Learning Chemical Reaction Via Augmented Reality

Mohd Anuar Nasri Bin Nasir
anuar@jenan.my
Department of Educational Science, Mathematics and Creative Multimedia, Faculty of Education, Universiti Teknologi Malaysia

Noraffandy Yahaya
afandy@utm.my
Department of Educational Science, Mathematics and Creative Multimedia, Faculty of Education, Universiti Teknologi Malaysia

Nor Hasniza Ibrahim,
p-norhaniza@utm.my
Department of Educational Science, Mathematics and Creative Multimedia, Faculty of Education, Universiti Teknologi Malaysia

Mohamed Noor Hasan
mnoor@utm.my
Department of Educational Science, Mathematics and Creative Multimedia, Faculty of Education, Universiti Teknologi Malaysia

Abstract

The possibility of using Augmented Reality (AR) program as supplementary material in learning chemistry is evaluated in this paper. Chemistry is regarded as difficult to learn due to abstract nature of the subject. The content learning of the subject comprises multiple levels of representation, which challenge the conceptual understanding and problem solving of a student. This study is trying to identify the difficulty of learning chemistry particularly in acids and bases topic in term of conceptual understanding and algorithmic problem solving. Students are known to consistently make mistake writing the symbol of chemical formulas and also confused between the use of subscript and coefficient of a chemical formula. These eventually lead to wrong stoichiometry in balancing the chemical equation. The mistakes snowball into bigger problems when students are not able to understand the chemical equation in term of the algorithm and also conceptual. In order to the address the issues, students' understanding regarding the chemical reaction of acids and bases should be investigated to elucidate student alternative conception if any in order to suggest suitable features for learning acids and bases chemical reaction using the AR program. As the issue is considered prevalent, the need of effective and promising solution is critical, thus AR should be evaluated as a supplementary teaching aid. AR helps students in visualizing the microscopic part of the reaction hence should promote correct understanding of the chemical reaction. The technology is considered recent and the use in chemistry field has been reported. However in chemical reaction learning, data supporting the effectiveness of the AR program is still insufficient. The effectiveness of the program towards students' algorithmic problems solving and conceptual understanding in the acids and bases topic can be investigated. The results from the study should suggest the significance of the AR program in learning chemical reaction and equation in chemistry.

Keywords: Augmented Reality, misconception, chemical reaction

1.0 Introduction

Chemistry is closely associated with chemical formula and equation. Anybody who is exposed to scientific knowledge will be able to relate chemical formula like H_2O with chemistry. However, the subject is seen by students as difficult to master (Halim et al., 2010; Sirhan, 2007) . The abstract nature of the subject, which means student have to learn about intangible concept such as particle and chemical bond. Hence could consequently result in weak understanding of important concept in chemistry.

Chemistry as any other science field, make use of symbolic languages extensively to convey ideas in term of algebra, numerical data and graphical forms. Symbolic representation such as chemical equation has important characteristic, which able to relate between macroscopic level and theoretical level of sub-microscopic model hence single chemical equation can explains both macroscopic and also sub-microscopic. Thus, research on teaching and learning regarding the technical language is among the important focus in chemistry subject (Taber, 2015).

By definition chemistry is a branch of physical science that studies the composition, structure, properties and change of matter (?). The essence of the chemistry knowledge according to the definition lies in a simple chemical equation. A chemical equation can be seen as a standardize tool to shows composition of a substance, properties in term of the states of matter and also the change occurring. As the nature of the chemistry subject is complex and abstract, a simple chemical equation can be heavily informative to play a significant role in understanding many other concepts in chemistry. Chemical equation makes use of symbolic writing to represent macroscopic level of a chemical reaction. A reaction in chemistry refers to the transformation of chemical substances to another different chemical substances. As chemical substance is consisted of matter, which is made up of particles, the reaction suppose to be kind of interaction among the particles which resulted in change of the matter chemically and physically.

In order to write the chemical equation, student needs to have the skills to relate symbolic representation such as chemical formula with microscopic and macroscopic entity of the reaction (Gardner, 1990). The ability of the students to build chemical formula and balance the equation will depend on the higher order cognitive skills especially analytical thinking (Tikkanen & Aksela, 2012). Procedural knowledge of the student will also be tested in order to write a correct and balance equation, whereby sub-knowledge such as specific understanding of chemical symbol, method and technique to verify a correct chemical symbol and also algorithm aspect of the equation should be mastered by students prior writing the chemical equation.

2.0 Difficulty in Learning Chemistry

Many reports claimed the difficulty of learning chemistry subject arises because of the triplet levels of conceptual understanding namely macroscopic, microscopic and symbolic which underlying every concept of chemistry knowledge (Dumon & Mzoughi-Khadhraoui, 2014; Guerra, de Lara, Malizia, & Díaz, 2009; Naah & Sanger, 2013; Rau, Michaelis, & Fay, 2015; Taber, 2015; Yaman & Ayas, 2015). In 1982, Alex Johnstone stated that chemist thinks about chemistry in three level of representations that is macroscopic, microscopic and symbolic (Taber, 2013). At macroscopic level, scientific phenomenon involve any observable that can be detected by human sense. This includes chemical or physical processes such as change in states of matter like the dissolution of solids, the gas liberated at the electrode in electrolytic cell and precipitation of solid when lead (II) nitrate added to sodium chloride. To understand the phenomenon of the reaction at microscopic level, a students need to make inference from the macroscopic observation.

From a macroscopic viewpoint, a colourless liquid poured into another colourless liquid can be either physical process or chemical process. For example, when water is added into an acid the process is only dilution without any chemical change hence there is no difference at the microscopic level before and after the addition of water. However when an alkali solution is added to an acid, neutralization occur thus at microscopic level the reactants have change into another chemicals. A microscopic understanding needs student to distinguish the type of particles involves in the neutralization and the change happens to them. As molecule, ion and atom are abstracts and intangible, this can make a simple addition process of a chemical to another chemical becomes difficult to students, furthermore the concept of the particles itself needs student to have the knowledge in the structure of the atom and chemical bonds. Symbolic representation is a method to communicate about the macroscopic events by making use of chemical equations, reactions mechanisms and models (Treagust, Chittleborough, & Mamiala, 2003). By making use of symbolic representation, a macroscopic event and microscopic entity are represented in term of symbolic such as chemical formula and equation.

The difficulty in learning chemical reaction also has to do with the level of cognitive needed to understand the concept. A study was conducted to analyze Finnish chemistry Matriculation Examination questions according to cognitive complexity reported a question asking about a chemical reaction may be classified as high order cognitive skills (Tikkanen & Aksela, 2012). For example, in a question asking about volume of acetylene forms when calcium carbide reacts with water, students need to analyze the question and write the chemical equation prior calculations to get the answer. In this case, successful answer is determined by the ability of the students to write a correct balance chemical equation, which has two characteristics; correct formula of reactants/products and also the equation must be balanced.

For the students to apply correct formula in writing the chemical equation, some students may memorize the formula or also write it via certain techniques taught by teacher. It was found that when students finally write a formula of a certain compound they wrongly provide the coefficient and the subscript of the formula (Sanger, 2005). Subscript error also reported when students write the ionization equation of salt in water (Naah & Sanger, 2012). As subscript determine the identity of a chemical formula (i.e; H_2O is water and H_2O_2 is hydrogen peroxide), the inability of students to write the chemical formula correctly prevents students in understanding further chemistry concept which might rely on the correct formula of the reactants and products, hence permit the writing of a balanced equation.

Another issue found was the inability of students to determine correct formula of products from a reaction between two reactants. Instead of new compound formation when reactants break its bond and products' form new bonds, students viewed chemical equation as an addition process i.e; $N_2 + O_2 \rightarrow N_2O_2$. In this case, the uses of subscripts in the product of the equation were carried over from the subscript of the reactants. This shows students understood compounds undergo reaction via combination to form new product with the same subscript (Ben-Zvi, 1987).

There are many other aspects of chemical equation that students have difficulty to understand reported by various researcher such as understanding the meaning, function, setting up and interpreting the chemical formula. In a review regarding students understanding of chemical formula, Taskin & Bernholt (2014) claimed students' difficulty regarding chemical representation (chemical formula, chemical equation etc.) is a persistent problem among students who learn chemistry. Though with time, student should be able to built correct conception, however the problem still can be found among university students.

Students' difficulty in learning chemistry is acknowledged by educational researcher. Learning chemistry, which involved abstract concept leads students to misunderstanding and becomes their conception, which is not in agreement with the correct one. Researchers had conducted various studies to address the problem. A review of research by Ozmen (2004) regarding misconceptions among students in chemistry subject underscore various concepts held by students were not scientifically accepted. The areas which have been studied to assess students misconceptions among others are chemical reaction, chemical bonding, chemical equilibrium, atoms and molecules, acids and bases, mole concept, solubility and solution and particulate nature of matter (Özmen, 2004). Particularly in chemical reaction sub-topic, many studies had been conducted to identify students' misconceptions regarding chemical reaction (Andersson, 1990; Ayas dan ¨Ozmen, 2002; Ben-Zvi et al., 1987; Boo & Watson, 2001; Hesse dan Anderson, 1992; Ayas, Özmen, & Çalik, 2010). Related knowledge underlying the concept about chemical reaction were also studied such as in chemical bond concept (Coll dan Taylor, 2001, 2002; Coll dan Treagust, 2001, 2002, 2003).

3.0 Misconceptions

Misconception can be referred as conception built by learner about something that is not scientifically correct (Demircioglu, Ayas, & Demircioglu, 2005). The occurrence can be due to learner's prior knowledge result from the interaction of an individual with the environment. Naah & Sanger, (2013) had conducted a study to address the issue in term of physical changes of ionic compound when dissolved into water. It was revealed that majority of students held misconception regarding the solubility of magnesium chloride in water by assuming the dissolution process will produced acid and base (magnesium oxide wand hydrochloric acid). By giving base and acidic answer of the dissolution process, students perceived the process as chemical reaction instead of physical. The answer shows student understood the process as double decomposition, which Mg from the $MgCl_2$ combined with Oxygen of water hence forming MgO. The same goes with formation of acid, H of water combined with Cl from the salt to form HCl. This shallow understanding proves students have difficulty to relate the macroscopic and microscopic aspect of the reaction with the symbolic representation.

Among other indicator that students perceived chemical reaction as physical process is when students assume the arrow sign of a chemical reaction means an equal sign (Yarroch, 1985). Researcher also reported even simpler causes that make symbolic representation difficult for students to learn. Some students cannot remember or having difficulty deriving the formula of the compound when the compound name is given. Other problems alike are as found by Glazar and Devetak (2002) and Keig and Rubba (1993), students write elemental symbol wrongly for a given particular compound. Students also do not sure the ionic charge of certain ion in a compound hence provide wrong answer such as Na^{2+} from sodium sulphate, Na_2SO_4 and Cl_2^- for ion in $CaCl_2$ (Barke, 1988). The charged possess by an ion is assigned on the basis of chemical bond principle and is related with the structure of the atoms. In order for student to begin understand the whole package of chemical reaction, they must ensure the underlying concepts are understood correctly. This is a challenge for educators because research has shown that students develop understanding about atom and molecule gradually hence it takes a lot of time for them to establish deep understanding (Øyehaug & Holt, 2013).

The misconception about basic rules in writing chemical formula has lead to a more serious problem. Stoichiometry of an equation is a concept, which directly related to correct use of chemical formula and their related coefficient and subscript. Many researchers agree that students have difficulty in learning stoichiometry of a chemical equation (Dahsah, Coll, Sung-ong, Yutakom, & Sanguanruang, 2008). In a review of students' understanding of chemical formulae, there are many ways a stoichiometry of a chemical equation can go wrong (Taskin & Bernholt, 2014) such as students were found could not say whether changing a subscript of a chemical formula is permitted in order to balance the equation. The finding was similar to another study in which students had changed the subscript instead of manipulating the coefficient when were given chemical equation to be balanced (Savoy & Steeples, 1994).

A correct stoichiometry of an equation will help students in solving algorithmic type of chemistry problem. Subsequently, the understanding of the equation qualitatively and quantitatively will ensure successful algorithmic problems solving (Osman & Sukor, 2013). In term of quantitatively students must be able to relate certain concepts such as mole to be able to calculate parameters such as mass. This kind of question can be done heuristically if a teacher able to teach students strategy to be used to answer the question. However, Chiu (2005) argues that students who are able to answer algorithmic chemistry problems still could not understand the concept underlying the problem. The same finding by Agung & Schwartz (2007) surfaced when they conducted study regarding chemical equation and found that 72% students were able to answer correctly when were given a task to calculate the mass of water forms in a reaction of hydrogen and oxygen gas, but the number drop to 32% when researcher asked a simple conceptual problem. In these study it shows that the ability to write balance chemical equation and calculate necessary parameter from the equation do not guarantee the understanding of the process conceptually. Thus students who are able to solve algorithmic questions may not understand it conceptually hence failed to answer conceptual problem. The same finding keep on resurfaced such as in Salta & Tzougraki (2011) study, when it was found that students score in algorithmic problem was independent from conceptual problem score and also performance in algorithmic type of questions was significantly better. The studies had successfully indicate that a conceptual problems is much more difficult to understand for students compare to algorithmic.

Student different performance between algorithmic and conceptual is acknowledged but little is known regarding the cause. One can hypothesize different cognitive demand between the two types of problem, that is algorithmic is easier relatively to conceptual problem. However according to (Gabel, 1993) symbolic representation is the level which is probably have been given more attention by teacher in the teaching of chemistry subject. The statement make sense as among the triplet of the representation, teaching symbolic representation is easier relatively to teaching a chemical reaction at the macroscopic and microscopic level. This is because to teach symbolic representation will only make do of simple teaching and learning aids such as chalk and writing board, instead of teaching macroscopic level, which a teacher need to prepare and execute laboratory activity in order to provide students with observable phenomena. Apart from the emphasize on the symbolic level without giving the necessary attention to the macroscopic and microscopic level, the nature of chemistry learning which make use triple representation also play a big role. Although the three levels are well taught to student, they do not necessarily connected with each other accordingly so knowledge in a particular concept are separated in students memory (Gabel, 1993). To put into perspective, a student might be able to recognize a salt or base dissolution process, which is a macroscopic event but he or she could not see the difference of salt dissolving and a base dissolving chemically.

Another reason that may cause the misconception in understanding chemical reaction is from the introduction activity of chemical reaction to student as the rearrangement of atoms without giving complete understanding of changes happen to the atoms of reactants (Eilks & Moellering, 2007). This may be evident from the atomic model used in textbooks, research articles or reference books, which visualize chemical reaction using Dalton atomic model to represent particles. Hence without proper explanation about the change in chemical bond and subatomic particles interaction such as transfer or sharing of electrons, students simply assume chemical reaction as the physical process. There are many attempts made by researchers in order to overcome the difficulty of learning in regards of the multiple representations in chemistry subject by making use of visualization.

3.0 Visualization

In general, education community agreed that visualization is effective as teaching and learning tool (Vavra et al., 2011). Visualization is an important approach in teaching and learning but to make the approach effective in the sense of meaningful learning and understanding, interaction of the visual with students must be in higher degree (Patwardhan & Murthy, 2015). This means, the visualization should be enriched with features that promote good interaction between learner and the software. According to Concise Oxford Dictionary, the word 'visualize' means 'form a mental image of; imagine' and 'make visible to the eye' (Gilbert, 2005).

Traditionally, learning using graphics such as drawings and diagrams are realized using drawing on whiteboard. It is a natural approach practice by educators to deliver the content of teaching. However, the advance in computer technology, which permits the use of powerful computer's hardware fosters the use of advance visual such as computer animation in education field (Gilbert, 2005). Moreover, advancement in digital image processing technological aspect especially in manipulating the visuals from one form to another also has attracted researcher attention (Lynch, 2015). Hence these conditions promote visualization as the alternative to traditional approach in teaching and learning.

According to Vavra et al., (2011) visualization is used to describe the process of creating graphical representation and there are three discrete crucial characteristics to understand visualization conceptually. Firstly 'visualization object', that is tool such as pictures, models, diagrams and illustration, which are delivered in different kind of media such as papers, videos and computer display. Secondly 'introspective visualization' which is the imagination of the mind regarding certain object. Lastly 'interpretive visualization', which is the inference made by the mind regarding introspective visualization and visualization of an object. Interpretive visualization is a result of cognitive activity after the mind interacts with the other two domain of visualization. As introspective and interpretive visualization involve the role of mind, both of them can also be considered as one. Hence there are two types of distinct visualizations. Visualization can be either 'internal visualization' or 'external visualization. Internal visualization some times also known as mental images (Gilbert, 2010).

A model that is represented for learners' visual perception and observation is an external visualization. Many efforts are made by researchers to build models for representation of certain chemistry concepts. Some of the example of visualizations used in order to enhance students understanding among others is Electrostatic Potential Maps (EPM) (Hinze et al., 2013). EPM visualizes electron distribution in a molecule where colour is utilized as a mean to show the polarity of different part of a molecule. Zhang & Linn (2013) have studied dynamic visualization using Web-based Inquiry Science Environment (WISE) draw tool to guide students in learning chemical reaction. The visualization was made to illustrate particles in motion when combustion occurs. Other special feature added into the visualization is the capability of the tool to be interactive thus enhance students experience by utilizing play, pause and reset program. Furthermore, students also could manipulate the energy to start the combustion process using a 'spark' button. Other advance visualization in chemistry such as virtual reality technology has made students more able to perceive the molecular structure and the changes happen during a chemical reaction (Laminou et al., 2008).

Martin et al. (2011) has conducted a study to analyze the evolution of technology trends in education from 2004 to 2014, the study reported new technology such as augmented reality (AR) that emerge in parallel of the advance in mobile device such as mobile phone and tablet. AR is relatively a new approach in visualization. The technology closed the gap between virtual reality and the 'true' reality in the sense that it is an extension of the virtual reality by providing a smooth and continuous interface for users that merge both real world and virtual world (Cai et al.,, 2014). 2015 Horizon reported that studio for AR learning is trending in the future particularly in the next three years.

4.0 Augmented Reality (AR)

AR is the extension of virtual reality that provides seamless interface which combine reality from the true world and virtual (Cai et al., 2014). The use of AR is the latest visualization technology that is able to bring visual of difficult to replicate phenomena or too dangerous to be simulated. Augmented reality (AR) is more than a set of technologies, it is a medium that not only engages human visual perception, but also can be made interactive (Craig, 2013a).

What made AR special compare to other visualization technology is it has characteristic that able to add digital information to the real world that we see visually. The technology is made to realize object visually so that an absent object can be made up and seamlessly combine with the real world. The advance of computer technology again has become one of the reasons this sort of visualization emerges in many fields of application. Todays computer capability such as vast storage of data and powerful processing capability has increase the ability of the computer to alter and augmenting the environment such as rendering three-dimensional (3D) computer graphic and creating objects that are impossible to be created in real environment (Craig, 2013b). As mention earlier, learning chemistry consists of many abstract concepts and students are not able to visualize structure of microscopic objects correctly especially at the early stage of learning chemistry (Cai et al., 2014). Cai et al. (2014) in a study of using AR learning tool in chemistry course for grade 2 students in China, it was found that AR has benefits low-achieving students in understanding the particles (molecules and atoms). As higher achieving students already able to understand the concepts correctly thus close the gap of having misconception, low achieving students on the other hand have higher margin for improvement, which can be achieved by using AR medium. One of the reasons why low achieving students are not able to visualize the microstructure of particles is the lack of visuospatial thinking.

Though the use of AR seems promising in the area of visualization, the research in education using the technology is still considered less matured relatively compared to other multimedia or web-based platform supported learning thus several initiatives need to be done in order to gain deep understanding regarding the use of the technology in learning (Wu, Lee, Chang, & Liang, 2013). The initiatives among others are to have more research that includes large sample and valid instrumentation. At this point of time, as the use of AR is still in the early stage particularly in certain area of subject such as chemistry, data and analysis of AR implementation in learning are still not quite enough. Hence there is not much information about AR especially on the features and affordance of the technology in order to highlight the educational value of AR, which cannot be offered by other media to support learning.

5.0 Conclusion

Chemical equation and reaction are the area, which is considered essential in learning chemistry. Beyond the equation, students are needed to infer a lot of information to come about correct conceptual and hopefully able to do various type of problem solving. Many reports are able to elucidate the problems or misconceptions regarding the learning of chemistry, almost every area or sub-chapter in chemistry syllabus has been highlighted in term of difficulties faced by learners. However, the problems have common ground, which indicates the root cause is students' lacking in dealing with multiple representation in chemistry.

Symbolic representations, which involve chemical formula, subscript, coefficient and other algorithm related knowledge have been prevalent problems in learning chemistry. Yet, report regarding suitable interventions and sufficient data to support the effectiveness of the interventions are still scarce. As microscopic world of chemistry is indeed intangible and difficult to be observed, visualization is a logic solution in order to relate the microscopic part to its symbolic representation. This in turn should improve learner conceptual and algorithmic understanding. This study is investigating the possibility of using the latest trend in visualization, which is augmented reality. Augmented reality, which is positioned between true reality and virtual reality is suitable to visualize the microscopic world of chemistry particularly particles and sub-atomic particles and at the same time still relates the 'made-up' visual to the real macroscopic world. This is important because the learning of chemistry should involve macroscopic, microscopic and symbolic at once to promote good understanding of the concept.

Augmented reality developed for the purpose of understanding chemical reaction can be a useful learning aid to help teacher overcome the difficulties in learning the topic. Hence this research is an attempt to address problems in chemistry learning, which had been frequently reported by applying the most recent and suitable tools. The results of the research should provides solution for the problem in learning microscopic and symbolic representation that continue to occur although it has always been highlighted by researcher.

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