individual species in the given formula. After that, based on their knowledge about names of at least the first 20 elements, they are taught the principles of naming compounds. It is at first surprising to note that they cannot do any of these when they enter the universities after Grade 12. This crop of trainees was not familiar with common names perchlorate, chlorate, chlorite, or hypochlorate for oxyanions of chlorine, as discussed for nitrogen, phosphorus, and sulfur in earlier submissions. Studies in the past have shown that most of these Ghanaian students only learn about some basic reactions and the subsequent outcomes by rote and not on principles (Hanson et al., 2011). Thus, during the remediation process, especially with the control group, trainees had to be taken through pictorial exercises where the particulate nature of reactants was depicted diagrammatically to show how they "broke up" and "re-joined" through ionic bonding to form new compounds were shown. Basic questions such as "how many chloride ions are bonded to each silver ion in silver chloride" were asked when trainees were to carry out a chemical reaction to form silver chloride from sodium chloride and silver nitrate. Then, the turning point question came up, where they had to give answers for their (correct) observations, if they could. In this particular exercise, the microactivity was also carried out, so the evidence of a precipitate (AgCl) from two non-precipitant reactants could be easily observed and appreciated by the trainees that a new compound had been formed.

The trainees' challenges could be attributed to their inability to form proper conceptual mental models, regardless of the practical activities that they engaged in. To understand how compounds are formed, learners must first understand how chemical reactions occur, how bonding occurs, how molecules interact, and what determines whether an interaction would be favorable or not; only then, can the outcome of the compound to be formed be determine. This chain of processes is oversimplified at lower grades and sometimes also taught in a rote-like manner by teachers who never understood the underlying principles of compound formation. Factors such as the thermodynamic processes involved, the nature of reacting species, the compatibility, and the feasibility of all must be considered. Talanquer (2008) carried out a study to find out the extent to which learners intuitively use an additive framework to predict the properties of a chemical product, rather than an approach that recognizes the emergent nature of the properties of chemical compounds. He found that most students relied on an additive heuristic to predict the properties of chemical compounds. They overlooked the possibility of emergent properties that could result from the interactions of atoms that composed the system. He suggested that teachers provide diverse opportunities for learners to identify properties in a variety of contexts.

The experimental group performed relatively better in writing word formulae and matched them correctly with their symbolic forms. This could also be related to the observation that they learned to associate word and symbolic formula (microscopic models) with images (macroscopic models) in their minds. The worksheets afforded the experimental group, the opportunity to participate in lessons more actively through the expression of individual thoughts, thereby taking responsibility for their actions and forming decisions through them. Thus, meaningful learning was achieved as per the constructivist paradigm. This led to the ingrain of permanent learning which was confirmed through results from the retention test. There is, therefore, a high possibility of using worksheets to improve learning outwardly and certainly momentarily. This possibility was confirmed when the trainees in the control group were introduced to pictorial diagrams on their board during remediation. In this exposure, they were taken through processes to appreciate the conceptions of elements and mixtures such that they were able to distinguish them from elements using atomic and molecular cores (nuclei). Similar observations where interactive approaches enabled the formation of mental conceptual models were made by Hanson (2017), Celikler (2010), Toman and Ergen (2014), Yakmaci-Guzel and Adadan (2013), and Yildrim et al. (2011).

The difference between the two groups in this current study was wider than observed in the post-test, in favor of the worksheet group ($\rho = 2.5 \times 10^{-12}$). This value implies that the constructivist worksheet prompted and promoted the ability to recall learning tasks and events at various levels of particulate interaction even 2 to 3 weeks after treatment. Three trainees in the control group had conceptual challenges with writing correct names for some elements and compounds. After their second exercise, it became evident that the basic particles in reactants could not be easily identified by some of the teacher trainees, especially those in the control group. For example, if an item (question) required them to identify the constituent particles that were contained in each of some given reactants that were to go on to form a feasible chemical compound from a chemical reaction, they failed to identify the particles correctly. A typical example was when they had to identify the particles in silver chloride (AgCl) and sodium nitrate ($NaNO_3$). The elements that could have been identified in silver chloride were silver and chlorine and the ions, silver ions and chloride ions. In the second reactant, they were to identify sodium (and its ions in a follow-up question) and then elements in the nitrate ion. Meanwhile, these posed challenges during class exercises. When asked to write the representative product, an even bigger challenge ensued. Formulae such as Na_2Cl, $NaCl_2$, Ag_2NO_3, $Ag(NO_3)_2$, and many more which were not too popular among the trainees came up. The principle of conservation of matter was again not applied by some students, which implied that they had conceptual misunderstandings. Numbers of species in the reactant and product sides did not sum up for both sides of their equations.

It was discovered from trainees' introductory worksheets during the treatment sessions that they had challenges with interpreting diagrams mentally. They failed to decipher the kind and numbers of each species that could possibly be found in the sub-microstate. Neither could they clearly distinguish among pictorial representations of particulate elements, mixtures, and compounds by using their cores, as mentioned earlier. This state where students have to decode and recode sub-microscopic species is very critical during the formation of chemical compounds. Mental visualization of abstract concepts was a skill that needed to be developed. Teachers have to discuss diagrams and photographs in textbooks or study materials at length with their students so that they come to appreciate the contextual effects. The principle of conservation of matter was not applied in trainees' interpretations of models on their worksheets. Trainees' initial inabilities to relate the models on their worksheets to occurrences at the microscopic level of chemical reaction were evident. For learners of chemistry to represent and interpret chemical compounds as correctly as possible, they must understand the basic nature of chemical change that matter is always conserved. Therefore, species presented in reactants must again be observed in the same quantities in their products. They must also be familiar with symbols of elements, their names, and patterns of common combinations and their names. For example, some common predictive outcomes to learn with understanding could be such as the reaction between acids and metals, alkalis or metal carbonates, and their subsequent products, as well as proper representation in word and formula form. Besides, discerning distinctions among matter must be gained through practice.

Familiarity and understanding of scientific terms or language were also identified as a problem for both groups but especially for the control group. Concepts such as "element," "mixture," and "compound" had to be well understood for the trainees to be able to form a better understanding of the concept of "compound" through distinction. For example, a trainee defining or ascribing a reason for a product being a compound with the statement, "it is a compound because it is a substance/product that consists of atoms of different elements joined together" is not definitive or distinctive enough. One would wonder what a mixture would be. Could the catchword for chemical compound be "different elements joined together"? Would teachers expect phrases like "chemically bound" to be more acceptable? One other shortcoming in that definition was that it was found not to include ionic materials. Therefore, it was important to give as much practice involving a variety of species to the teacher trainees and to ensure that, in each case, a "chemical reaction" was observed to have occurred, with correctly assigned reasons. This was found to be very important to facilitate the participants' understanding of reactions that result in compound formation. Obtained data from worksheets showed that components that learners invoke to make sense of properties of matter and chemical phenomena may change with sequenced and engaging tuition, but the underlying reasoning persists. Learners assume that observed tangible (macro) behaviors are dependent on the "types" of atoms present in a system and determined by those individual atom's inherent characteristics (Talanquer, 2017).

Chemical language is also specialized with governing rules that have evolved over the years, with their own meanings, functions, and syntax of chemical formulae, which cause problems for students. This was observed in how trainees failed to name chemical formulae of compounds that they had correctly discerned. Some of their naming errors resulted from strong mental associations between principles for naming binary compounds, trivial or familiar names, and lack of conceptual differentiation. Inability to properly differentiate between some formulae as was observed for the oxides of nitrogen and sulfur led the trainees to overlook the number of oxygen atoms attached to other central atoms, even as they paid undue attention to irrelevant entities during their naming tasks.

Through practice and group interactions, trainees in the experimental group were able to interpret diagrams appropriately, which subsequently facilitated their representational expressions from the MSE activities that they performed. Trainees in the control group, nevertheless, had to work extra hard to visualize and represent exactly what was happening at the microscopic level of reaction without much success, as they had no visual models and so failed to get their representational expressions of chemical reactions correct, especially in the retention test. This was enough to show that the worksheets had provided adequate forum for the experimental group to form mental images which they could fall on without practically engaging in laboratory activities. In this case, conceptual understanding was well developed; deep enough, to enable learners conceptualise in the abstract. This was because they were allowed and able to build and accommodate their own scientific concepts in a responsible, yet affable environment. Like other students in other parts of the world (Yan and Talanquer, 2015; Barke et al., 2009), trainees, in this study, had challenges with mental models and nomenclature of compounds as anionic parts of binary compounds were represented and named wrongly. If learners engage in learning by investigating, inquiring, collaborating, discussing, and forming mental models in multiple representational modes, they will learn more meaningfully and make conceptual gains, through distinction and the creation of patterns. Through the creation of patterns, learners' ideas could be organized into cohesive knowledge structures and reasoning schemas (Talanquer, 2017). It was also evident from the study that hands-on activities enhanced student learning.

Informal observations of the trainees at work showed that they were excited not only to work with the worksheets but also the MSE which was also a new concept that was introduced in the Chemistry and Physics Departments just before this current study. Studies by Hanson (2016), Sebuyira (2001), Supasorn (2015), and Zakaria et al. (2012) show that students who used micro equipment in other settings were excited and felt safe with their use, such that they disregarded fear of explosions as could occur from macrochemical activities. They saw these microactivities as fun and it engaged them in an interactive manner as the traditional tuition could not. This was what Hake (1998) meant when he said that lessons must be engaging and interactive for learners to form their own concepts in a nontasking and friendly manner. Sometimes, predictions about the outcomes of chemical reactions that trainees had to perform before engaging in the microactivities were expected. After obtaining their experimental results, they had to compare them with their predictions and then compare them with theoretical results or models. This further enhanced their generalizations of how different compounds could be formed for application in new situations when no practical activities could be performed. Such "personal-formed" correct and authentic concepts are often held for long periods before learners forget them as was observed from the results of the experimental group's test scores in this study.

CONCLUSIONS

It was determined that teacher trainees had a number of misconceptions about how chemical compounds were formed for which remediation was attempted successfully. Basic concepts such as element, mixture, physical change, and chemical change had to be well understood for the concept "compound" as well as its underlying principles for its formation could be appreciated by trainees. The study supports earlier research that has revealed that many students struggle to understand chemical reactions. Students often have differentiation problems and over rely on basic over-simplified knowledge that must be extended and expanded. It was deduced that most of the trainees' cognitive structures for knowledge constructs and reasoning strategies were implicit as they exhibited representations of the properties of diverse types of chemical entities, events, processes, and states without attributing them to any particular pattern. Teachers must, therefore, develop clearer understanding of student reasoning as was attempted in this study.

The use of the activities in this study initiated reflective thinking skills in the teacher trainees. This enabled them to acknowledge some deficiencies in their naive idiosyncratic thinking processes about compound formation overtly and restructured them. This progress was because the trainees were able to gain visuality and tangibility (Say and Ozmen, 2018) not only through the worksheets but also through the practical activities (Sebuyira, 2001; Supasorn, 2015; Zakaria *et al*., 2012). Again, the activities increased the teacher trainees' retention spans, interest, and motivation for learning. Thus, the possibility of using worksheets to enhance conceptions about the formation of chemical compounds is favorable. The alternative conceptions identified in this study showed similar patterns with findings from related literature about students' conceptions of matter and its behaviour, which implies that it is a global problem that requires attention but could be solved using worksheets when all other modern technologies prove unattainable as was observed in this study. In this study, the teacher trainees showed interest and joy in the use of both microscale equipment and the worksheets, which together facilitated conceptual understanding of principles that govern the formation of chemical compounds; yet, a few conceptual difficulties persisted in their reasoning. Their explanations for chemical compounds were more of molecular than ionic models and so would require more laboratory practice, identification, and worksheet practice that involve ionic compounds.

IMPLICATIONS

This study has several implications for teaching and learning. It is important to note that the participants in this study were undergraduate students who were trained to become future teachers. Therefore, it was important that their own conceptions were identified and corrected early, if misconceptions existed, so that they would not transfer their wrong ideas and inefficiencies to their future students. It also has implications for chemistry curriculum developers and chemistry book writers so that they include more interactive and engaging activities in chemistry curricula and textbooks. Definitions of basic concepts which culminate into or form part of the conceptual framework for chemical compounds must be defined in diverse authentic ways so that learners gain "secure" conceptual models of each contributing concept. For example, terms such as elements, mixtures, physical change, chemical change, energy change, and a few more will have to be explained and connected in meaningful ways so that learners can also apply them appropriately in descriptions about the nature of matter. Besides these three suggestions, interactive strategies would have to be developed to teach chemical compound formation, as this topic forms one of the bedrocks of sound chemistry teaching and learning. Furthermore, the results are beneficial to educators who are particularly interested in conceptual development and learning progression.

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APPENDICES

Appendix A: Pre-test/Post-test

1. What particles (such as ions, atoms, and molecules) are present in sodium hydroxide and hydrochloric acid?
2. Aqueous sodium hydroxide reacts with aqueous hydrochloric acid to form.
   ....
3. What particles would be present after aqueous sodium hydroxide and hydrochloric acid react?
4. Would you say that a physical or chemical change has occurred?
5. Explain how the particles are bonded to each other. State the numbers of particles in the combinations.
6. Make a schematic or two-dimensional sketch of the reactants and products formed.
7. Write out the reaction in word and formula form.

Appendix B: Abridged Retention test

Write formula equations for the reactions below (1–4) and write the names of the resulting compound. Explain why you have formed your products of choice.

1. Trioxonitrate (v) acid reacts with aqueous calcium hydroxide.
   ....
   From items 5–8, fill in the missing species and explain your answer
4. Zinc carbonate +. → Zinc sulfate
   I write this answer because...
   For items 9–10, choose one of the answers given and explain your choice
9. What are the products of the reaction between aqueous barium hydroxide and hydrochloric acid?

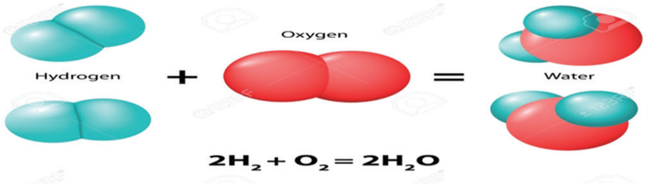
a. Barium chloride and water	c. Barium chloride and barium hydroxide
b. Barium hydroxide and water	d. Hydrochloric acid and barium

   I make this choice because …………………………………………………………….
10. Would you say that the change in Q9 is a physical or chemical process?
   Explain:………………………………………………………………………….

Appendix C: Sample of Worksheet

Complete the following word equations and explain your reason for supplying the missing components

1. Nitric acid +............. → potassium nitrate + water
2. Magnesium + dilute tetraoxosulfate (vi) acid →.............
3. Calcium carbonate + hydrochloric acid (aq) →.............
4. Sodium + sulfur →.............
5. Rubidium + salt solution →.............
6. Acid + alkali →.............
7. Interpret the figure below with respect to events at the particulate level:



Appendix D: Examples of daily class exercises

1. Sodium reacts slower with water than potassium metal
   i) True ii) False
   Reason
   a) Sodium metal is smaller and so forms a second layer of water molecules around it, rendering it slow in reacting with water,
   b) Potassium metal has a heavier mass and so reacts more vigorously with water,
   c) The bonding in potassium metal is not as "tight" or compact as in sodium metal due to its large size,
   d) Both sodium and potassium atoms have a valency of one but different sizes (sodium being smaller). Therefore, cohesive forces are stronger in sodium, thereby making it react less vigorously with water.
2. Predict whether aluminum would react faster or slower than magnesium with water.
   i) Aluminum ii) Magnesium
   Reason
   a) Aluminum will react faster than magnesium because it has a larger atomic number and more valence electrons,
   b) Calcium will react faster than aluminum because it is bigger in size and has less valence elections,
   c) Magnesium will react faster than aluminum. Reactivity of the elements with water increases down the group and decreases across a period. The factors which account for this are size, electronic configuration (valence electron), and nature of species concerned,
   d) Aluminum will react faster than magnesium. Reactivity of the elements with water increases down the group and decreases across a period. The factors which account for this are size, electronic configuration (valence electron), and nature of species concerned.

In the following questions, you will be required to make a choice by placing a tick (√) against a statement you think is correct and then justify the choice you have made in the space provided.

3. ☐ Br^{7+} is more stable than Br^- ……………………………………………….
   ☐ Br and Br^- are equally stable ……………………………………………….
   ☐ Br is less stable than Br^- ……………………………………………….
   ☐ I do not know …………………………………………………………….
   I make this choice because…………………………………………….
4. ☐ Mg^{2+} is more stable than Mg ………………………………………….
   ☐ Mg^{2+} and Mg are equally stable ………………………………………..
   ☐ Mg^{2+} is less stable than Mg ……………………………………………
   ☐ I do not know ………………………………………………………….
   I make this choice because …………………………………………….
5. Read the statement and choose whether a definition is correct or wrong. Decide if the definition is helpful and state why you made that choice: An element is a substance which cannot be split up into simpler substances. Is the definition correct? Would it help someone to understand?
   ☐ Yes
   ☐ No, it is wrong
   ☐ I am not sure
   I make this choice because ……………………………………………………

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Appendix E: Sample of tiered practical activity sheet

How many drops were added? A [2]… A [3]:… Average:…

Q1. What is the volume/Ratio of aqueous sodium hydroxide to Acid A?

i) Repeat steps iii and iv in wells A [4] and A [5] but use B now instead of acid A. How many drops of aqueous sodium hydroxide did you add? Why did you have to add the said drops?
A [4]:……… A [5]:……… Average:………

Q2. What is the volume ratio of NaOH (aq)/Acid B?

Q3. From your outcomes, what is the answer to the focus question above?

Q4. What can you conclude about acids A and B? Give possible molecular formulae for acids A and B.

Q5. Write and balance equations for the proposed reactions between the sodium hydroxide solution and acids A and B.

Q6. a. Find the amount of substance contained in 25 cm^3 of 0.10M NaOH (aq).

b. What would be the amount of substance contained in 25 cm^3 of 0.10 M acid B, if it should react with 25 cm^3 of 0.10M NaOH (aq)? Explain how you obtained the answer why it is so.

Q7. a. Explain the terms precision and accuracy.

b. Are the volumes of base used precise or accurate? Explain

Q8. If the average number of drops of base required to titrate 6 drops of acid A was experimentally determined to be 8 while the true value should have been exactly 6, would the experimentally determined results be imprecise or accurate? Explain your choice in detail.