International Journal of Scientific Research in Education, SEPTEMBER 2012, Vol. 5(3), 214-222.

An Investigation into Senior High School Students' Difficulties and Understanding in Naming Inorganic Compounds by IUPAC Nomenclature

Rexford Baah[i]
Department of Science & Mathematics Education
University of Cape Coast
Cape Coast, Ghana.

&

Christian Anthony-Krueger[ii]
Department of Science & Mathematics Education
University of Cape Coast
Cape Coast, Ghana.

Abstract

This study assesses the difficulties that students have when naming inorganic compounds by IUPAC nomenclature. It uses a cross-sectional survey comprised of both quantitative and qualitative methods. The sample for the study consisted of 334 elective science Senior Secondary School (SSS 3) students in 2008/2009 academic year. Students were drawn from all schools offering elective science in the New Juaben Municipality of the Eastern Region of Ghana in that year. Of the sample population, 252 students were male and 82 were female with a mean age of 17 years and a standard deviation of 1.8 years. The instruments used for data collection were an achievement test and an interview. Some of the key findings include: students' inability to write the correct names of certain elements in compounds, students' inability to determine the central atom in compounds, students' inability to determine or calculate the oxidation numbers of central atoms in compounds, students' inability to write the correct names of radicals, and students' lack of knowledge about valency. This study recommends that teachers pay particular attention to assisting students in locating central atoms of compounds and hence calculating their oxidation numbers. This study also recommended that chemistry teachers focus more intently on helping students to name radicals correctly.

Keywords: Ghana Senior High School, Student Learning, Chemistry Students, Inorganic Compounds.

Reference to this paper should be made as follows:

Baah, R., & Anthony-Krueger, C. (2012). An Investigation into Senior High School Students' Difficulties and Understanding in Naming Inorganic Compounds by IUPAC Nomenclature. *International Journal of Scientific Research in Education, 5*(3), 214-222. Retrieved [DATE] from http://www.ijsre.com

INTRODUCTION

In the early practice of chemistry, the chemical name of a compound and its chemical formula had little or no relationship to one another. For example the compound Na_2CO_3 was called soda ash. The name "soda ash" contains no information about the type or number of elements in the compound. Modern naming methods have corrected this lack of connection. Todays rules for naming chemical compounds are set by the Nomenclature Committee of the International Union of Pure and Applied Chemistry (IUPAC). Older names, such as soda ash, are now generally referred to as common names. The correct IUPAC name for Na_2CO_3 or soda ash is sodium trioxocarbonate (IV).

Students' ability to write correct IUPAC names is central to learning and understanding chemistry. The West African Examination Council (WAEC), the body responsible for organizing examinations in West Africa, has for some time been concerned about students' inability to systematically name inorganic compounds correctly. The 1995 WAEC Chemistry Chief Examiner (CE) report stated that many candidates had problems with the systematic naming of inorganic compounds. The 1999 CE report also indicated that students were generally unable to provide the IUPAC names of some given inorganic compounds. Student difficulties with naming inorganic compounds have resulted in their inability to write correct chemical formulae (CE report for 1994, 2001, 2004 and 2005).

In a study conducted by Baah (2009), 334 senior high school students were asked to write the chemical formula for copper (I) oxide. Of those who participated in the study, 199 could not correctly write the formula. Of those who answered incorrectly, 120 wrote the formula as CuO and noted that this was because copper (I) is Cu and oxide is O. In the same study, the students were asked to write the formula for iron (II) sulphide. More than half (53.3%) could not write the formula for the compound. Of those who could not write, 107 students wrote the formula as Fe_2S, their reason being that iron (II) is Fe_2 and sulphide is S. It was clear from the study that students lacked the understanding of the meaning of the Roman Numeral in the bracket. They lacked knowledge of valency and the role valencies play in the writing of chemical formulae.

Hence the present study, which sets out to investigate the problems students have with understanding the systematic naming of inorganic compounds, is an important one. The fact that little academic research appears to have been done in this area, also makes this study a valuable one.

This study probed students' understanding of and difficulty with naming inorganic compounds using IUPAC nomenclature. The performances of students from both well-endowed and less-endowed schools were also compared so as to determine if the difficulties were more pronounced in a certain type of school. The following research question was used to structure the study:

1. What difficulties do SSS 3 students' have when naming inorganic compounds using IUPAC nomenclature?

The following null hypothesis was also used to guide the study:

2. There is no significant difference between the performance of students from well-endowed schools and those from less-endowed schools in the naming of inorganic compounds by IUPAC nomenclature.

METHODOLOGY

In this study, students understanding of the systematic naming of inorganic compounds and the difficulties they have with such naming were investigated. A cross-sectional survey was used to accomplish this. This study was comprised of two stages in which a mixture of methods – quantitative and qualitative – was used to collect data.

In the first stage, an achievement test based on the systematic naming of inorganic compounds was administered to SSS 3 elective science students from all seven of the Senior Secondary Schools (SSS) offering science as elective in the New Juaben Municipality of the Eastern Region of Ghana. In the second stage, group interviews were administered to students who provided incorrect answers in the test. The interview was conducted to ascertain their reasons for getting the items wrong. The instruments were administered to the students in their various schools.

Population

The target population for this study was all SSS 3 students enrolled in elective science in the 2008/2009 academic year in the New Juaben Municipality of the Eastern Region of Ghana. These students had studied chemistry for almost three years and were therefore deemed able to make a meaningful contribution to the study. The seven schools were

classified as well-endowed and less-endowed based on their science facilities and the grade with which students were admitted to pursue the science programme.

Sample

The sample for this study consisted of 334 SSS 3 elective science students. The sample was drawn from all the schools in the population. Table 1 shows the number and gender of science students who were present in their respective schools at the time of the study and who participated in the study.

Table 1: Number and gender of students in the schools that participated in the study

Schools	Males	Females	Total
A	61 (87.1%)	9 (12.9%)	70
B	19 (63.3%)	11 (36.7%)	30
C	50 (62.5%)	30 (37.5%)	80
D	55 (100.0%)	0 (0.0%)	55
E	26 (61.9%)	16 (38.1%)	42
F	24 (68.6%)	11 (31.4%)	35
G	17 (77.3%)	5 (22.7%)	22
Total	252 (75.4%)	82 (24.6%)	334

Instruments and Data Collection Procedure

The main data collection instruments used in this study were an achievement test and an interview. In developing the test instrument, items were constructed by the researchers and administered to SSS 3 elective science students at the University Practice Senior Secondary School, Cape Coast (a school not used in the main study). The responses from these students then guided the construction of the achievement test. The achievement test was shown to chemistry lecturers in the Department of Science and Mathematics Education of the University of Cape Coast, Cape Coast, Ghana and their input on the validity of the instrument was sought. The instrument was then pilot-tested with a sample of 54 elective science students attending Ofori Panyin Senior Secondary School in Tafo in the Eastern Region of Ghana. Finally, the Statistical Package for the Social Sciences (SPSS) was used to determine the Cronbach alpha coefficient of reliability for the items in the test. An alpha value of 0.90 was obtained for the items. The difficulty and discrimination index for each item was determined and items found to be too difficult or too easy were deleted.

The test was administered to the sample students in their various schools and the answered scripts were collected immediately after the test. The test lasted for one and half hours and it took five days for all the schools to take the test.

After the scripts were marked, students who encountered difficulty with the test had their names recorded. Researchers then returned to the individual schools and used a group interview schedule to interview those students. The interview was unstructured and its purpose was to determine why students had provided incorrect answers in the test.

Percentages were used to standardize students' performance in the test. An independent samples t-test analysis was used to test for differences in performance of students from well-endowed and less-endowed schools. Qualitative data gathered during the interviews were transcribed and used to help explain students' test answers.

RESULTS AND DISCUSSION

In the achievement test, SSS 3 elective science students were given six inorganic compounds to name using IUPAC nomenclature. These compounds were:

(a) H_2S
(b) $Cu(OH)_2$
(c) $(NH_4)_2SO_4$
(d) $KMnO_4$

(e) NaCN
(f) Na_2CO_3

The results of the performance of the students in the various schools are shown in Table 2.

The correct naming of each compound carried 1 mark making 6 the maximum mark for the question. On the first item, H_2S, in four (A, C, D and G) of the seven schools more than two-thirds of students scored this item correctly. In school F, more than half of the students named the compound correctly using IUPAC nomenclature. In school B less than half of the students could name the compound whereas in school E less than one-third of the students could name the compound using correct IUPAC nomenclature. In schools E, F and G less than half of the students named the compound $Cu(OH)_2$ correctly. For the compound $(NH_4)_2SO_4$, it was only in school C that more than two-thirds of the students named the compound correctly. In schools A, B and G, less than half of the students could name the compound. In schools E and F less than one-fourth and less than one-third respectively could name the compound $(NH_4)_2SO_4$ correctly. With respect to the compound $KMnO_4$ it was only in schools C and D that more than half of the students named the compound correctly. In schools A, B, E, F and G, less than half of the students could name the compound $KMnO_4$ using IUPAC nomenclature. Performance was even poorer with the compound NaCN than it was in $KMnO_4$. This was because performance deteriorated in schools A, E, F and G. Performance in school D on this question, however, was surprising as over 90% of the students named NaCN correctly. Finally, performance for the compound Na_2CO_3 was okay because four schools out of seven had more than half of their students name the compound correctly. Generally, most students found the naming of Na_2CO_3 easier than $KMnO_4$ even though both compounds involve the same number of steps in their naming. Hence it is possible that some students have committed the names of some compounds to memory. The performance of the schools is shown in Table 2.

The null hypothesis tested for any significant difference between the performance of students from well-endowed and less-endowed schools in naming inorganic compounds by IUPAC nomenclature. The independent samples t-test analysis was used and as shown in Table 3, there was significant difference between the performance of students from well-endowed and less-endowed schools. The mean score for well-endowed schools ($\underline{M}$ = 0.630, $\underline{SD}$ = 0.294,) was significantly ($\underline{t}$ (332) = 8.734, $\underline{p}$ = 0.001) higher than the mean score for less-endowed schools ($\underline{M}$ = 0.350, $\underline{SD}$ = 0.285) with an effect size = 1.0.

H_2S

Of the 334 students who participated in the study, 209 students (62.6%) gave the correct IUPAC name for H_2S as hydrogen sulphide. As shown in Table 2 below, the proportion of students who could write the IUPAC name of H_2S correctly was higher in well-endowed schools as 75.1% of students in these schools succeeded compared to 42.6% of students from less-endowed schools. In all of the well-endowed schools, more than two-thirds of their students correctly named the compound.

Table 2: Performance by school for correctly writing the names of IUPAC compounds

Schools	H_2S	$Cu(OH)_2$	$(NH_4)_2SO_4$	$KMnO_4$	NaCN	Na_2CO_3
Well-endowed						
A	47	40	26	29	21	32
N = 70	(67.1%)	(57.1%)	(37.1%)	(41.4%)	(30.0%)	(45.7%)
C	61	59	63	52	50	49
N = 80	(76.2%)	(73.7%)	(78.7%)	(65.0%)	(62.5%)	(61.2%)
D	46	47	30	38	50	38
N = 55	(83.6%)	(85.5%)	(54.5%)	(69.1%)	(90.9%)	(69.1%)
Overall	154	146	119	119	121	119
N = 205	(75.1%)	(71.2%)	(58.0%)	(58.0%)	(59.0%)	(58.0%)
Less-endowed						
B	13	17	10	12	12	14
N = 30	(43.3%)	(56.7%)	(33.3%)	(40.0%)	(40.0%)	(46.7%)
E	9	9	7	9	5	7
N = 42	(21.4%)	(21.4%)	(16.7%)	(21.4%)	(11.9%)	(16.7%)

F	18	17	9	16	9	18
N = 35	(51.4%)	(48.6%)	(25.7%)	(45.7%)	(25.7%)	(51.4%)
G	15	10	7	8	6	15
N = 22	(68.2%)	(45.5%)	(31.8%)	(36.4%)	(27.3%)	(68.2%)
Overall	55	53	33	45	32	54
N = 129	(42.6%)	(41.1%)	(25.6%)	(34.9%)	(24.8%)	(41.9%)

Table 3: Independent samples t-test analysis of performance of well-endowed and less-endowed schools when naming compounds using IUPAC nomenclature

Schools	N	Mean	SD	t	df	p
Well-endowed	205	0.630	0.294	8.734	332	.001*
Less- endowed	129	0.350	0.285			

*Significant at $p<0.05$

In schools B and E, both of which are less-endowed schools, less than 50% and 30% respectively had the naming of the above compound correct. Overall and as shown in Table 2, 37.4% out of 334 students who participated in the study could not give the correct IUPAC name for H_2S. Reasons given by students for their incorrect answers are presented in Table 4.

$Cu(OH)_2$

Of the 334 students who took part in the study, 199 students (59.6%) gave the correct IUPAC name of $Cu(OH)_2$ as copper (II) hydroxide. As shown in Table 2, two out of three well-endowed schools that participated in the study had more than two-thirds of their students give the correct IUPAC name. Of the four less-endowed schools, only one had more than half of its students score this item correct. More than two-thirds of the students from well-endowed schools therefore answered this item correctly compared to less than half of students from less-endowed schools. As shown in Table 2, 40.4% of students who took part in the test could not give the correct IUPAC name for $Cu(OH)_2$. Reasons given by these students for their incorrect responses are shown in Table 5.

Table 4: Students' responses and reasons for writing the IUPAC name of H_2S incorrectly (N = 125)

IUPAC Name Given by Students	Students' Reasons for the Name Provided	Number and Percentage of Students
Hydrogen (II) sulphate	S is sulphate, H is hydrogen and H_2 is hydrogen (II)	50 (40.0%)
Sulphur (II) acid	S is sulphur and the presence of H makes it acidic therefore H_2 would make the name sulphur (II) acid	33 (26.7%)
Sulphuric acid	Because in the formula of sulphuric acid, there are H_2 and S	17 (13.4%)
Hydrogen sulphur	Because S is sulphur and H is hydrogen	17 (13.4%)
No response	Because we thought there was a mistake with the formula	8 (6.5%)

$(NH_4)_2SO_4$

Of the 334 students involved in the study, 152 students (45.5%) gave the correct IUPAC name for the compound $(NH_4)_2SO_4$ as ammonium tetraoxosulphate (VI). Only one of the three well-endowed schools had more than two-thirds of its students give the correct IUPAC name. In school A (well-endowed), less than half of the students answered this

item correctly. Less than half of the students from any of the less-endowed schools provided the IUPAC name of the compound. More than half, 54.5% of 334 students, could not give the correct IUPAC name of $(NH_4)_2SO_4$. Reasons for their incorrect responses are presented in Table 6.

Table 5: Students' responses and reasons for writing the IUPAC name of $Cu(OH)_2$ incorrectly (N = 135)

IUPAC Name Given by Students	Students' Reasons for the Name Provided	Number and Percentage of Students
Copper hydroxide	Because the subscript 2 in the formula does not take part in the naming of the compound.	50 (37.0%)
Copper dioxohydrogen	Because both the oxygen and the hydrogen are two	33 (24.4%)
Copper dihydroxide	Because the OH groups are two	50 (37.0%)
No formula	Because we did not know whether to calculate the oxidation number of Cu or H before naming the compound	2 (1.5%)

Table 6: Students' responses and reasons for writing the IUPAC name of $(NH_4)_2SO_4$ incorrectly (N = 182)

IUPAC Name Given by Students	Students' Reasons for the Name Provided	Number and Percentage of Students
Ammonium sulphate	NH_4^+ is ammonium ion and SO_4^{2-} is sulphate ion so when they bond, that is the name we would have.	61 (33.5%)
Ammonium sulphuric	NH_4^+ is ammonium ion and SO_4^{2-} is derived from sulphuric acid (H_2SO_4) therefore when the two ions bond, such name would be the resultant name.	16 (8.9%)
Ammonium tetraoxosulphide	NH_4^+ is ammonium ion and SO_4^{2-} is tetraoxosulphide ion, therefore when they bond, such name would be the resultant name.	33 (18.1%)
Ammonium (II) tetraoxosulphate	NH_4^+ is ammonium ion and SO_4^{2-} is tetraoxosulphate ion so when two of NH_4^+ ions bond with one SO_4^{2-} ion such name would be the result	33 (18.1%)
Diamine tetraoxosulphate (VI)	NH_4^+ is amine and two of it is diamine and SO_4^{2-} is tetraoxosulphate (VI) ion	16 (8.9%)
Ammonium tetraoxosulphate (IV)	NH_4^+ is ammonium ion and SO_4^{2-} is tetraoxosulphate (IV) ion	12 (6.6%)
Ammonia tetraoxosulphate	NH_4 is ammonia and SO_4 is tetraoxosulphate	11 (6.0%)

$KMnO_4$

Of the 334 students who took the test on the IUPAC naming of $KMnO_4$, 164 students (49.1%) gave the correct IUPAC name of the compound as potassium tetraoxomanganate (VII). More than half of the students from the well-endowed

schools gave the correct IUPAC name while less than half of the students from the less-endowed schools performed the same task correctly. Again, in none of the less-endowed schools did even half of the students score this item correctly. As shown in Table 2, 50.9% of 334 students could not give the IUPAC name of the compound. Reasons given by these students for their incorrect responses are presented in Table 7.

Table 7: Students' responses and reasons for writing the IUPAC name of $KMnO_4$ incorrectly (N = 170)

IUPAC Name Given by Students	Students' Reasons for the Name Provided	Number and Percentage of Students
Potassium tetraoxomanganate	K is potassium and MnO_4 is tetraoxomanganate	(25.3%)
Potassium manganate (IV) oxide	K is potassium and MnO_4 is manganate (IV) oxide	33 (19.4%)
Potassium tetraoxomagesium (VII)	K is potassium and MnO_4 is tetraoxomagesium (VII)	33 (19.4%)
Potassium tetraoxomanganese (IV)	K is potassium and MnO_4 is tetraoxomanganese(IV)	34 (20.0%)
Potassium tetraoxomanganate (V)	K is potassium and MnO_4 is tetraoxomanganate (V)	13 (7.6%)
Potassium tetraoxomanganate (VI)	K is potassium and MnO_4 is tetraoxomanganate (VI)	10 (5.9%)
Potassium tetraoxomanganese	K is potassium and MnO_4 is Tetraoxomanganese	4 (2.4%)

NaCN

Of 334 students, only 153 students (45.8%) gave the correct IUPAC name of NaCN as sodium cyanide. As shown in Table 2, only school D (well-endowed) had more than two-thirds of its students answer this item correctly. In school B (less-endowed) less than half of the students answered this item correctly. In the remaining less-endowed schools fewer than one-third of the students could answer this item correctly. More than half of the students participating in the study (54.2%) could not give the correct IUPAC name for the compound NaCN. Reasons given by students for their incorrect answers are presented in Table 8.

Table 8: Students' responses and reasons for writing the IUPAC name of NaCN incorrectly (N = 181)

IUPAC Name Given by Students	Students' Reasons for the Name Provided	Number and Percentage of Students
Sodium cyanate	Na is sodium and CN is cyanate	33 (18.2%)
Sodium cynaide	Na is sodium and CN is cynaide	33 (18.2%)
Sodium cynide	Na is sodium and CN is cynide	34 (18.8%)
Sodium cylide	Na is sodium and CN is cylide	17 (9.4%)
Sodium cynite	Na is sodium and CN is cynite	17 (9.4%)
Sodium nitrogen Carbonate	Na is sodium and CN is nitrogen carbonate	14 (7.7%)
Sodium carbon Nitrogen	Na is sodium, C is carbon and N is nitrogen	16 (8.8%)
Sodium cynade	Na is sodium and CN is cynade.	17 (9.4%)

Na_2CO_3

Of 334 students, 170 students (50.9%) gave the correct IUPAC name of Na_2CO_3 as sodium trioxocarbonate (IV). In two of the three well-endowed schools, more than half of the students scored this item correctly. Likewise, two of four of the less-endowed schools also had more than half of their students score this item correctly. It was only in school E (less-endowed) that less than one-fifth gave the correct IUPAC name for Na_2CO_3. Students' reasons for giving the incorrect response are presented in Table 9.

Table 9: Students' responses and reasons for writing the IUPAC name of Na_2CO_3 incorrectly (N = 164)

IUPAC Name Given by Students	Students' Reasons for the Name Provided	Number and Percentage of Students
Sodium carbonate	"that is what we know"	164 (100%)

CONCLUSIONS

The difficulties found among SSS 3 students with the systematic or IUPAC naming of inorganic compounds were:

(a) Inability to write the correct names of some elements in compounds. With H_2S, for example, students thought that S was sulphur rather than sulphide and in $KMnO_4$ that Mn was manganese rather than magnate.
(b) Inability to determine the central atom in compounds.
(c) Inability to determine or calculate the oxidation numbers of central atoms in compounds.
(d) Inability to write the correct names of radicals. For example, some students recorded the OH in $Cu(OH)_2$ as dioxohydrogen, the NH_4 in $(NH_4)_2SO_4$ as ammonia or diamine and the SO_4 as sulphuric tetraoxosulphide, and the CN in NaCN as cyanate, cynide, cylide, cynite, cynade and/or carbon nitrogen.
(e) Lack of knowledge about valency.

Implication for Research and Practice

The results of the study show that students from less-endowed secondary schools have increased difficulty naming inorganic compounds using IUPAC nomenclature when compared with students from well-endowed schools. The results also suggest that students from both well-endowed and less-endowed secondary schools have difficulty naming some radicals correctly. Chemistry teachers should therefore pay attention to this area of IUPAC naming. The results of the study also show that students from both schools have very limited knowledge about valency. More research could be carried out to further examine the causes of this limited knowledge.

REFERENCES

Baah, R. (2009). *Senior high school students understanding of chemical formulae and chemical equations.* Unpublished MPhil Thesis, University of Cape Cost, Ghana.
West African Examinations Council (1994). *Chief Examiners' Report*, SSSCE, Nov-Dec, Accra.
West African Examinations Council (1995). *Chief Examiners' Report*, SSSCE, Nov-Dec, Accra.
West African Examinations Council (1999). *Chief Examiners' Report*, SSSCE, Nov-Dec, Accra.
West African Examinations Council (2001). *Chief Examiners' Report*, SSSCE, Nov-Dec, Accra.
West African Examinations Council (2004). *Chief Examiners' Report*, SSSCE, Nov-Dec, Accra.
West African Examinations Council (2005). *Chief Examiners' Report*, SSSCE, Nov-Dec, Accra.

---

[i] Rexford Baah is a principal research assistant and a PhD student at the Department of Science and Mathematics Education, University of Cape Coast, Cape Coast, Ghana. He can be reached on E-mail: rexfordbaah@yahoo.com

[ii] Christian Anthony-Krueger is a PhD holder and a senior lecturer at the Department of Science and Mathematics Education, University of Cape Coast, Cape Coast, Ghana.