IJAMS
INTERNATIONAL JOURNAL OF ADVANCED MULTIDISCIPLINARY STUDIES
Volume 1, Issue 2, ISSN: 2782-893X

5e's Teaching and Learning Model for A 21st Century Science, Technology, Engineering and Mathematics (Stem) for the Program in General Chemistry 1

RUSSEL T. SOLTURA, PHD
Quezon Science High School
Department of Education – Quezon
russel.soltura@deped.gov.ph

ABSTRACT

This study aimed to test the effectiveness of 5E's learning model instructional material in General Chemistry 1. Perceived difficult topics in General Chemistry 1 were determined during the first semester. The respondents were the 250 Grade 12 students enrolled in STEM strand of Senior High School and the 71 science teachers of the four (4) selected schools within DEPEd Division of Quezon, S.Y. 2017 – 2018. Questionnaires were developed to determine the perceived difficult topics, the factors that make the topics difficult in General Chemistry 1 and the level of acceptability of the instructional material. The material and the achievement test were developed, evaluated and validated. Science teachers perceived "stoichiometry", "gases", and "electronic structure of the atom" as difficult topics. In general, learning environment, nature of the topics, student and teacher-related factors made the topics difficult. The material included the perceived difficult topics. Both groups are equivalent in pretest scores and Grade 11 general average since the t-values of 0.92 and 0.45 are less than the tabular value of 1.96 at α=0.05. Hence, posttest-only controlled group design was used. There is a significant difference between the two (2) groups in terms of posttest scores since the t-value of 10.58 is higher than the tabular value of 1.96 at α=0.05. It means that students who are exposed to 5E's learning model performed well in the said subject as compared to the controlled group. Students strongly agree when it comes to the acceptability of the material.

KEYWORDS: 5E's learning model, STEM curriculum, difficult topics, chemistry

Introduction

Throughout the previous decades, science education highlighted strategies to improve the quality of science education and enhance effective school-based science education programs. Today, there are challenges among science educators because their principal duty is to foster inquiry-based instruction (National Research Council, 2012). Lee, Quinn, and Valdes (2013) pointed out that preparation connected to science describes inquiry-based scientific concepts. They are similar with scientific inquiry and help the learners comprehend and employ science in real-life situations. Hence, Science, Technology, Engineering and Mathematics (STEM) Program for the Senior High School (SHS) was developed.Science, technology, engineering and mathematics (STEM) is a strand for senior high school within the academic track, which is in fact created on

the notion of educating the learners in four (4) particular subjects in an integrative and realistic approach. Instead of teaching the four (4) disciplines as isolated and distinct subjects, the STEM strand place collectively these disciplines into a coherent paradigm created on real life and genuine applications (Hom, 2014). Global affairs for enhancing STEM education have been strengthened and intensified in the previous decades and reveal no indication of such low performance in learning (Caprile et al., 2015; Prinsley & Baranyai, 2015; Honey et al., 2014; The Royal Society Science Policy Centre, 2014; Marginson et al., 2013). Cruz (2014) also stressed that learners from STEM are expected to become an expert in the field of science to elucidate and rationalize more complex science disciplines. One of the specialized subjects to be taken in the said strand is General Chemistry 1.

The decline in science education emanated from the notion of Gagnon and Mattingly (2012), who studied schools' plan and other systems related to schools' resources and its distribution, as well as tracked result of shortage of some instructional materials, including books. In addition, after educators examined DEPEd textbooks, they detected several errors (Ortilla, 2015). These problems may lead to low academic performance among the learners, which led to the low performance of the Philippines in the 2015-2016 Global Competitiveness Report of the World Economic Forum, in which our country ranked 67th out of 140 countries in terms of the quality education for mathematics and sciences. Moreover, based from 2016-2017 data, the country ranked 79th out of 138 in the said disciplines (Dela Cruz, 2017). In order to solve the said problem, it is very necessary to provide a material that integrates the 5E's instructional model for the curriculum and instruction. This notion is in accordance with Section 10.3 of DEPEd Order No. 43, s. 2013 dealing with executing the rules and regulations of Republic Act No. 10533, known as The Enhanced Basic Education Act of 2013. This section states that creation and enhancement of instructional learning materials shall be fostered among educators (Department of Education, 2013). These materials must be incorporated with hands-on activities into educative process so that the students will become more skilled and competent in chemistry. Enhancing the quality of education motivates the students to take an active role in the learning process that will be the basis for the implementation of 5E's learning model. Therefore, learners will continue attaining the ultimate goals of science education by constructing new concepts and meanings (Hickey, 2015; Corpuz, and Salandanan, 2007).

The researcher encountered some negative attitudes during the teaching-learning process among the students regarding General Chemistry 1. There may be resistance, which may come in the form of work avoidance. Some students do not care enough about the experiments and other forms of activities to fully engage in it. Others who hastily solve a problem, do not sufficiently utilize available resources, so as to move on to a more engaging stage of the inquiry process. This experience is similar to the findings of Pond (2014) in which learners reveal the low academic performances in the universities and colleges. In addition, based on the researcher's experiences and observations, the students' low achievement in chemistry were because of the weak foundation

of chemistry from the high school level, wherein the learners find the topics in chemistry very difficult. Hence, students do not have enthusiasm and motivation since they consider the passive approach within the learning process. Most of the time, chemistry is usually considered as a challenging and difficult discipline, a conclusion that occasionally repels learners from learning chemistry. Chemistry education must be highlighted within secondary education in terms of class instruction, since chemistry has an essential function in integrating other science disciplines. The problem is that students are not successful in the said discipline at alarming rates in basic education for the previous decades (Uchegbu et al., 2015; Agogo, & Onda, 2014). Although many educators shared their findings to why learners have low academic performance in chemistry, problems still exist. Learning difficulties can be attributed to lack of instructional materials in the senior high school despite the existence of curriculum guides.

Literature Review

Several theories and principles in the teaching-learning process provide the basis of the current study in relation to 5E's instructional model to enhance the components of the 21st century STEM curriculum and instruction in General Chemistry 1 among the senior high school students. The components of the 21st century STEM curriculum can be associated with constructivism as a learning theory proposed by Bruner (1961) in which the concept of the spiral curriculum was integrated. This involved information that were structured so that complicated ideas can be delivered in a simple manner first, and then re-visited at higher levels later on. Hence, learners would be taught at levels of gradually increasing difficultly (hence the spiral analogy). Preferably, teaching in this manner should direct learners to be able to provide solutions to the existing problems.

In addition, the 5E's learning model has a strong connection to the theory of Bruner (1961) since the said learning model allows the learners to build their own knowledge through organizing and categorizing information using a coding system. It was considered that the most efficient process to develop a coding system is to explore it instead of relying heavily to the teacher. The application of the spiral curriculum can help the process of inquiry learning. Constructivism is a philosophy in education that suggests that learners are required to create their own understanding about the new ideas. Well-known educators discussed several researches about constructivism from the past decades in the fields of learning theory and cognition. Well-known authors like Jean Piaget, Eleanor Duckworth, George Hein, and Howard Gardener have discovered these ideas in-depth.

In the 5E's learning model, the learners develop their skills through examining and evaluating evidences, experiencing and discussing, and talking to their colleagues about their own understanding. Learners work in groups with others to provide solutions to the problems including planning of investigations. Most of the learners find that the learning process is effective when

they work with others in a collaborative environment in contrast with working alone in a highly competitive environment. When they are active, cooperation in the group is directed toward scientific inquiry, and the learners tend to succeed in performing their own explorations. They formulate questions, observe, analyze, interpret, discuss, formulate conclusions, and ask a new set of questions. These inquiry-based learning include both those that involve learners performing hands-on activities and those in which learners formulate explanations through critical and logical thinking. It only indicates that that both critical and creative thinking skills fall under constructivism approach of discovery learning of Bruner (1961).

The concepts as discussed above can be inferred that the 5E's instructional model also incorporates Vygotsky's socio-cultural learning theory (Vygotsky, 1978). The said theory emphasize that adults should perform an active role in facilitating the learning process. In addition, the said theory emphasized the social nature of learning, referring to other people that they should assist learners to enhance their skills through scaffolding. The idea of scaffolding is very similar to Vygotsky's notion of the zone of proximal development (ZPD). Scaffolding refers to facilitating and well-planned interaction between an adult and a learner, with the aim of assisting the learner to achieve a certain and specific goal. The theory dealing with social learning of Vygotsky is one of the integral components of the 21st century STEM curriculum and instruction as mentioned by Chang (2008).

Likewise, the meaningful learning theory of Ausubel (1968) served also as the basis in the conduct of the present study. In Ausubel's view, students should provide strong connections between new knowledge (concepts and propositions) to their prior existing knowledge to acquire meaningful learning. Ausubel (1968) proposed the notion of an advanced organizer as a way to assist learners to connect their ideas with new material or concepts. Ausubel's theory of learning argued that new ideas to be learned can be integrated into more comprehensive concepts or ideas. This feature can be observed among the procedures specified in each stage of the 5E learning model.

Lastly, when it comes to communication as part of the 21st century STEM curriculum and instruction components, experiential learning theory appears to be more effective for teaching and learning communication skills. Experiential learning theory of Kolb (1984) stated that this theory refers to the process of learning new information through experiences. This theory is described as learning through reflection on doing. Knowles (1984) suggested that for effective learning and teaching of communication skills using the experiential learning approach, the following elements are important: observation, well-defined delineation and definition of the important skills; observation; well-intentioned, comprehensive and explanatory feedback; journals using video or audio recording; training of the required skills; and active learning in a small-group or one-on-one.

The literature and studies reviewed served as the benchmark to come up with a conceptual framework for this research. The researcher employed the model of Bybee (2006) referring to the 5E's learning model based from inquiry approach and constructivism since the learners utilized their prior experiences and schema along with their primary knowledge gained from new explorations. Each stage of the said model has a distinctive function that promotes the teacher's unified instruction. It also allowed the students to formulate a better understanding about scientific and technological knowledge, attitudes, and skills. The study of Acisli, et al. (2011) also provided such concepts in the current study considering that learning process in chemistry can be solved through 5E's learning model, in which learners can explore and study the main concepts of the subject on their own through formulating questions, discovering, using primary knowledge, and connecting to the real-life scenarios.

Based from the statement mentioned above, it can be analyzed that the use of the said learning model can strengthen the weak foundation of chemistry concepts among the students based from the study of Demircioglu, et al. (2009), Agung, & Schwartz (2007), Chandrasegaran, et al. (2007), Schmidt, et al. (2007), and Demircioglu, et al. (2015) and Ozmen (2004). The said related studies identified also the difficult topics based from the interviews and questionnaires among the student-respondents. Furthermore, The current study is similar to the study of Uchegbu, et al. (2016), Agogo and Onda (2014), Gongden, et al. (2011), Jimoh (2000) and Agwai (2008) in which they identified selected topics in chemistry, where the learners experienced such difficulties in understanding the different concepts in the said field of science. Like the previous studies of Agogo and Onda (2014), Gongden, et al. (2011), Samba and Eriba (2012), Agwai (2008), Mailumo, Agogo and Kpagh (2007), as well as Mahajan and Singh (2015), the current study also aimed to identify the other possible factors that contributed to the level of difficulty in learning chemistry among the senior high school students.

In connection with the use of the 5E's instructional model, the present study used the concept of Chang (2008), who identified the different components of the 21st century STEM curriculum and instruction that includes critical thinking, creative thinking, and problem solving, communicating and cooperative learning. The said components are the main highlights of the K to 12 Basic Education Curriculum in the country. These components served as the bases to come up with the different learning theories in the educative process.

This study aimed to test the effectiveness of 5E's learning model instructional material for the STEM program for the program in General Chemistry 1 among the Grade 12 students enrolled in the said strand, SY 2017-2018. Specifically, it sought to answer the following objectives: 1) determine the topics in General Chemistry 1 that are difficult for senior high school students to learn; 2) identify the factors that make the topics in General Chemistry 1 difficult; 3) develop an instructional material integrated with the 5E's learning model; 4) find out the significant difference between the profile of the control and experimental groups in terms of pretest scores, and Grade

11 general average; 5) ascertain if there is a significant difference between the posttest mean scores of the students in the control and experimental groups after using the 5E's learning model instructional material; and 6) evaluate the level of acceptability of the 5E's learning model instructional material as perceived by the student-respondents in terms of learning objectives, learning activities, accuracy clarity, appeal, and usability.

Methodology

Research Design

This research study used the true-experimental type of research specifically posttest-only controlled group design since it was found out that the matching variables such as the scores in pretest and the general average in Grade 11 between the control group and experimental group are equivalent.

Research Site

This study was conducted among the four (4) selected public secondary schools that offer STEM program for the senior high school in Quezon Province, Philippines namely Dr. Maria D. Pastrana National High School, Claro M. Recto National High School, Gumaca National High School, and Lopez Comprehensive National High School. Seventy-one science teachers from the four (4) selected public secondary schools served as the respondents to identify the difficult topics and the factors that make the topics difficult in General Chemistry 1. The said respondents were selected through purposive sampling. In addition, two (2) groups of Grade 12 students in the four (4) selected public secondary schools that offer STEM program curriculum in Quezon Province served as the control and experimental groups, respectively. They were selected as the respondents of the study with a total of 250 student-respondents.

Instrumentation

To enhance the components of STEM instruction in General Chemistry 1, the researcher developed a questionnaire on the list of difficult topics in General Chemistry 1, questionnaire regarding the causes of difficulties, the 5E's learning model instructional material in General Chemistry 1, achievement test for validation and experimentation, and a questionnaire on the level of acceptability for the student-respondents.

This instrument's main objective was to determine the topics in the said subject that are difficult for the senior high school students to learn. It included a list of topics in relation to the composition, structure, and properties of matter; quantitative principles, kinetics, and energetics of transformations of matter; and fundamental concepts of organic chemistry. The researcher presented the questionnaire on the list of difficult topics to the researcher's adviser for comments. The said questionnaire used Likert scale to identify the perceived difficult topics in the said subject matter. It also included the factors that served as the main reasons why such topics are difficult based on the experiences of the teacher-respondents.

In order to identify the factors that make the topics in General Chemistry 1 difficult, the researcher used a Likert scale among the teacher-respondents. It consisted of a list of possible factors why the students have difficulties in the said subject. These factors served as the categories. It included learning environment, nature of the topic, student and teacher-related factors. The researcher presented the questionnaire on the causes of difficulties in learning chemistry to the researcher's adviser for further suggestions.

In developing the said instructional material, the researcher identified the topics through the use of the curriculum guide for General Chemistry 1 as prescribed by the Department of Education (DEPEd) for the Academic Track (STEM strand) for the Senior High School. The topics for the said subject included the identified difficult topics based on the science teacher-respondents' perception. The said material covered included difficult topics like stoichiometry, gases, electronic structure of atoms and periodicity. In addition, the identified difficult topics in the said subject including the causes of such difficulties were considered in the development of the said instructional material. Hence, it served as an assessment tool, which served as the basis in designing the said instructional material. The researcher utilized a wide variety of literary sources like textbooks, electronic references, encyclopedias, existing modules related to chemistry and other reference materials. Each topic in the said instructional material was composed of five (5) main parts in accordance to the 5E's learning model.

The researcher constructed a 30-item multiple choice achievement test to validate the 5E's learning model instructional material in General Chemistry 1 during the pilot study as shown in Table 1.This research instrument was administered among the student-respondents as pretest and posttest right after the students utilized the said material. This form of assessment was used also for match-pairing in order to determine the student-respondents that were assigned to experimental and control groups. The achievement test was used to test the significant difference between the posttest mean scores of the student-respondents in the control and experimental groups after using the said material to determine its effectiveness. The researcher constructed the table of specification that was based from the identified difficult topics in General Chemistry 1. Each topic consisted of learning competencies that were specified in the table of specifications. The test was tried out to one (1) section of Grade 12 students, who took General Chemistry 1. The pilot testing was necessary to formulate conclusion in relation to the time element, learning activities, graphic materials, clarity of vocabulary words, and the direction and the construction of the questions. The achievement test was assessed and item analyzed in order to determine the index of difficulty and discrimination. Items that are too easy and too difficult with negative discriminating power were eliminated from the said questionnaire.

The researcher adapted the modified questionnaire of Queaño (2012) in order to find out the level of acceptability of 5E's learning model instructional material as perceived by the student-respondents. The researcher used a four-point Likert scale questionnaire in order to evaluate the respondents' perception according to objective criteria. Furthermore, the said questionnaire was

subdivided into five (5) major criteria with regard to the level of acceptability namely: learning objectives, learning activities, accuracy and clarity, appeal of the material and usability.

The researcher sought suggestions and comments from the panel of experts for their recommendations and supervision for the validity and reliability of all the questionnaires involved in this study. The validity was established by the experts in the field of chemistry education. It was suggested that the internal consistency of the items in each factor should be checked to ensure how closely related a set of items are as a group. Hence, Cronbach's alpha was used to verify the internal consistency. The researcher validated the said instructional material by requesting time and asking for assessment and evaluation from the experts in the field of science education. Prior to this, the researcher asked for the approval from the selected science teachers and education program supervisors for science secondary education from the division that allowed the researcher to consult them in their available time.

Data Collection

The researcher used frequency and weighted mean in order to identify the difficult topics, as well as the factors that make the topics difficult in General Chemistry 1. It was used also to determine the level of acceptability for the instructional material. In addition, t-test for independent samples was used to determine if there is a significant difference between the control and experimental groups' profile in terms of pretest scores and Grade 11 general average. This statistical treatment was used also to ascertain out the significant difference between the posttest mean scores of the students in the control and experimental groups after using the said 5E's learning model instructional material.

Results and Discussion

The teacher-respondents agreed that the concepts dealing with gas stoichiometry and the kinetic molecular theory (3.33 WM) and quantum mechanical description of the atom and its electronic structure (3.31 WM) are very difficult to learn on the part of their students. It was also revealed that the science teacher-respondents perceived mole concept, calculations involving chemical formulas and equations, gas laws, electronic structure, electronic configuration and the periodic table, as well as periodic variation in atomic properties are difficult. These topics obtained weighted mean values of 2.96, 3.20, 3.23, 2.87, 3.19, and 3.20, respectively.

The factors that made the topics in General Chemistry 1 difficult included the learning environment (2.59 WM), nature of the topics (2.74 WM), student-related (2.50 WM) and teacher-related factors (2.59 WM). Also, the nature of the topic obtained the highest frequency values for the following concepts: mole concept (34), calculations involving chemical formulas and equations (39) and gas stoichiometry and the kinetic molecular theory (35), quantum mechanical description of the atom and its electronic structure (34), electronic structure (24), periodic variation

in atomic properties (30) and the electron configuration and the periodic table (31). On the other hand, student-related rating as the factor making some selected topics in General Chemistry 1 difficult had shown the highest frequency value of 30 for the topic gas laws.

The 5E's learning model instructional material in enhancing the components of 21st century STEM curriculum and instruction in General Chemistry 1 was developed. The topics included in the material are those which are perceived as difficult, such as stoichiometry, gases, and electronic structure of atoms.

The overall mean values of experimental group and control group in terms of Grade 11 general average are 90.64 and 90.43, respectively. On the other hand, 85.36 and 83.66 are the overall mean values of experimental and control groups in terms of pretest score. There emerged the mean difference of 0.21 and 1.70 between the control group and experimental group in terms of Grade 11 general average and pretest scores, respectively. The overall computed t-values of 0.45 (Grade 11 general average) and 0.92 (pretest score) are less than the tabular value of 1.96 at 0.05 level of significance, which means that there is no significant difference between the experimental group and control group in terms of Grade 11 general average and pretest score. There is a mean difference of 16.86 between the posttest score of the experimental group (64.07) and the control group (47.21). The computed t-value of 10.58 is greater than the tabular value of 1.96 at 0.05 level of significance, which means that there is a significant difference between the experimental group and the control group in terms of posttest scores. The 5E's learning model instructional material got a weighted mean of 3.54 for the learning objectives, 3.55 for the learning activities, 3.46 for clarity, 3.51 for accuracy, 3.44 for the appeal to the target users and 3.52 for the usability of the instructional material. All of these criteria fall under the descriptive rating of "strongly agree".

Conclusion

The perceived difficult topics in General Chemistry 1 are stoichiometry, gases, and electronic structure of the atom. These difficulties may lead to misconceptions in chemistry as described in the study of Chiu (2007) and Uchegbu, et al. (2015) in which they found out that gases, mass-volume relationship, and atomic structure are some concepts in which the learners have also several misconceptions. It means that there are some factors why chemistry students find some concepts difficult to learn. In general, learning environment, nature of the topic, student and teacher-related factors served as the root cause that made the topics in General Chemistry 1 more difficult. Specifically, the nature of the topic, as well as student-related factors made stoichiometry, gases, and electronic structure of the atom more difficult due to mathematical aspects, abstract nature, and lack of motivation among the learners since they cannot visualize the real-life application of the topics in their everyday lives that will lead to the understanding of the concepts. The abstract nature of the subject was actually described in the study of Agogo and Onda (2014), and Samba and Eriba (2012).

The developed 5E's learning model instructional material in General Chemistry 1 is ready for adoption. The experimental group and the control group are equivalent before the conduct of the study. Gay, Mills, and Airasian (2009) emphasized that differential selection of participants should be avoided in which subjects have differences before the start of the study. Hence, the researcher selected groups that are equivalent to avoid bias in determining the effectivity of the instructional material. The developed 5E's learning model instructional material, which enhanced the components of the 21st century STEM curriculum is a valid and effective tool in teaching General Chemistry 1. The results stated above are parallel to the idea of Acisli, et al. (2011), who stressed that problems in the learning process dealing with chemistry can be enhanced through 5E's learning model in which learners can explore and learn the main concepts of the topic on their own through inquiry method, as well as relating the concepts in everyday lives. Similarly, Manzo, et al. (2016) pointed out that 5E's learning model actively engage students in a continuous stages that help them create their own knowledge and experiences, construct meaning, and evaluate their understanding of new information. The positive result can be attributed to the educational objectives of the 5E's learning model instructional material that are specific, measurable, achievable, and reasonable within the ability of the learners. It also includes a wide variety of learning activities that address the students' needs and give authentic examples that promote active learning. It only indicates that the learning material matches the students' experiences with their expectations. Thus, they are able to understand the difficult topics in General Chemistry 1. The developed 5E's learning model instructional material, which enhanced the components of 21st century STEM curriculum, is commendable to be used in General Chemistry 1.

Teachers may adopt the developed 5E's learning model instructional material in enhancing the components of 21st century STEM curriculum that can be integrated in the Junior High School in order to improve the academic performance on the perceived difficult topics in chemistry subject and to lighten their task of guiding students to understand and facilitate learning. School intervention programs may be implemented in order to provide solutions towards the existing factors related to learning difficulties in chemistry, as well as in other fields. The 5E's learning model instructional material for the 21st century STEM for the program in General Chemistry 1 can be utilized by high school students and science teachers. The 5E's learning model may be integrated with other science-related subjects since these subjects require the application of inquiry and constructivist approach in accordance with the K to 12 Basic Education Curriculum. Summative evaluation of validated instructional materials in other science-related subjects may be done to determine the effectiveness of the material in enhancing the components of the 21st century STEM curriculum. The same type of material for the succeeding topics in other science fields may be developed to address the needs of the students to learn and understand the other difficult topics in other science-related subjects.

REFERENCES

Acisli, S., et al. (2011). Effects of the 5E learning model on students' academic achievements in movement and force issues. *Procedia Social and Behavioral Sciences, 15,* 2459–2462.

Agogo, P. O., & Onda, M. O. (2014). Identification of students perceived difficult concepts in senior secondary school chemistry in Oju local government area of Benue State, Nigeria. *Global Educational Research Journal, 2(4),* 44–49.

Agung, S., & Schwartz, M.S. (2007). Students' understanding of conservation of matter, stoichiometry and balancing equations in Indonesia. *International Journal of Science Education, 29,* 1679-1702.

Agwai, V. (2008). Strategies for improving students interest in learning scientific concepts. *Journal of Research Education, 2,* 225–230.

Ausubel, D. P. (1968). *Educational psychology. A cognitive view*. Holt, Rinehart and Winston, Inc.

Bruner, J. (1961). Principles of Learning. https://principlesoflearning.wordpress.com/dissertation/chapter-3-literature-review-2/the-constructive-perspective/discovery-learning-jerome-bruner-1961/

Bybee, R. W. (2006). *The BSCS 5E instructional model: Origins, effectiveness, and applications*. Colorado Springs: BSCS.

Caprile, M., Palmen, R., Sanz, & Dente, G. (2015). *Encouraging STEM studies for the labour market* (Directorate-General for Internal Policies: European Parliament).

Chandrasegaran, A.L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. *Chemistry Education Research and Practice, 8,* 293-307.

Chang, R. P. H. (2008). *Challenges in STEM education*. Northwestern University, Arlington, VA.

Chiu, M.H. (2007). A national survey of students' conceptions of chemistry in Taiwan. *International Journal of Science Education, 29,* 421-452.

Corpuz, B., & Salandanan, G. G. (2007). *Principles of teaching 1*. Lorimar Publishing.

Cruz, I. (2014, July 3). The STEM strand. *The Philippine Star*. http://www.philstar.com/education-and-home/2014/07/03/1341906/stem-strand

Dela Cruz, M. (Mar. 11, 2017). Science ed and a thinking society. *Pressreader*. https://www.pressreader.com/philippines/philippine-daily-inquirer/20170311/281754154122594

Demircioglu, G., Ayas, A., & Demircioglu, H. (2015). Conceptual change achieved through a new teaching program on acids and bases. *Chemistry Education Research and Practice, 6,* 36-51.

Demircioglu, H., G., Demircioglu, & Calik, M. (2009). Investigating the effectiveness of storylines embedded within a context-based approach: The case for the periodic table. *Chemistry Education Research and Practice, 10,* 241-249.

Department of Education. (2013). *DEPEd Order No. 43, s. 2013 Implemented Rules and Regulations (IRR) of Republic Act No. 10533*. http://www.deped.gov.ph/sites/default/files/order/2013/DO_s2013_43.pdf

Gagnon, D., & Mattingly, M. J. (2012). *Beginning teachers are more common in rural, high-poverty, and racially diverse schools*. In The Carsey Institute at the Scholars' Repository. http://scholars.unh.edu/carsey/173

Gay, L., Mills, G., & Airasian, P. (2009). Educational research: Competencies for analysis and application, 9th edition. New Jersey: Lawrence Erlbaum Associates, Publishers.

Hickey, E. (2015). Education and Training. http://www.education.vic.gov.au/school/teachers/support/Pages/e5.aspx

Hom, E. J. (Feb. 11, 2014). *What is STEM education?* Live Science. http://www.livescience.com/43296-what-is-stem-education.html

Honey, M., Pearson, G., & Schweingruber, A. (2014). *STEM integration in K-12 education: status, prospects, and an agenda for research*. National Academies Press.

Jimoh, A. T. (2010). Perception of difficult topics in chemistry curriculum by students in Nigeria secondary schools. *Ilorin Journal of Education, 4(1),* 1-5.

Knowles, M. (1984). *The adult learner: A neglected species (3rd Ed.).* Gulf Publishing.

Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development*. Prentice Hall.

Lee, O., Quinn, H., & Valdés, G. (2013). Science and language for English language learners in relation to next generation science standards and with implications for common core state standards for English language arts and mathematics. *Educational Researcher, 42 (4).*

Mahajan, D. S., & Singh, G. S. (2015). University students' performance in organic chemistry at undergraduate level: Perception of instructors from universities in the SADC region. *Chemistry, 14 (1),* 1–20.

Mailumo, P.H., Agogo, P.O., & Kpagh, J.E. (2009). *Education in fundamental chemistry*. Makurdi: Journal of Publishers (Nig.) Ltd.

Manzo, R. D., et al. (2016). The impact of the 5E Teaching model on changes in neuroscience, drug addiction, and research methods knowledge of science teachers attending California's ARISE professional development workshops. *Journal of Education and Learning, 5(2),* 109-120.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country comparisons*. Australian Council of Learned Academies.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academy Press.

Ortilla, M. (2015). *Problems hounding K-to-12 program (Part 2): Errors in textbooks*. CNN Philippines.

Ozmen, H. (2004). Some student misconceptions in chemistry: A literature review of chemical bonding. *Journal of Science Education and Technology, 13,* 147-159.

Pond, R. (2014). *Inquiry and the national science education standards.* Washington DC: National Academy Press.

Prinsley, R., & Baranyai, K. (2015). STEM skills in the workforce: what do employers want? *Occasional Papers Series, (9).*

Queaño, R. (2012). *Development and Validation of Differentiated Instructional Material in Teaching Algebraic Expressions.* (Unpublished Master's Thesis), Manuel S. Enverga University Foundation, Inc., Lucena City.

Samba R.M.O., & Eriba, J.O. (2012). *Background information on teaching difficult science concepts. Innovative Approaches in teaching difficult science concepts*. Makurdi, Nigeria: Destiny Ventures.

Schmidt, H.J., Marohn, A., & Harisson, A.G. (2007). Factors that prevent learning in electrochemistry. *Journal of Research and Science Teaching, 44,* 258-283.

Thyer, E. (2015). Critical thinking. http://www.criticalthinking.org/ pages/defining-critical-thinking/766.

Uchegbu, R. I., et al. (2015). Teacher's perception of the impediments to chemistry teaching in secondary schools in Imo State. Nigeria. *Open Science Journal of Education, 3 (5),* 26-31.

Uchegbu, R. I., Oguama, C. C., Elenwoke, U. E., & Ogbuagu, O. E. (2016). Perception of difficult topics in chemistry curriculum by senior secondary school (II) students in Imo State. *AASCIT Journal of Education, 2(3),* 18-23.

Vygotsky, L. (1978). *Interaction between learning and development*. New York: Scientific American Books.