
2 test tubes
1 Wash bottles containing water
Powdered chalk
Students in their groups were instructed for activity four.
In your respective group and using the materials provided, perform an experiment that shows the differences between a solution and a suspension.
1. Carry out the investigation, make keen observations and record your observations on a sheet. Data should include responses to the following
a. Which of the two leaves a residue on a filter paper after filtration?
b. Which one can allow particles to settle after putting them aside in a test tube for 10 minutes?
c. A test tube containing one of them can be used if inclined to read letters in a book. Which one?
3. Summarize the main differences between suspension and solution in your conclusion?
4. What is the practical everyday application of solutions and suspensions?

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Appendix B: Students' Activity worksheets

Chemistry Activity Work Sheet for Activity 1

Date: March 12, 2021

Activity: The effect of ~~par~~ particle size of a solid on its solubility in water

Scientific question: What is the effect of particle size of a solid on its rate of dissolution in water.

Experimental Design:

(1) 

10.0g of lumps, granular and powdered Sugar were put in 3 test tubes AB and C

(2) 

50mL of water at 29.8°C added to testubes A, B and C as the stop watch was made to read

3) 

The sugar samples dissolved at different rates. The times for dissolution were recorded.

Time ~~Observation:~~ Data

Without shaking

Test tube	Temp of water (°C)	Mass of sugar(g)	Volof H_2O added(mL)	Time to dissolve (s)
A (lump)	~~(lump)~~ 29.8	~~29.8~~ 10.0	~~10.0~~ 50.0	12.0
B(grain)	29.8	10.0	50.0	8.0
C(powder)	29.8	10.0	50.0	6.0

observation ~~Explanation and analysis:~~ when the same amount of water (50mL) at a fixed temp was added to equal amounts of the lump grannlar and Powdered sugar, in 3 different test tubes, the took different times for the 3 samples to dissolve because they exposed different surface areas to the water that did the dissolving. The powdered sugar molecules exposed the greatest surface area and hence dissolved fastest where as the lumps, which exposed the least surface area dissolved slowest.

Conclusion: The smaller the particle size, the greater the surface area, and the faster the rate of dissolution in water.

Practical everyday Application: (1) Food particles are reduced in sizes by chewing for faster digestion in the stomach. (2) most medicines require chewing so that they can be easily and quickly dissolved in the stomach fluid for quicker action.

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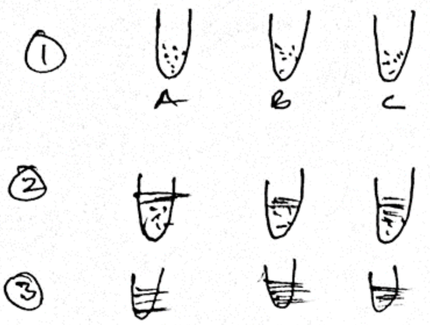
Chemistry Activity Work Sheet for Activity 2

Date: March 5, 2021

Activity: Effect of temperature on solubility of a solid in water

Scientific question: What is the effect of temperature on the solubility of a solid in water

Experimental Design:



10.0g of granular sugar was placed in 3 different test tubes

50 mL of water at 29.5, 53.2 and 85.7°C were added to ~~test~~ sugar crystals in test tubes A, B and C respectively.

The stopwatch was used to determine the time taken by each of the samples to dissolve.

Data ~~Observation~~:

Test tube	Temp of water (^{0}C)	Mass of sugar(g)	Volof H_2O added(mL)	Time to dissolve (s)
A (~~lump~~)	29.5	10.0	50.0	8.0
B(~~grain~~)	53.2	10.0	50.0	4.0
C(~~powder~~)	85.7	10.0	50.0	2.0

Observation ~~Explanation~~ and analysis: When 50mL of water at different temperatures were added the same amount of sugar crystals in the 3 test tubes, it was observed that the sugar crystals dissolved at different rates. The sugar crystal on which the hottest water was added dissolved fastest, ~~followed by~~ whereas the sugar crystal on which the coldest water was added dissolved slowest.

Conclusion: higher temperature leads to faster dissolution; the higher the temperature the faster the rate of dissolution of a solid in water.

Practical everyday Application: 1 Tea is mixed with ~~hot~~ water to dissolve the milk and sugar quickly

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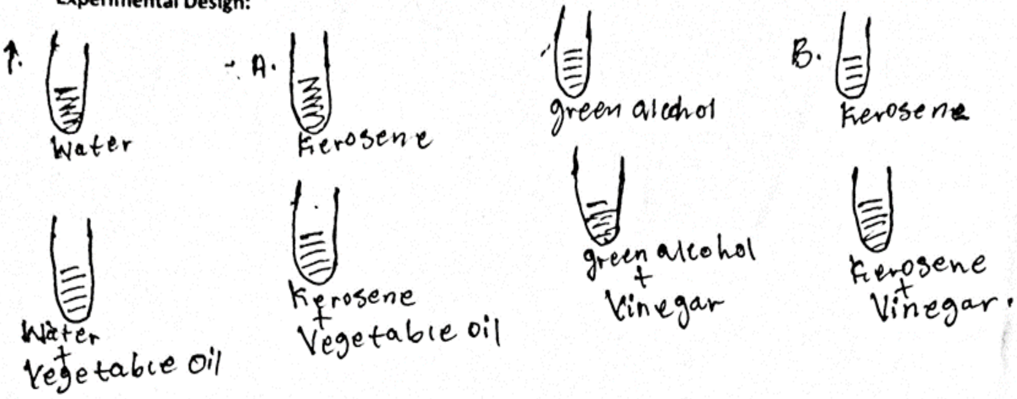
Chemistry Activity Work Sheet for Activity 3

Date: 19 March 2021

Activity: Effect of Intermolecular forces on miscibility and solubility liquids

Scientific question: What is the effect of Intermolecular forces on miscibility and solubility liquids

Experimental Design:



Data
~~**Observation**~~**: Write your observation in the table below. Indicate "M" if two liquids are miscible. Indicate "I" if the two liquids are Immiscible**

	Water	Vegetable oil	Kerosene	Green Alcohol	Vinegar
Water	x	I	I	M	M
Vegetable oil	I	x	M	I	I
Kerosene	I	M	x	I	I
Green Alcohol	M	I	I	x	M
Vinegar	M	I	I	M	x

Observation and analysis: ~~**Explanation**~~ **and analysis:** Two types of liquids were observed, and one type includes water, vinegar, green alcohol. The second type includes vegetable oil, and kerosene. Liquids of the same type are miscibl but are immiscible in the other type.

Conclusion: Liquids of the same type have intermolecular forces common to them that makes them disolve in each other, but not in liquids of a different type, which have different intermolecular forces.

Practical everyday Application: Painters use kerosene to dissolve and remove the paints from their hands and walls.

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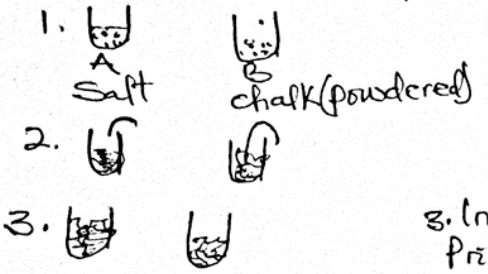
Chemistry Activity Work Sheet for Activity 4

Date: 03/26/2021

Activity: Difference between Solutions and Suspensions

Scientific question: What are the difference between Solutions and Suspensions?

Experimental Design:



1. Put 10.0g of Sugar in one test tube (A) and 10.0g of powdered chalk in a 2nd test tube (B).
2. Add 50mL of water at room temperature to both test tubes and shake
3. Incline the test tubes and try to read a printed matter through the test tube
4. leave to stand on a test tube rack for 10minutes
5. Filter the contents of each test tube.

Data
~~**Observation:**~~

Sample	Mass of sugar(g)	Vol of water added(mL)	observation after 10 min of settling	Observation after filtering	Observation of attempt to read a print
Sugar + water (A)	10.0	50.0	Clear Solution	No Sediment	Print could be seen and read
Chalk+ water(B)	10.0	50.0	Particles settle at the bottom of the test tube	Sediments left on the Filter paper	Print could not be seen or read

Observation
~~**Explanation**~~ **and analysis:** It was observed that sample A did not settle any particles at the bottom of the test tube upon shaking and standing for 10minutes. No sediments are left on the filter paper after filtration. Also, a printed matter was read through a solution in test tube A. However, For test tube B, the particles settled at the bottom of the test tube, and after filtration, Sediments left on the filter paper. Also, the printed matter through the content of test tube B. Could not be read

Conclusion: While in Suspensions, particles settle at the bottom, sediments are left on the filter paper after filtration and printed matter ~~Could~~ cannot be read through it, a solution does not produce particles at the bottom, no sediments are left on the filter paper during filtration and a printed matter can be read through it.

Practical everyday Application:

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