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Understanding Students' Misconceptions about Chemical Formula Writing and Naming Ionic Compounds

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Abstract

Difficulties in the competency of chemical formula writing and naming ionic compounds are common to General Chemistry 1 learners. Hence, this study is formulated to understand 34 General Chemistry 1 learners' misconceptions about chemical formula writing and naming ionic compounds. This descriptive case study research used a two-tier test and interview questionnaire as the main data-gathering instruments. From the conducted study, analysis shows that in terms of chemical formula writing, the learners misrepresent ionic compounds as charged species, show a lack of understanding of valency and the use of the cross-charge method, and mispresent radicals. In naming ionic compounds, the learners generally misname some of the elements found in binary ionic compounds and misname metal ions with more than 1 charge and polyatomic ions. These misconceptions were validated by the difficulties experienced by the learners in answering the two-tier test, as mentioned in their interviews. Despite the misconceptions and difficulties of the learners in chemical formula writing and naming ionic compounds, they mentioned several ways of addressing them.

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Introduction

The Senior High School of the K to 12 program started in the Philippines in the year 2016 as prescribed in the Enhanced Education Act of 2013. It is a specialized upper secondary education program taken for two years (Grades 11 and 12) and each learner can choose from three tracks based on aptitude, interest, and school capability. Science, Technology, Engineering, and Mathematics (STEM) is one of the strands a Senior High School learner may take in the program's Academic Track. One of the specialized subjects taken by STEM learners is General Chemistry 1 and as stated in the General Chemistry 1 and 2 Curriculum Guide, the subject focuses on composition, structure, and properties of matter; quantitative principles, kinetics, and energetics of transformations of matter; and fundamental concept of organic chemistry (DepEd, 2016). It can be noted in the subject description that General Chemistry 1 and 2 are made up of topics that are taught at macroscopic, microscopic, and symbolic levels. These levels of teaching Chemistry are important to meaningfully understand the subject (Hinton & Nakhleh, 1999; Johnstone, 1993). In addition, understanding their interactions and distinctions is crucial in learning Chemistry and if a difficulty arises from one level, other levels will be affected (Sirhan, 2007).

Shapes that are pictorial, algebraic, physical, and computational are used to depict the symbolic level. At this level, teachers can employ equations in chemistry, graphs, reaction mechanisms, symbols, formulas, analogies, model kits, and numbers (Tüysüz et al., 2011). For instance, the ionic compound Sodium Chloride commonly known as the table salt, can be shown in the symbolic level as NaCl. The formation of the said inorganic compound can also be represented at the symbolic level as $2Na_{(s)} + Cl_{2(g)} \rightarrow NaCl_{(s)}$. Chemistry as taught at the symbolic level makes it challenging for students to understand it. As communicated by Taber (2019), Chemistry uses a significant quantity of abstract ideas based on theoretical information and these are frequently addressed and taught mostly in terms of theoretical, non-observable phenomena. As cited by Fitriani et al. (2021), Fitriani et al. (2017) further mentioned that studying Chemistry is one of the science classes that is considered difficult. Learners dislike Chemistry classes because they are generally abstract and complicated.

One of the symbolic lessons in Chemistry is chemical nomenclature and chemical formula writing. To show or represent the composition of a certain compound, a chemical formula which is made up of element symbols and subscripts is used. In a chemical formula, the element symbols and subscripts will tell the elements and number of atoms present in the compound. For example, the compound Hydrogen peroxide is represented by the chemical formula H_2O_2, where the element symbols H and O and the number 2 as subscripts tell that the compound is made up of two atoms of Hydrogen and two atoms of Oxygen. On the other hand, chemical nomenclature entails the use of sets of rules in naming compounds. The rules are being set by the International Union of Pure and Applied Chemistry (IUPAC). Many students find naming chemical compounds challenging, but it is a critical aspect of chemistry (Wood & Donnelly-Hermosillo, 2019). This is because students need to learn how to use the set rules of IUPAC in naming elements and compounds that are at the symbolic level. Chemical nomenclature and chemical formula writing are two basic skills that students use in their entire exploration of Chemistry. Baah and Krueger (2012) further posit that the student's ability to write the names of compounds following the rules set by IUPAC is fundamental to learning and understanding chemistry – all other topics are connected to correctly naming and writing a chemical formula.

Recurring yearly, it was observed that General Chemistry 1 learners have difficulty in the competency of formula writing and naming ionic compounds. Although some can follow the rules in ionic compound formula writing and naming, some learners cannot still write properly the symbolic representations of the ionic compounds – some write the charges of ions but do not do the cross-charge method and if others do the cross-charge method, the learners tend not to reduce the subscripts into simplest form or ratio. In terms of naming the ionic compounds, some students are confused about how to use the Stock and Classical systems. For instance, the compound $CaCl_2$ is properly named as calcium chloride, but some would name it using the stock system as calcium (II) chloride. Generally, General Chemistry 1 learners cannot properly name ionic compounds with polyatomic ions. Since they are struggling at the symbolic level, it may also result in their difficulties in understanding the microscopic and macroscopic levels of Chemistry and higher-level lessons. It is therefore important to invest time and explore their conceptions to plan for better instruction and remediation. As also built up earlier, Chemistry is one of the most conceptually challenging subjects. Hence, it is essential for anyone who teaches it to have a good understanding of the challenging areas (Dula, 2018).

In the past years, it has been noted in different related research that learners have difficulty understanding chemical nomenclature and chemical formula writing. In the investigations done by Savoy (1988) and Hines (1990), it was shown that learners struggle to write chemical formulae. If learners are not able to fully understand chemical formula writing and naming, the tendency is that they will be hard up in learning concepts related to stoichiometry, chemical reactions, and balancing equations among others. This is supported by the findings of Lazonby, Morris, and Waddington (1982) in their research that learners' failure to accurately write chemical formulae is linked to their ongoing struggles in solving problems concerning stoichiometric calculations. This was also observed in the study of Galacer et al. (2013) that students failed stoichiometry due to a lack of fundamental chemical knowledge, including compound nomenclature.

Furthermore, in the series of tests conducted by the West African Examination Council (WAEC), the association responsible for establishing examinations in West Africa, it was revealed that many of the test takers in 1995 and 1999 had problems in naming inorganic compounds systematically and generally cannot give the IUPAC names of selected ionic compounds (WAEC, 1995 & 1999). Since learners have issues with naming inorganic compounds, this has led to their incapability to accurately write chemical formulae (WAEC, 1994; WAEC, 2001; WAEC, 2004; & WAEC, 2005). Similarly, Baah and Krueger (2012) tested 334 senior high school students in terms of their ability to name and write the chemical formula of ionic compounds. Their study determined that students have trouble in naming and chemical formula writing and that they lack understanding of the meaning of the Roman Numeral in brackets and the role of valency in writing chemical formulae. Glažar and Devetak (2002) also recorded some problems of students with chemical language. In their investigation, they saw that: (1) students do not understand the connection between a compound’s name and its formula; (2) they don’t possess a mastery of using suffixes; (3) they don’t correlate the use of oxidation numbers of elements in naming substances; and (4) occasionally, they use incorrect symbols of elements.

According to Taskin and Bernholt (2014), these difficulties in chemical nomenclature are generally linked to language (meaning, function, and syntax of formula) and conceptual (links between macroscopic, microscopic, and symbolic levels) difficulties.

In addition, Naah and Sanger (2012) explored learners' alternative conceptions of stoichiometric equations for electrolyte solutions. One of the results of the study shows that among the 37 college students who participated in the semi-structured interview, there were students who exhibited confusion on how to properly use subscripts and coefficients. Confusion about the use of subscripts concerning simple compounds containing polyatomic ions was also documented by Habiddin (2014). Related to this, Habiddin (2014) also noted that learners tend to misname compounds with radicals because they fail to memorize the names of polyatomic ions. Espinosa et al. (2016) also recorded a misconception among learners in writing chemical formulae regarding putting charges to supposed neutral species. While students show difficulties in naming compounds and chemical formula writing, it is also good to point out that one of the results from the study of Amazona, Jr., and Vallejo (2020) shows that the student's performance in writing formulae is categorized as "nearly proficient". It appears that the students quite easily remember how to write chemical formulae.

Given the past and recent studies, it is important to note that students have difficulties in chemical formula writing and naming ionic compounds. If these difficulties are not determined and not taken action upon, these may result in other conceptual problems and challenges in understanding higher-level topics in Chemistry. Thus, this study is formulated to understand the misconceptions related to the difficulties of General Chemistry 1 learners in formula writing and naming ionic compounds. This present study is also considered worthwhile because it appears that little research has been done in this area and findings can be used for proper remediation and planning for instructional activities. The following questions are used in conducting the study: (1) What are the students' misconceptions about formula writing and naming ionic compounds?; and (2) What are the challenges of the students in formula writing and naming ionic compounds and how do they address these challenges?

Method

Research Design

In this study, the misconceptions of General Chemistry 1 learners on formula writing and naming ionic compounds were investigated. To accomplish this, a descriptive case study research design was used. This type of case study illuminates the intricacies of an experience (Stake, 1995). The descriptive case study was chosen to understand the misconceptions and difficulties experienced by the learners in chemical formula writing and naming ionic compounds. The descriptions of the misconceptions observed in the study will help to correct and avoid alternative conceptions.

The study utilized a two-tier test to gauge the performance and misconceptions of the Grade 11 learners in formula writing and naming ionic compounds. The top 10 and bottom 10 learners have undergone an interview to dig deeper into their reasons or conceptions for answering the questions in the test. The students were asked about their challenges or difficulties in answering the test and how they addressed them. The interview followed the interview protocol prescribed by Creswell (2009). After the collection of data, the gathered sets of information are summarized, taking into consideration the students' misconceptions, reasons, and processes to systematically interpret the results and understand misconceptions of students on formula writing and naming ionic compounds.

Participants

A total of 34 Grade 11, General Chemistry 1 learners for the academic year 2022 - 2023 were taken as the source of data for this study. Twenty students were purposively selected from the 34 General Chemistry 1 learners based on their scores or performance from the two-tier test and were subjected to an interview. For ethical considerations, the respondents were made aware of the purpose of the study before participating. The necessary data collected from the participants were only used to shed light on the posted research questions. The identity of the school and the learners was not disclosed in presenting data.

Research Instruments

To avoid deception in data gathering, the researcher made a graded two-tier test to gauge the General Chemistry 1 learners' conceptions and possible alternative conceptions of formula writing and naming ionic compounds. The formula writing and naming ionic compounds questionnaire was content and face-validated by chemistry and chemistry education experts.

The test covered 3 items of formula writing and 3 items of naming ionic compounds. The content of the two-tier test was taken from JCE Software: Inorganic Nomenclature by David Shaw and adapted for the web by Laura Yindra which is a web page for a tutorial on naming and writing chemical formulae of simple inorganic compounds (Shaw & Yindra, 2003). The questions are arranged in increasing difficulty. In the first part of the test, the learners need to write the chemical formula given the names of the inorganic compounds on the blank spaces provided. Below the blank spaces are boxes where the learners need to write their explanations on how they come up with their answers. The same process was done on the second part of the test but learners need to write the name of the inorganic compounds given their chemical formulae instead and explain how they arrived at their answers inside the boxes.

After the two-tier test, the top 10 and bottom 10 went to an interview to probe into their challenges in chemical formula writing and naming ionic compounds and how they address them.

Procedure

Validation of the two-tier test and securing approval to conduct research from chemistry education experts and the Dean of the College are done before the collection of data. Subsequently, after several lessons in chemical formula writing and naming ionic compounds, the researcher gave the graded two-tier test to the learners. After the test, the top 10 and bottom 10 were identified by the researcher. The 20 purposively selected learners went into an interview with the researcher following the interview protocol set by Creswell (2009) to dig deeper into their difficulties in answering the test. Their ways on how they address their problems in chemical formula writing and naming ionic compounds were also asked. Data analysis followed after the collection of needed information.

Data Analysis

The number of correct responses of the learners in the two-tier test was tabulated and presented in frequency and percentages to know their performance. Furthermore, their written responses and their reasons for their answers in each item were grouped according to common errors. From these responses, the common misconceptions about chemical formula writing and naming ionic compounds were derived and described. The common difficulties in answering the test items were audio-recorded in an interview, transcribed, and grouped to further validate and understand the misconceptions on chemical formula writing and naming ionic compounds. In the same manner, the responses of the participants in the interview on how they addressed their difficulties were audio-recorded, transcribed, and grouped.

According to how they address their difficulties, the learners were categorized using the VARK model of learning styles. As discussed in the study of Sintia et al. (2019), learners can be classified using the VARK model of learning styles developed by Fleming. Visual learners acquire and process information with the use of visuals like photos, graphs, and charts; the aural learners, on the other hand, like listening to discussions and tutorials; read/write learners tend to like to see and read printed or written texts and to take down notes then reread them; lastly, the kinesthetics learners like it the most to learn by doing or experiencing things that are with connection to real-life situations. Sintia et al. (2019) also noted that learners with more than one preference for learning can be considered “multimodal”.

Results and Discussion

Data were gathered during the first grading period of the first semester of the academic year 2022-2023 in a certain school in La Union, Philippines. The two-tier test on formula writing and naming ionic compounds was administered to Grade 11 learners enrolled in General Chemistry 1. After the checking of the test, the identified top 10 and bottom 10 have undergone an interview. Table 1 summarizes the performance of the learners in chemical formula writing and naming ionic compounds.

Table 1. Percentage of correct response

Test Items	Correct Response (N = 34)	Percentage (%)
Part I. Chemical Formula Writing	23	68
	20	59
	3	9
Part II. Naming Ionic Compounds	31	91
	17	50
	3	9

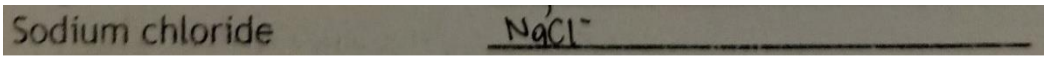
It is deemed in Table 1 that students' performance in chemical formula writing and naming ionic compounds are both decreasing following the increasing difficulty of questions. Although there are students who can answer the questions in formula writing and naming ionic compounds correctly, the low and decreasing number of correct responses in the administered test tells that the students still experience difficulties and might have possible misconceptions about the topics.

Misconceptions in Chemical Formula Writing

From the written answers of the learners in the two-tier test, several common alternative conceptions in chemical formula writing are listed. These misconceptions are summarized in the following themes.

Misrepresentation of ionic compounds as charged species.

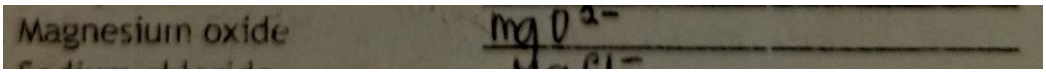
It is noted from the answers of the respondents that they are misrepresenting the chemical formula of ionic compounds as charged species. Instead of being neutral, the learners are putting charges in the chemical formula. For instance, in writing the chemical formula of Sodium chloride, the learners retained the charge of the Chloride ion in the written chemical formula of the compound. A sample unedited answer and explanation are shown in Figure 1.



"I input the chemical symbol of the 2 [ions]: Na for sodium and Cl for chloride. There's a negative [charge] in chloride since it's a non-metal."

Figure 1. The answer of learner 5 to item I.1

In the case of writing the formula of Magnesium Oxide, learner 34 has written correctly the element symbols for Magnesium and Oxygen in the chemical formula but a charge of two negative (2-) is written after the symbol of Oxygen, making the species not neutral. When asked about the reason, the learner recalled the rule of representing non-metal ions in symbols. It is seen that the learners can represent the monoatomic ions in symbols, but they are confused about using these symbols to represent the chemical formula of ionic compounds. The unedited response of Learner 34 is given in Figure 2.



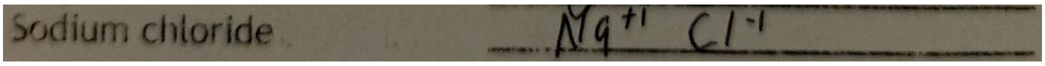
"Magnesium is Mg and Oxide is O negative because oxide has -ide."

Figure 2. The answer of learner 35 to item I.2

This misconception is also seen in the study of Espinosa et al. (2016) in their investigation of pre-service Chemistry teachers' problem-solving strategies where some students also put a negative (-) sign at the end of a chemical formula of a compound.

Lack of Understanding of Valency and Cross-Charge Method

To attain the chemical formula of an ionic compound, charges should be identified correctly and the cross-charge method should be done properly. In the case of the General Chemistry 1 learners, it is common that they are confused about how to represent the charges of the ions involved in making the compound – they often misrepresent it as oxidation numbers. Others made the representation of the ions correct but it is noticeable that the cross-charge method to get the chemical formula of the compound is not done. Below are Figures 3 and 4 showing the unedited responses from the learners.



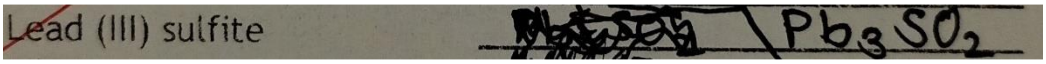
"I got my answer by identifying the chemical symbol of the following and putting a negative or positive sign if it is an anion or cation."

Figure 3. The answer of learner 16 to item I.1

"I first looked at the names of the elements in the periodic table then I wrote the symbols of each element and put a positive sign on the metal and a negative sign on the nonmetal."

Figure 4. The answer of learner 32 to item I.1

In addition, when prompted to write the chemical formula of Lead (III) sulfite, the learners show misconception about the use of the Roman numeral found in the name. Supposed to be, the Roman numeral represents the charge of the metal ion but the learners are making it as the subscript of the metal ion when the compound's chemical formula is written. As written by learner 17 in the two-tier test (Figure 5), the Roman numeral beside the lead is converted as its subscript. The cross-charge method is not used in this process.



"*I wrote the chemical symbol of lead (Pb) with the numerical number (3), then the chemical symbol of sulfite (SO) because it contains oxygen, then I wrote (2) because I was basing on these examples: hyposulfite (1), sulfite (2), sulfate (3), persulfate (4).*"

Figure 5. The answer learner 17 to item I.3

On the other hand, other learners can represent the charges of ions properly and attempted to do the cross-charge method but failed to simplify the subscripts. Like for example, learner 4 has written the chemical formula of magnesium oxide as MgO_2. The learner recognized that Magnesium and Oxide ions have charges of 2+ and 2- respectively but failed to carry out the cross-charge method and retained 2 as a subscript for oxygen in the chemical formula. When asked about his/her reason, since both ions have the same opposite charges, the whole compound takes 2 as a subscript. Below is the sample unedited answer of learner 4 (Figure 6).

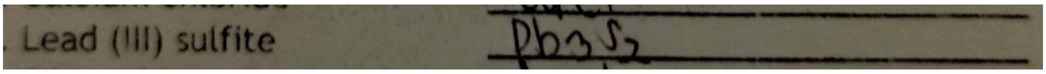
"Magnesium oxide is made up of Mg^{2+} *and* O^{2-} *ions and are connected to each other by an ionic bond. However, they have both 2 ions that's why I put 2 in the chemical formula, therefore the formula of magnesium oxide is* MgO_2*."*

Figure 6. The answer of learner 4 to item I.2

Problems with valency and the use of the cross-charge method were also reported in some studies. Baah and Krueger (2009) made senior high school students write the chemical formulae of some ionic compounds and concluded that they lacked knowledge of valency and its importance in writing the chemical formula of ionic compounds. In the examination of the secondary school students' ability to transform among representation levels, Celikkiran (2020) noticed that most of the incorrect responses were made in the subscripts of chemical formulae. Even if these studies were done almost a decade apart, the problem of valency and the correct usage of the cross-charge method is still evident.

Misrepresentation of Radicals

Of the three items in the chemical formula writing part of the two-tier test, only Lead (III) sulfite contains a radical or a polyatomic ion. In item number three of chemical formula writing, only 3 learners are able to write the chemical formula of Lead (III) sulfite correctly. All those who did not get the chemical formula for Lead (III) sulfite correctly do not know how to represent the sulfite ion in a symbol. It can be noted that they have difficulty following rules in writing the symbol of a polyatomic ion or oxyanion. The learners know the symbol for lead as Pb but it is evident from their answers that they have misconceptions on what to do with the given charge of the metal element which is enclosed in a parenthesis. For instance, learner 33, made the charge of lead as its subscript and mistakenly took the symbol for sulfur (S) as sulfite because of the suffix -ite, in which sulfur when in ion form should be in -ide suffix. Learner number 33 has written the subscript of the supposed sulfite in the compound from the charge of the sulfide ion. The answer of learner 33 is shown in Figure 7.



"Lead III sulfite because lead is Pb3 and the sulfite is 2 because it has -ite."

Figure 7. The answer of learner 33 to item I.3

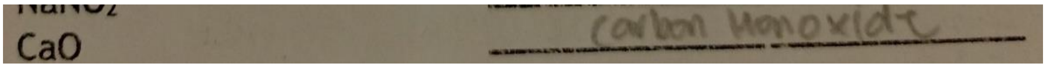
This finding corroborates with one of the findings of Habiddin (2014) that first-year chemistry undergraduate students have difficulty writing the chemical formula of ionic compounds containing polyatomic ions. For the compound Iron (III) sulfate, Habiddin (2014) noted answers such as Fe_2S_3 and Fe_3S similar to what was observed in this present study.

Misconceptions in Naming Ionic Compounds

Several misconceptions in naming ionic compounds are noted in this study. Most of the misconceptions are related to naming ionic compounds with polyatomic ions. The following themes summarized these misconceptions.

Misnaming Metal and Non-Metal Elements in Ionic Compounds

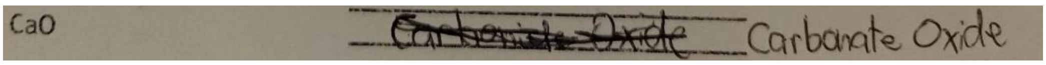
Based on Table 1, 31 learners or 91% of the total population have written the name of CaO correctly. Although almost all correctly named CaO, some misconceptions are still noted. Learner number 4 is not familiar with the symbol and name of the element calcium – he/she named Ca as carbon. Aside from being unfamiliar with the element symbol, learner number 4 was also confused about what rules to use in naming the oxide ion; the learner used the rules in naming molecular compounds. Shown in Figure 8 is the original answer of learner 4.



"I identified Ca as an element named Carbon and O for Oxygen then I put mono because the atom of Oxygen is 1."

Figure 8. The answer of learner 4 to item II.1

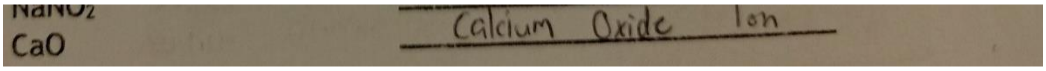
Similar to learner 4, learner 31 is also not familiar with the name of the given metal in the chemical formula. Instead of naming it calcium, learner 31 named it carbonate. He/she named the non-metal ion in the chemical formula correctly (Figure 9).



"I have answered carbonate oxide because Ca is Carbon and O is oxide. I just guessed the suffix of carbon to be -ate because I don't know what to use between -ate and -ite."

Figure 9. The answer of learner 31 to item II.1

On the contrary, learner 30 had the correct process of naming the ionic compound but he/she forgot to remove the word “ion” from the ion name of oxygen (Figure 10).



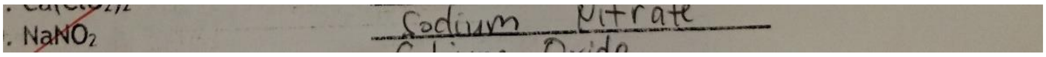
“[I arrived at my answer] by identifying the name of the symbol and putting "ide" at the end of the root word for the non-metal [ion].”

Figure 10. The answer of learner 30 to item II.1

Baah and Krueger (2012) also detected the same problem. The learners cannot name some elements found in the inorganic compounds. For instance, in the compound H_2S, learners believed that S is named sulfur instead of sulfide.

Misnaming Radicals

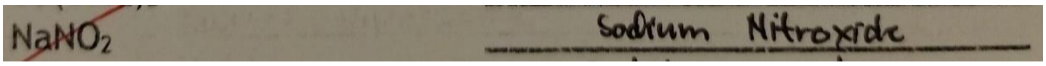
Under the ionic compound naming part of the two-tier test, $NaNO_2$ is the only compound containing a radical or polyatomic ion. Only half of the General Chemistry 1 learners were able to name $NaNO_2$ as sodium nitrite. It is evident from the answers of the learners that they have difficulties naming ionic compounds containing radicals. There are several misconceptions listed regarding the naming of $NaNO_2$. One misconception seen is that the learners tend to be confused about the rules on naming oxyanions. Instead of naming NO_2- ¬ion in the compound as nitrite because it contains two oxygen atoms, the learners named it as nitrate which is supposed to be used if the number of oxygen atoms is three. A sample unedited answer from learner 25 is shown in Figure 11.



“I used the element name of Na (Sodium) and NO is an oxyanion which consists of nitrogen and oxygen so I used the root word of Nitrogen and added the suffix "-ate" because nitrate is NO_2 making it Sodium Nitrate.”

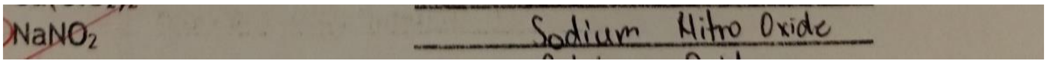
Figure 11. The answer of learner 25 to item II.2

In addition, learner 28 thought that N and O in the given chemical formula of $NaNO_2$ are not taken as a polyatomic ion, instead, he/she combined the root words of Nitrogen ion and Oxygen ion and then added the suffix -ide (Figure 12). The same misconception is seen from learner 2 who explained it as naming simple covalent compounds (Figure 13).



“I just find the element symbol on the periodic table, then copied their names.”

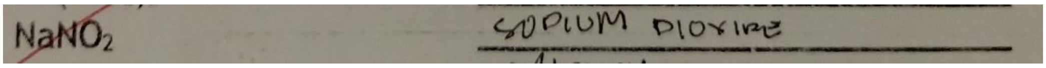
Figure 12. The answer of learner 28 to item II.3



"Basing on the periodic table: Na (Sodium) and N (Nitrogen). For my answer, after I got [the names of] the elements, I wrote them together. I answered it by using the rules of naming simple covalent compounds. That's why I got Sodium Nitro Oxide."

Figure 13. The answer of learner 2 to item II.2

In other answers, the learners still do not recognize that there is a polyatomic (oxyanion) in the given chemical formula. The learners dropped the nitrogen and disregarded the number of oxygen atoms from the oxyanion NO_2- when they named the whole compound, resulting in an answer of Sodium oxide. Others considered the subscript of Oxygen and named it using the rules in naming simple covalent compounds. Figure 14 shows a sample answer from learner 4.



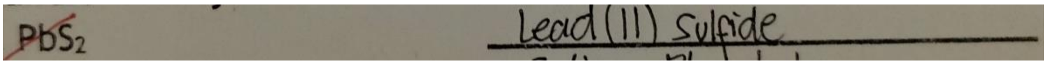
"I simply named the chemical formula. I used "di" in oxide since there are 2 ions in it."

Figure 14. The answer of learner 4 to item II.2

Naming ionic compounds that contain polyatomic ions is somewhat more difficult for the learners to answer since they show the inability to correctly name radicals (Baah & Krueger, 2012; Habiddin, 2014). Although Habiddin (2014) mentioned that this difficulty result from failing to memorize the names of polyatomic ions, the learners in the study are generally just confused about what set of rules in naming compounds should be followed.

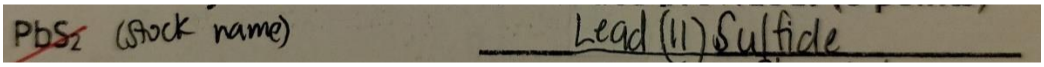
Misnaming transition metal ions with reduced subscripts of non-metal ions

Item number three is considered the most difficult question in naming ionic compounds part of the two-tier test as evidenced by the low percentage of students who named it correctly – 9%. The noted misconception is how to identify the charge of the metal ion in the compound. Since lead is found in Family B metals, it can make ions of different charges, in the case of PbS_2, the charge of the lead ion is 4+ as evidenced by the reduced subscript of sulfur in the chemical formula. The majority of students recognize that from the cross-charge method, the subscripts are the interchanged charges of the ions involved in the chemical formula but the learners were not able to analyze that the subscript found in Sulfur is already reduced into simplest form, thus their answer is Lead (II) sulfide. About this misconception, Figures 15 and 16 show unedited answers from learners 14 and 6 respectively.



"Using the stock method, I identified the cation first and then the anion, and given the formula PbS_2, we See that sulfur has a subscript of 2 so the lead will have a charge of 2."

Figure 15. The answer of learner 14 to item II.3



"I've come up with the answer by the process of Naming Ionic Binary Compounds- Stock Systems of naming. The first step I did is to write the Roman Numeral indicating the charge of the element written in parentheses after the English name of the metal. Then, the non-metal with the suffix-ide."

Figure 16. The answer of learner 6 to item II.3

Difficulties Encountered in Chemical Formula Writing and Naming Ionic Compounds

From the results of the two-tier test, it can be seen that the General Chemistry 1 learners have difficulties and misconceptions about chemical formula writing and naming ionic compounds. These difficulties observed in their answers were further probed and confirmed from the interview.

Generally, the learners find it difficult to look for the element symbols in the periodic table since they claim that they are not familiar with all of the element symbols. This explains why learners tend to misname some of the elements that are seen in the chemical formula of ionic compounds. For instance, learner 4 misnamed the element symbol Ca as carbon. Another common difficulty stated by the learners is that they are hard up in identifying what suffix to use in naming the concerned anions in the ionic compounds. Related to this, the usage of suffixes in naming polyatomic ions, especially oxyanions, was not followed correctly. When asked about their reasons, they said that they were confused about what rules on naming should be considered. Below is an excerpt from the interview of learner 8.

Learner 8: *"The methods in naming are confusing because there are too many methods that can be applied in naming."*

In addition, concerning the stock method of naming ionic compounds, the learners find it difficult to identify the charge of the involved transition metal ion when the chemical formula of the compound is given. They generally know that the subscripts in the chemical formula tell the charges of the ions but the learners are confused in identifying the charge of the transition metal ion, especially if the subscripts are already written in their simplest form.

Similar to naming ionic compounds, the learners also stated that their inability to recognize the symbols of elements present in the given IUPAC name of the compound makes it difficult for them to properly represent the compound in its chemical formula. Since they are not familiar with the element symbols and their names, they still need to inspect the periodic table of elements. Furthermore, the learners also mentioned that they find it difficult to identify the charges of ions if the only given is the IUPAC name of the ionic compound – the identification of the charges is important to correctly write the chemical formula, following the cross-charge method. It is also noted from the interview that the learners encountered difficulty in writing the subscripts found in the chemical formulae – they are having a hard time identifying where to put the subscript especially if the compound contains a polyatomic ion and they don't know what subscripts to be reduced in their simplest form. This confirms one of the results of the study conducted by Naah and Sanger (2012) that students exhibited confusion on how to properly use subscripts and coefficients in writing ionic compounds in a balanced chemical equation. Some excerpts from the interviews concerning these difficulties are as follows:

Learner 30: *"I am confused with the use of charges in the Criss Cross rule to write the subscripts and when to reduce them like reducing the subscript from 4 to 2."*

Learner 14: *"I am hard up in identifying the charges and writing subscripts of polyatomic ions to be enclosed in parenthesis."*

It is also important to note that learners experienced difficulty in writing the chemical formula of ionic compounds because there are too many rules to be followed and they are confused about what set of rules to use. This difficulty could be associated with what was described by Danili and Reid (2004) in their study on strategies to improve performance in school chemistry. They have mentioned that learning will fail if the working memory space is overloaded with information.

General Chemistry 1 Learners' Ways of Addressing Their Encountered Difficulties in Chemical Formula Writing and Naming Ionic Compounds

In the conducted interview, there are several ways in which the General Chemistry 1 learners tend to address in addressing their difficulties in chemical formula writing and naming ionic compounds. Based on their ways, the learners fit into some categories prescribed by the VARK model of learning styles. Most of the learners have said in their interview that one of their ways of addressing their noted difficulties is to reread the PowerPoint presentations related to the rules in chemical formula writing and naming ionic compounds. Aside from rereading the lectures in PowerPoint presentations, the learners also said that they go over their notes and try to memorize or familiarize themselves with the said rules and the table of common ions. With the mentioned ways of addressing their difficulties related to ionic compound nomenclature and chemical formula writing, these learners can be considered with a read/write learning style. Furthermore, other learners prefer to address their problems by listening to the lectures or review lessons given by the teacher. They often couple it with asking for some help from the teacher and/or from other learners in class for additional explanations, clarifications, and examples. These learners can be considered aural learners. Concerning their difficulty in identifying symbols of elements and their names, some students tried to employ visual learning by familiarizing the periodic table of elements. Lastly, some learners help themselves by watching video tutorials found on video-sharing websites that contain some visuals to explain how chemical formula writing and naming ionic compounds are done. In watching these videos, they are not only processing information with the use of the visuals but also with the use of the audio and text explanations embedded in the videos, hence they are employing multimodal ways of learning.

While there are several ways noted in addressing difficulties in chemical formula writing and naming ionic compounds, the are no recorded kinesthetic ways from the learners.

Conclusion

The study sought to understand the misconceptions of General Chemistry 1 learners on chemical formula writing and naming ionic compounds. In terms of chemical formula writing, the learners misrepresent ionic compounds as charged species, show a lack of understanding of valency and the use of the cross-charge method, and mispresent radicals. In naming ionic compounds, the learners generally misname not only some of the elements found in binary ionic compounds but also misname metal ions with more than 1 charge and polyatomic ions. These misconceptions were validated by the difficulties experienced by the learners in answering the two-tier test. The learners mentioned they experienced difficulty in naming some element symbols or representing the metal ions into symbols for they are unfamiliar with the periodic table. They are also hard up in naming the ionic compounds vis-à-vis representing them in chemical formulae because they are confused with the numerous rules to consider. Also, the learners mentioned that they are not quite sure how to identify the charges of the ions, where to put them as subscripts in the chemical formula, and when to reduce them in their simplest form. Despite the misconceptions and difficulties of the learners in chemical formula writing and naming ionic compounds, they mentioned several ways of addressing them. The following are their ways: (1) Visual learning – Familiarizing themselves with the periodic table of elements; (2) Aural learning – Listening to class discussions or reviews provided by the teacher and/or their co-learners; (3) Read/write learning – Reviewing PowerPoint presentations and their notes on chemical formula writing and naming ionic compounds; and (3) Multimodal learning – Watching video tutorials.

Recommendations

From this study's findings, the researcher recommends the following. For teachers of chemistry, it is recommended to fortify instruction of basic concepts in chemistry related to chemical formula writing and the nomenclature of compounds to avoid alternative conceptions. The periodic table should be maximized not only to make students familiarized with the names and symbols of elements but also to make students aware that the periodic table can also be used to identify charges of metal and non-metal ions. Before naming ionic compounds and writing their chemical formula, lessons on naming and representing ions and polyatomic ions in symbols should be taught properly. Visual representations of the cross-charge method can also be used to show how the subscripts are formed and how they are simplified in attaining the chemical formula of an ionic compound. The use of the Stock system in naming ionic compounds with transition metals should also be revisited. Furthermore, students' learning styles should be considered to effectively plan for instruction.

Information to be given should be chunked to avoid overloading of working memory space. For future researchers, it is recommended to conduct the study on college students taking General Chemistry courses to see if they have the same results. Since this research only dealt with understanding the misconceptions and difficulties of General Chemistry 1 learners related to chemical formula writing and naming ionic compounds and how they address them, it is therefore recommended that a study on a teaching strategy or intervention to improve performance is to be done.

References

Amazona, Jr. P., & Vallejo, O. (2020). naming compounds, writing formulas, balancing equations abilities and it's correlates. *International Journal of Scientific and Research Publications, 10* (3), 412-419.

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.

Celikkiran, A.T. (2020). Examination of secondary school students' ability to transform among chemistry representation levels related to stoichiometry. *International Journal of Progressive Education*, *16*(2), 42–55.

Creswell, J. (2009). *Research Designs: Qualitative, quantitative, and mixed methods approach* (3rd ed.). SAGE Publications.

Danili, E. & Reid, N. (2004). Some strategies to improve performance in school chemistry, based on two cognitive factors. *Research in Science and Technology 22*(2), 203–226.

Department of Education (DepEd). (2016). General chemistry 1 and 2 curriculum guide. https://www.deped.gov.ph/wp-content/uploads/2019/01/General-Chemistry-1-and-2.pdf

Dula, D. (2018). Improving the problems of writing chemical symbols, formulae, and chemical equations action research. *Annals of Reviews Research*, 4(3), 1-9.

Espinosa, A., Nueva España, R. & Marasigan, A. (2016). Investigating pre-service chemistry teachers' problem solving strategies: Towards developing a framework in teaching stoichiometry. *Journal of Education in Science, Environment and Health (JESEH), 2*(2), 104-124.

Fitriani, H., Imanda, R., Rahmi, A., & Nurmalinda, S. (2021). The development of flashcard learning media based on make a match on colloid. *International Journal for Educational and Vocational Studies*, 3(5), 373. https://doi.org/10.29103/ijevs.v3i5.6069

Fitriani, H., Situmorang, M., Darmana, A. (2017). Pengembangan bahan ajar inovatif dan interaktif melalui pendekatan sainstifik pada pengajaran larutan dan koloid. *Jurnal Edukasi Kimia (JEK)*, Vol. 2 No. 1: 48-53

Glažar, S. A., & Devetak, I. (2002). Secondary school students' knowledge of stoichiometry. *Acta Chimica Slovenica*, *49*(1), 43-53.

Gulacar, O., Overton, T., Bowman, C. R., & Fynewever, H. (2013). A novel code system for revealing sources of students' difficulties with stoichiometry. *Chemistry Education. Research and Practice*, 14(4), 507–515. https://doi.org/10.1039/c3rp00029j

Habiddin, H. (2014). The 1st year chemistry undergraduate students' understanding in naming simple compounds. *Proceeding of International Conference on Research, Implementation and Education of Mathematics and Sciences.* https://doi.org/10.13140/RG.2.2.17579.23840

Hines, C. (1990). Students' understanding of chemical equations in secondary schools in Botswana. *School Science Review, 72*(285), 138-140.

Hinton, M.E., & Nakhleh, M. B. (1999). Students' microscopic, macroscopic, and symbolic representations of chemical reactions, *Chem. Educator*, 4, 158–167.

Johnstone, A.H. (1993). The development of chemistry teaching. *Journal of Chemical Education*, 70(9), 701-705.

Lazonby, N., Morris, J.E., & Waddington, D.J. (1982). The muddle some mole. *Education in Chemistry 19*, 109-111.

Naah, B. M., & Sanger, M. J. (2012). Student misconceptions in writing balanced equations for dissolving ionic compounds in water. *Chemistry Education Research and Practice, 13*(3), 186-194.

Savoy, L. G. (1988). Balancing chemical equations. *School Science Review, 69*(249), 713-720.

Shaw, D. (2003). Inorganic Nomenclature. *Journal of Chemical Education, 80*(6), 711.

Shaw, D. & Yindra, L. (2003). Inorganic nomenclature. https://www.chemedx.org/JCESoft/jcesoftSubscriber/InorgNomen/index.html

Sintia, I., Rusnayati, H., & Samsudin, A. (2019). VARK learning style and cooperative learning implementation on impulse and momentum. *Journal of Physics: Conference Series, 1280*(5), 1–7. DOI: 10.1088/1742-6596/1280/5/052032

Sirhan, G. (2007). Learning Difficulties in Chemistry: An Overview. *Journal of Turkish Science Education, 4*(2), 2–20. https://dspace.alquds.edu/handle/20.500.12213/742

Stake, R. (1995). The art of case study research. Thousand Oaks, CA: Sage.

Taber, K. S. (2019). *The Nature of the Chemical Concept: Constructing chemical knowledge in teaching and learning*. Cambridge: Royal Society of Chemistry.

Taskin, V., & Bernholt, S. (2014). Students' understanding of chemical formulae: A review of empirical research. *International Journal of Science Education*, *36*(1), 157-185.

Tüysüz, M., Ekiz, B., Bektaş, O., Uzuntiryaki, E., Tarkın, A., & Alemdar, M. (2011). Pre-service chemistry teachers' understanding of phase changes and dissolution at macroscopic, symbolic, and microscopic levels. *Procedia - Social and Behavioral Sciences*. https://doi.org/10.1016/j.sbspro.2011.03.120

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.

Wood, J., & Donnelly-Hermosillo, D. (2019). Learning chemistry nomenclature: Comparing the use of an electronic game versus a study guide approach. *Computers & Education*, 141, 103615. https://doi.org/10.1016/j.compedu.2019.103615

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