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Senior high school chemistry students' performance in IUPAC nomenclature of organic compounds

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Abstract

This paper reports on a study that investigated the performance of Chemistry students in IUPAC nomenclature of organic compounds from two school types. The study focused on senior high school (SHS) students' performance in IUPAC nomenclature of organic compounds. A cross-sectional survey provided the study with quantitative data. Stratified random sampling procedure was used to select 245 students from four out of 18 schools who offer elective science for 2010/2011 academic year in the Kumasi Metropolis of Ghana. An achievement test of 30 items was used for collection of the quantitative data. The results from the study showed that the SHS Chemistry students had showed low performance in IUPAC nomenclature of organic compounds. The independent-samples t-test analyses of the results show that there were no statistical significant differences between the scores of students from well-endowed and less-endowed schools on both naming and writing structural formulae of organic compounds using the IUPAC nomenclature system. It is therefore recommended that any assistant provided by the Ministry of Education and the Ghana Education Service to help students to improve on their performance in IUPAC nomenclature of organic compounds should be independent of the school-type.

Keywords: IUPAC Nomenclature, Organic Compounds, Structural Formulae.

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1. Introduction

According to Solomons and Fryhle (2008), after the nineteenth century, there emerged a formal system for naming organic compounds. It must be noted that many organic compounds were discovered prior to the nineteenth century and the names of those compounds were based on the respective sources of the compounds. For example, a carbon compound from vinegar was named as acetic acid, which takes its name from the Latin word for vinegar called acetum. Also, formic acid was obtained from some ants, which in Latin word are referred to as formicae and thereby the name, formic acid. Ethanol (ethyl alcohol) was once referred to as grain alcohol as it was obtained from fermentation of grains. These old names (that is acetic acid, formic acid, grain alcohol, and the like) are currently referred to as "common" or "trivial" names (Solomons & Fryhle, 2008). Gillette (2004) pointed out that some of the carbon compounds (organic compounds) were also given trivial names by the scientists who were the first to have discovered them, for example, acetylene (C_2H_2), benezene (C_6H_6), and acetone (C_3H_6O). According to Gillette (2004), some organic compounds used to have more than one trivial name and at times brought confusion among chemists and biochemists during communication. Chemists and biochemists from most part of the world today still use the trivial names.

The International Union of Pure and Applied Chemistry (IUPAC) came out with the formal system of naming organic compounds and thereby the name, IUPAC nomendature (Fessenden & Fessenden, 1990; Gillette, 2004; Heger, 2003; Solomons & Fryhle, 2008). From Woodcock (1996), there are other systematic nomenclature systems that came prior to the IUPAC system and that IUPAC names may not be the most commonly used one. According to Fessenden and Fessenden (1990), "the IUPAC system of nomenclature is based upon the idea that the structure of an organic compound can be used to derive its name and, in turn that a unique structure can be drawn for each name" (p. 92). The IUPAC system has been in use since 1892 and has been revised many times to update it. The current IUPAC rules of nomenclature were updated in 1993. From Solomons and Fryhle (2008), "each different compound should have an unambiguous name" (p. 134). This serves as the basic principle of the IUPAC system where no organic compound will have more than one name. Any chemist or biochemist who is used to the rules of IUPAC system can write the correct name or structural formula of any organic compound that comes on his or her way. Klinger, Kolarik, Fluck, Hofmann-Apitus and Friedrich, (2008) noted: "trivial names can be searched for with a dictionary-based approach and directly mapped to the corresponding structure at the same time" (p. i268). But IUPAC and IUPAC-like names are identified with respect to the structure of the organic compound (Kolarik *et al*. as cited in Klinger *et al.*, 2008).

The IUPAC system of naming organic compounds is dependent on the functional groups, which is grouping compounds by shared structural features (Gillette, 2004; Woodcock, 1996). For instance, all alkanoic acids and alkanols contain the carboxyl (–COOH) group and hydroxyl (–OH) group respectively bonded to carbon atom. From Skonieczy (2006), preference should always be given to a functional group that has the highest precedence when the organic molecule in question contains more than one functional group. The principal functional group is usually named as the suffix and the others as the prefixes. According to Clark (2000), there are two skills a Chemistry student can develop in using the IUPAC nomenclature system to name organic compounds. These are the:

1. Ability to draw or write the structural formula of an organic compound from its IUPAC name, and
2. Ability to write the IUPAC name of an organic compound from its structural formula.

Clark (2000) has pointed out that the ability of Chemistry students to translate the IUPAC name of an organic compound into its structural formula is the most important and most flexible as compared to the ability of Chemistry students to give the IUPAC name of any given structural formula. In any Chemistry examination, if a student finds it difficult to write a structural formula of any named compound, he or she will find it difficult to understand what

the examiner is looking for. Hence, the performance of such a student is affected on such questions (Clark, 2000).

Woodcock (1996) explained that though almost every organic compound contains carbon and hydrogen atoms, the names of these two elements do not appear directly in the names of the respective compounds. The IUPAC names of organic compounds are influenced partly by the number of carbon atoms in the longest continuous carbon chain (Woodcock, 1996).

In simplest form, there are three parts to each organic molecule. These are a root (parent); which shows the number of carbon atoms in the longest continuous carbon chain, and suffix (ending); which shows the family to which the organic compound belongs. The third part is prefix; which is dependent upon the number, position, and identity of any atoms or groups of atoms that have replaced any hydrogen atom or atoms in the parent compound (Gillette, 2004; Woodcock, 1996). Gillette (2004) stressed that if any Chemistry student is able to learn to apply and interpret these three parts of organic compound names, then he or she will be able to "write the chemical names of organic compounds base on their Lewis structures; and draw the Lewis structures for organic compounds based on their IUPAC names. The same will be true for condensed structural formulae and line-angle drawings" (p. 2).

Gillette (2004) has pointed out that the study of IUPAC nomenclature of hydrocarbons, which are organic compounds containing only carbon and hydrogen atoms, must come first to that of organic compounds containing functional groups. According to Gillette (2004), "once you have mastered the IUPAC nomenclature for the different types of hydrocarbons, you will be able to apply the same basic naming principles to organic compounds containing other functional groups" (p. 1). A look at the 2008 Teaching Syllabus for Chemistry at the SHS level showed that the study of Alkanes, Alkenes, and Alkynes, which are hydrocarbons come before the study of organic compounds with functional groups such as Alkanols, Alkanoic Acids, Amides and Alkyl Alkanoates (Esters) (Ministry of Education, Science, and Sports [MOESS], 2008). This implies that the 2008 Teaching Syllabus for Chemistry agrees to the fact that a good understanding of students in IUPAC nomenclature of hydrocarbons enhances a good understanding of such students in IUPAC nomenclature of organic compounds containing other functional groups.

In Ghana, one of the general aims of Chemistry teaching syllabus is to help Ghanaian Chemistry students from SHS2-4 to appreciate and use the IUPAC system to name chemical compounds (MOESS, 2008). According to MOESS (2008), the IUPAC nomenclature of carbon compounds is introduced at the SHS3 level under section 6 of the Chemistry teaching syllabus, and is to be completed at the same level. The IUPAC nomenclature is studied under areas such as Alkanes, Alkenes, Alkanols, Alkanoic Acids and Alkanoic Acids derivatives (for example, Amides and Esters) (MOESS, 2008). The specific objectives outlined in the Chemistry teaching syllabus are:

A. Describe the nomenclature and isomerism of alkanes, alkenes, and alkynes.

B. Write the names and structures of given alkanols, alkanoic acids, amides and alkyl alkanoates (MOESS, 2008).

The WAEC Chief Examiner of Chemistry at the SHS level in Ghana has repeatedly lamented on the weakness of most students in IUPAC nomenclature of organic compounds (WAEC, 2000-2007; 2010a). In 2001, the Chief Examiner's Report showed that many candidates attempted Question 2 but some candidates could not give the IUPAC names of the compounds. In 2002, according to the Chief Examiner's Report, candidates showed weakness in IUPAC naming of simple organic compounds. For example, candidates could not name C_6H_5Cl as chlorobenzene. In 2004, the Chief Examiner's Report indicated that candidates referred to $CH_3–CH(NH_2)–COOH$ as 2-amidepropanoic acid instead of 2-aminopropanoic acid.

In 2005 and 2010a, according to the Chief Examiner's Reports, candidates could not correctly write the IUPAC names of the structural formulae of some given organic compounds. For example, in 2005, candidates could not write the correct IUPAC names of $HCOOCH_3$, $CH_3CHOHCH_2OH$, and C_6H_5COOH as methyl methanoate, propane-1, 2-diol, and phenylmethanoic acid respectively. In 2006, the Chief Examiner's Report pointed out that

candidates could not give the correct IUPAC names and structure of some organic compounds. From the above revelations of the Chief Examiner's Reports, it is clear that Ghanaian students have been facing a challenge with the IUPAC naming of organic compounds in their Chemistry final examinations conducted by WAEC.

Empirical studies on the use of IUPAC nomenclature system have showed that students had difficulties in the use of the IUPAC nomenclature system (Adu-Gyamfi, Ampiah & Appiah, 2012; Bello, 1988; Hines, 1990; Wu, Krajcik & Soloway, 2001). From Wu et al. (2001), it was identified that students had difficulty in writing formulae of organic compounds. This led to the introduction of eChem by Wu et al. (2001), which assisted the students to overcome their difficulty in writing the structural formulae of compounds such as CH_3CH_2OH. The study conducted by Adu-Gyamfi et al. (2012) has showed that Chemistry students had difficulties in writing structural formulae of Alkanes, Alkenes, Alkanols, Alkanoic acids and Alky alkanoates. The students' difficulties in writing structural formulae of organic compounds stemmed partly from the students' inability to identify the number of carbon atoms in the parent chain, functional, and substituent groups from an IUPAC name. The students also found it difficult to attach the substituent group or the functional group to the correct carbon atom in the parent chain as given by the IUPAC name (Adu-Gyamfi et al., 2012).

A careful look at Hofstein, Bybee and Legro (1992) research work has revealed that the performance of science students depends on several factors of which the school environment and teaching and learning materials and equipment are among. This gives an indication that the type of school attended by a student has as influence on his or her performance on scientific concepts and principles. High schools are classified as well-endowed and less-endowed institutions in most parts of the world. The classification of the schools are informed by the availability of certain facilities such as boarding (hostel) or day facilities, libraries, and science laboratories. The classification is further influenced by other factors such as the high school being single sex or co-educational (mixed) institution and the number of professionally qualified teachers in the school. In Ghana the classification has in one way or the other been influenced by the degree to which these facilities exist (WAEC, 2010b). A school with high percentage of these facilities existing is referred to as an endowed school and a school with a very low percentage of the existence of these facilities is referred to as a less-endowed school. It has been found out that these categories have some influenced on science students' performance in the school sciences. According to Ruby (2006), the implementation of curriculum in the less-endowed schools suffered some setback for lack of common means of implementation. Thus, science content instruction suffers a reduction whenever there is lack of day-to-day lessons, materials, equipment, and teacher understanding of the curriculum. Also, in such less-endowed schools as Ruby (2006) pointed out, science teachers usually use whatever material they may have accessed to regardless of its quality in teaching scientific concepts and principles. Such situations undoubtedly affect the performance of students in the science subjects.

Lankford, Loeb & Wyckoff (2002) asserted that science teachers who teach in the less-endowed schools are inadequately prepared and lack teaching experiences in the science subjects they teach. The less knowledgeable and less experienced science teachers are known to deliver less capable instruction. And this lowers standards and hence, affects the overall performance of science students in science subjects.

A significant proportion of middle school students in high-poverty urban areas in US recorded very low performance in the science (Ruby, 2006). This has been seen as a threat to their success in high school science. Almost all high-poverty urban middle schools in US lack science curricula, science materials and equipment. Such schools also make do with unqualified science teachers, which affect teachers' instruction and the performance of science students in the sciences (Ruby, 2006). The less-endowed schools are used to the use of unqualified science teachers in the sense that they usually lose the highly qualified professionals to the well-endowed schools (Lankford et al., 2002). The US National Assessment of Educational Progress [NAEP] (as cited in Ruby, 2006) survey of US showed that students' performance in science have deteriorated significantly in the inner-city middle schools under conditions such as the use of unqualified science teachers to teach the science subjects.

Having seen the difficulties of students in the use of the IUPAC nomenclature system and that the performance of students in the school sciences could be affected by the school type, it was therefore necessary to investigate the performance of students in IUPAC nomenclature of organic compounds with respect to the school type.

1.1 Purpose of the Study

In this study, the performance of Chemistry students from two school types in IUPAC nomenclature was investigated. This helped to compare the two school types on their mean scores on IUPAC nomenclature of organic compounds. This was done by giving students an achievement test of 30 items. The research question used to guide the study was: what is the difference between the performance of students from well-endowed and less-endowed schools on naming and writing structural formulae of organic compounds by IUPAC nomenclature?

2. Methodology

2.1. Sample

The Chemistry students were selected from four schools. The four schools were classified as well-endowed and less-endowed based on the fact that the Ghana Education Service considers some SHSs as most prestigious and academically competitive, attracting students from all parts of the country whereas others are not (Ampiah, 2007). The classification of the four schools was also based on the grade in science with which the students were admitted into the General Science programme at the SHS level. The well-endowed schools selected only students with grade one in Science into the General Science programme whereas students with grade two or better in Science were selected into the General Science programme for the less-endowed schools. Table 1 shows the number of Chemistry students who were present in their respective schools at the time of the conduction of the study and took part in the study. In all, the sample consisted of 245 SHS4 Chemistry students.

Table 1: Number of Students from the Two School Types who took Part in the Study

School	Type of school	N
A	well-endowed	56
B	well-endowed	92
C	Less-endowed	45
D	Less-endowed	52

2.2. Instrument

The achievement test was in two sections consisting of 30 test items. In section 1, the 20 test items required the students to correctly name some given structural formulae of organic compounds by IUPAC nomenclature. The test items covered Alkane, Alkene, Alkyne, Alkanol, Alkanoic acid, and Alkyl alkanoate areas of organic compounds. Any correctly named structure attracted one mark. The purpose was to find out the performance of Chemistry students on naming structural formulae of organic compounds by IUPAC nomenclature.

In the first part of section 2, the test items required the students to provide condensed and graphical formulae of the five given IUPAC names of organic compounds. These compounds consisted of unbranched and unsubstituted chains of hydrocarbons together with an Alkanol, Alkanoic acid, and Alkyl alkanoate. Any correct condensed or graphical formula provided to each test item carried one mark. The purpose was to find out the performance of Chemistry students on supplying condensed and graphical formulae to a named organic compound by IUPAC nomenclature. In the second part of section 2, the test items required the students to provide the structural formulae of the five given IUPAC names of organic compounds. These compounds

consisted of branched- and substituted-chains of hydrocarbons together with an Alkanol, Alkanoic acid, and Alkyl alkanoate areas of organic compounds. The correct structural formula provided to each test item carried one mark. The purpose was to find out the performance of students on supplying a structural formula to a named organic compound by IUPAC nomenclature.

The achievement test items were constructed by the researchers. In the process of designing the instrument, the test items were compared to standardized questions on IUPAC nomenclature of organic compounds set by the WAEC for the West African Secondary School Certificate Examinations. The purpose of this was to ensure that the instrument was valid. To further ensure the validity, the instrument was showed to two Chemistry teachers from Obuasi Senior High School where it was pilot-tested for an expert judgment on the content. The purpose was for them to determine the validity of the achievement test and offer suggestions.

The instrument was pilot-tested with 10 SHS4 Chemistry students from Obuasi Senior High School in Obuasi Municipality of Ashanti Region. After the pilot test, the test items were subjected to item analysis. This was to facilitate the determination of the difficulty and discrimination indices of the test items, which helped to improve on the internal consistency of the instrument. Hence, test items that were found to be too difficult or too easy were deleted. After the test items that were too difficult or too easy have been deleted, the KR 21 coefficient of reliability was established as 0.8.

2.3. Data Analysis

Percentages, means, and standard deviations were used to answer the general performance aspect of the research question, and the independent-samples t-test was used to test for the difference in performance of Chemistry students from well-endowed and less-endowed schools on naming and writing structural formulae of organic compounds using the IUPAC system.

3. Results

This is seen at two stages. At the first stage, the general performance of students on both naming and writing structural formulae of organic compounds were determined through the scores obtained by the students in the achievement test. The independent-samples t-test analyses on the mean scores of students from both well- and less-endowed schools were presented and discussed at stage two.

3.1. General Performance of Chemistry Students on Naming Organic Compounds by IUPAC Nomenclature

The research question sought to find out students' performance on naming organic compounds using IUPAC nomenclature. To be able to do this, 245 SHS4 Chemistry students were given the structural formulae of 20 organic compounds consisting of Alkanes, Alkenes, Alkynes, Alkanols, Alkanoic acids and Alkyl alkanoates and asked to name them using the IUPAC nomenclature. The correct naming of each organic compound carried one mark and the maximum score on the 20 test items was 20 marks.

The mean of the distribution of the scores on naming organic compounds was 7.3 (SD = 4.2) out of a maximum score of 18. The scores of almost two-thirds of students on naming organic compounds were in the range of 3.1 to 11.5. The large standard deviation of 4.2, which was the measure of the extent of error in the distribution of the scores on naming organic compounds using the IUPAC nomenclature system, could be due to the relatively small total marks for the test. The general performance of students on naming structural formulae of organic compounds was low as only 25.7% of the students scored more than half of the total marks.

3.2. Performance of Students from Well- And Less-Endowed Schools on Naming Organic Compounds

The performance of students from the four schools is presented and discussed. The purpose is to find out whether there was any difference between the students from the individual schools. The percentages of students from each school type who scored more than half the total marks on IUPAC naming of organic compounds are presented in Table 2.

Table 2: Performance of Students from the Two School Types on IUPAC Naming of Organic Compounds

School	Type	N	n	%	M	SD	Max score
A	Well-endowed	56	9	16.1	6.7	3.5	16
B	Well-endowed	92	22	23.9	7.2	4.1	17
C	Less-endowed	45	15	33.3	8.2	4.6	18
D	Less-endowed	52	17	32.7	7.3	4.6	17

Where n is the number of students who scored more than half of the total marks on the test items on naming organic compounds from each school.

From Table 2, for school A, out of 56 students with low mean (M = 6.7, SD = 3.5, Max score = 16), only 16.1% of the students scored more than half of the marks and for school B, out of the 92 students with low mean (M = 7.2, SD = 4.1, Max score = 17), only 23.9% of the students obtained scores which were more than half of the total marks. For the less-endowed schools, out of the 45 students who took part in the study from school C with a low mean (M = 8.2, SD = 4.6, Max score = 18), 33.3% of the students scored more than half the total marks and for school D, out of the 52 students with low mean (M = 7.3, SD = 4.6, Max score = 17), 32.7% of the students scored more than half of the total marks on naming organic compounds using the IUPAC nomenclature system. The findings show that more students from the less-endowed schools C and D attained high scores on IUPAC naming of organic compounds than their counterparts from the well-endowed schools A and B. This could be attributed to the presence of some exceptional students who were found in the less-endowed schools.

The general scores obtained by Chemistry students from well-endowed and less-endowed schools on naming organic compounds are presented in Figure 1.

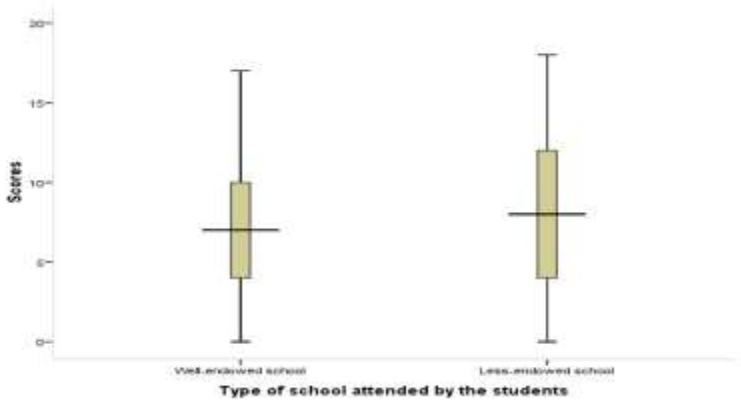

Figure 1. Boxplots of school-type differences in students' scores on IUPAC naming of organic compounds.

The boxplots in Figure 1 show that there were differences in the average performance between students from well-endowed schools and less-endowed schools on naming organic compounds. The median scores for the two boxplots for well-endowed and less-endowed schools were seven and eight respectively. As shown in Figure 1, there was considerable overlap in the distributions

of scores between well-endowed and less-endowed schools. The interquartile range was higher for less-endowed schools (8) than well-endowed schools (6). This means that the middle 50.0% of the distribution of scores was higher for less-endowed schools. This could be attributed to the presence of some exceptional students who were found in the less-endowed schools.

The independent-samples t-test analysis was used to find out whether there was any statistical significant difference between the mean scores of the two school types on naming organic compounds. The results are presented in Table 3.

Table 3: Independent-Samples T-Test Results of Scores for Well-Endowed and Less-Endowed Schools on Naming Organic Compounds by IUPAC Nomenclature

School	N	M	SD	t	df	p
Well-endowed	148	7.0	3.9	1.3	243	0.211*
Less-endowed	97	7.7	4.6			

* Not significant, p > 0.05

The results in Table 3 show that there was no statistical significant difference between the scores of students from well-endowed and less-endowed schools on naming organic compounds using the IUPAC nomenclature system. The mean score for the students from well-endowed schools (M = 7.0, SD = 3.9) on naming organic compounds using the IUPAC nomenclature system was not statistically significantly different from the mean score for students from less-endowed schools (M = 7.7, SD = 4.6, t(243) = 1.3, p = 0.211) with relatively small effect size (d = 0.006).

3.3. General Performance of Chemistry Students on Writing Structural Formulae of Organic Compounds by IUPAC Nomenclature

The research question further sought to find out students' performance on writing structural formulae of organic compounds using IUPAC nomendature. To accomplish this, the students were given 10 IUPAC names of compounds belonging to the families of Alkanes, Alkenes, Alkanols, Alkanoic acids, and Alkyl alkanoates to provide their respective structural formulae. The first five test items sought to look for both condensed and graphical formulae of the compounds from the given IUPAC names. This gave a total score of 10 marks. The next five test items sought to find out structural formula of the IUPAC names of the given compounds. These also gave a total score of five marks. In all, the total score on writing structural formulae of organic compounds was 15 marks.

With the mean of 5.0 (SD = 3.2) out of a maximum score of 15 on writing structural formulae of organic compounds, the scores of almost two-thirds of the students were in the range of 1.8 to 8.2. The large standard deviation of 3.2 could be attributed to the relatively small total marks for the test. Chemistry students' performance on writing structural formulae of organic compounds was very low as only 21.6% of them scored more than half the total marks. Since the performance of the students was low in writing structural formulae of organic compounds, it was therefore necessary to investigate the performance of the students with respect to the school type.

3.4. Performance of Chemistry Students from Well-Endowed and Less-Endowed Schools on Writing Structural Formulae

The numbers and percentages of the students from the two school types who scored more than half of the total marks on writing structural formulae of organic compounds using the IUPAC nomendature system are presented in Table 4.

The results in Table 4 show that for school A, out of the 56 students with low mean (M = 5.5, SD = 2.0, Max score = 10), only 17.9% of the students scored more than half of the total marks

and for school B, out of the 92 students with low mean (M = 4.6, SD = 3.3, Max score = 12), only 20.7% of the students scored more than half of the total marks. For the less-endowed schools, out of the 45 students from school C with a low mean (M = 6.0, SD = 3.9, Max score = 15), 35.6% of the students scored more than half the total marks and for school D, out of the 52 students with low mean (M = 4.3, SD = 3.2, Max score = 12), only 15.4% of the students scored more than half of the total marks on writing structural formulae of organic compounds using the IUPAC nomenclature system.

Table 4: Performances of Students from the Two School Types on Writing Structural Formulae using IUPAC Nomenclature

School	Type	N	n	%	M	SD	Max score
A	Well-endowed	56	10	17.9	5.5	2.0	10
B	Well-endowed	92	19	20.7	4.6	3.3	12
C	Less-endowed	45	16	35.6	6.0	3.9	15
D	Less-endowed	52	8	15.4	4.3	3.2	12

Where n is the number of students who scored more than half of the total marks on the test items on writing structural formulae from each school.

The findings from Table 4 show that one-third of the students from the less-endowed school C attained high scores on writing structural formulae of organic compounds using the IUPAC nomenclature system and therefore performed better than the students from the well-endowed schools A and B as well as the less-endowed school D. This could be due to the presence of some exceptional students who were found in the less-endowed school C.

The general scores obtained by students from well-endowed and less-endowed schools on writing structural formulae of organic compounds from IUPAC names are presented in Figure 2

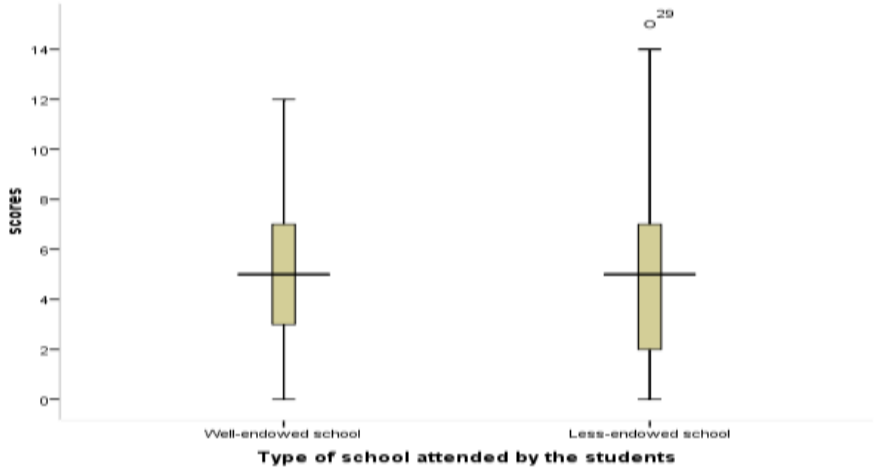

Figure 2. Boxplots of school-type differences in students' scores on writing structural formulae of organic compounds using the IUPAC system.

From Figure 2, it can be seen that there was considerable overlap in the distribution of scores between the students from well-endowed and less-endowed schools. The interquartile range for the students from the less-endowed school was higher (6) than that of the interquartile range for the students from the well-endowed schools (4). This shows that the middle 50.0% of the distribution of scores for the students from the less-endowed schools was higher. This could be due the exceptional student in the less-endowed schools who scored all the maximum 15 marks on writing structural formulae of organic compounds.

The independent-samples t-test analysis was used to ascertain whether there was any statistical significant difference between the mean scores of students from well-endowed and less-endowed schools on writing structural formulae of organic compounds from the IUPAC names. The results for the independent-samples t-test are presented in Table 5.

From Table 5, there was no statistical significant difference between the scores of students from well-endowed and less-endowed schools on writing structural formulae of organic compounds using the IUPAC nomendature system. The mean score for students from well-endowed schools (M = 4.9, SD = 2.9) on writing structural formulae of organic compounds using the IUPAC nomenclature system was not significantly different from the mean score for students from less-endowed schools (M = 5.1, SD = 3.6, t(243) = 0.5, p = 0.649) with relatively small effect size (d = 0.0009).

Table 5: Independent-Samples T-Test Results on Scores for Well-Endowed and Less-Endowed Schools on Writing Structural Formulae of Organic Compounds

School	N	M	SD	t	df	p
Well-endowed	148	4.9	2.9	0.5	243	0.649*
Less-endowed	97	5.1	3.6			

* Not significant, p > 0.05

4. Discussion

The findings on the general performance of the students in naming and writing structural formulae of organic compounds which was low reflects the revelation in the WAEC Chief Examiner's Reports (2000-2007; 2010a) on the weakness of most SHS Chemistry students on IUPAC nomenclature of organic compounds. For instance, the Chief Examiner's Report pointed out that candidates fail to provide the correct IUPAC names of the structural formulae of some organic compounds provided from certain given molecular formulae (WAEC, 2005). This low performance of the Chemistry students on the IUPAC nomenclature of organic compounds could not be attributed to the type of school attended by the students. This is because the performance of the students from well-endowed schools was not statistically significantly different from that of the performance of the students from the less-endowed schools. This disconfirms the findings of Ruby (2006) and NAEP (as cited in Ruby, 2006) where the performance of the students from less-endowed schools was lower than the performance of the students from well-endowed schools in the school sciences. Could this be that the less-endowed with less quality students compared to the students from the well-endowed schools are now enriched with high quality manpower that could handle the IUPAC nomenclature concept as it is being done in the well-endowed schools as opposed to the observation made by Lankford et al. (2002)? Hence, the students show a performance which is not different from their counterparts from the well-endowed schools on IUPAC nomenclature of organic compounds.

5. Conclusions

The study has showed that students generally show low performance in IUPAC nomenclature of organic compounds and this confirms the WAEC Chief Examiner's Reports on the general weakness of Chemistry students at the SHS level in IUPAC nomenclature of organic compounds. Generally, the students showed the weakness in IUPAC naming and writing of structural formulae of Alkenes, Alkynes, Alkanols, Alkanoic acids and Alkyl alkanoates.

The study has also showed that there were no statistical significant differences between performances of students from well-endowed and less-endowed schools on both naming and writing structural formulae of organic compounds using the IUPAC nomenclature system.

6. Recommendations

Since the Chemistry students showed low performance in IUPAC nomenclature of organic compounds, it is therefore recommended that the Chemistry teachers who prepare students for WASSCE could assist students in improving on their performance in IUPAC nomenclature by providing them with more worked examples on Alkenes, Alkynes, Alkanols, Alkanoic acids and Alkyl alkanoates.

It is also recommended that any assistance to be provided by the Ministry of Education and the Ghana Education Service to help students to improve on their performance in IUPAC nomenclature of organic compounds should be independent of the school-type as there was no statistical significant difference between the performance of students from well-endowed and less-endowed schools.

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