The Eurasia Proceedings of
Educational & Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2016

Volume 5, Pages 20-25

ICRES 2016: International Conference on Research in Education and Science

EFFECTIVENESS OF GREEN CHEMISTRY WITH SCIENCE WRITING IN ENHANCING UNDERSTANDING CHEMISTRY CONCEPTS

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Abstract: In this study attempt was made to investigate the effectiveness of green chemistry with science writing heuristic (SWH) enhancing understanding of chemistry concepts among pre-university students. Students enrolled in the Matriculation Colleges in Malaysia are the top notch students in the country. For this purpose data has been collected from 208 pre-university students in the study as an experimental or control groups. The experimental group was taught the content using SWH instructional approach while the control group was taught the same content using traditional approach. The data was analysed using ANCOVA and findings obtained from the quantitative analysis on understanding of chemistry concepts reveals that there is a significant change in understanding of concepts ($F(1,204) = 99.549$, $p < 0.05$ partial eta squared $=0.335$ which favours the experimental group. These results revealed that the green chemistry with SWH can improved their chemistry concepts understanding. The implication of the study with respect to pre-university education has been provided with some highlights on the limitation of the study well as contribution, recommendations and suggestion for further research.

***Keywords*:** Understanding chemistry concept, science writing heuristics, green chemistry

Introduction

Chemistry is a difficult subject for many students as the underpinning concepts are not sufficiently grasped by the students (Zoller 1990; Nakhleh 1992; Ayas & Demirbas, 1997; Coll & Treagust 2001; Nicoll, 2001). This is mainly because chemical knowledge is learned at three levels: sub-microscopic, macroscopic and symbolic and the link between these levels should be taught (Johnstone, 1991; Bagel 1992; Harrison and Treagust, 2000; Ebenezer, 2001; Ravialo, 2001; Treagust et al., 2003). Previous studies reported that a pedagogical approach that enables the chemistry concepts to be taught at these three levels encourages understanding of abstract chemistry concepts. Studies also indicate that for the pedagogical approach to reflect on the three levels the pedagogical strategy should enable the students to reflect the concepts learned in their real life scenario. According to Gott & Duggan (1995), green chemistry provides a platform to understand and enjoy chemistry besides giving the opportunity to fully develop transferable skills during laboratory work. Additionally, SWH was used to foster a generated working laboratory activities with manipulative skills, make well-reasoned links between their laboratory tests, observations, inferences and most importantly encourage an understanding of nature of science. Following these claims, in this study, green chemistry integrated with SWH will be used to improve matriculation students' environmental literacy and understanding of chemistry concepts.

Problem Statement

Inherently, the aforementioned general vision and mission of education included in the curriculum specification is also reflected in the science education curriculum specification. The science curriculum aims to produce

- Selection and peer-review under responsibility of the Organizing Committee of the conference

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active learners, capable of applying science process skills, thinking skills and thinking strategies for thoughtful learning. The science curriculum was designed with the intention that students will be trained to see science and technology in wider context and learns to relate their knowledge to the world beyond the school.

Science writing heuristic (SWH) is designed to promote connections among investigation questions, procedures, data, evidence and knowledge claims that may not initially be apparent to the students (Keys, 1999). Merging the two approaches that is green chemistry with SWH in teaching chemistry to produce better understanding of chemistry concepts is very much relevant to daily application besides enhancing higher order thinking and problem solving skills that will be retained over time. However, green chemistry integrated with SWH which will probably will result in improved understanding of chemistry concepts is still lacking in the literature.

According to Martine (2006) learning of scientific concepts is more than a cognitive process as it is blended with interest and attitude towards learning. A learner is believed to understand scientific concepts only when the learner can explain every day phenomena by seeking connections among various pieces of information or applying the newly learned information to everyday life (Paris, Cross & Lipson, 1984). Various studies suggest that students do not acquire a satisfactory understanding of scientific conceptions due to traditional teaching method (Morgil, Oskay,Yaruz & Arda, 2003). Students need to be involved in the learning process in order to achieve in-depth understanding (Kiboss, 2002; Kiboss, Ndirungu & Wekesa, 2004).

Cepni, Tas & Kose, (2006) argued that chemistry teachers need to use alternative teaching approaches especially teaching abstract science concepts as these pedagogical approaches can influence cognitive development and further increase the achievement in chemistry. This is in par with the Malaysian Science Curriculum, as its main objective is to provide students with the knowledge and skills in science and enable them to solve problems and make decisions in everyday life based on scientific attitudes (CDC, 2002).

Literature Review

Learning takes place when a learner involves actively in the learning process. Learning outcomes do not only depend solely on teacher's presentation but rather as an outcome of interactive results within the learner's existing structure and newly encountered knowledge. As the main aim of science education is to make a meaningful understanding of science concepts, therefore constructive approach is an effective way of providing meaningful learning. Students construct their knowledge by making links between the idea and new concepts through experience they acquire. These experiences can result in assimilation in which new knowledge is incorporated into existing cognitive structure. When the new knowledge is incorporated into the existing cognitive structure, it can lead to inequlibrium bringing to conceptual change (Bodner, 1986). Posner's Model of conceptual change is reflected in context when students involve in conducting activities on green chemistry with SWH. According to Posner et al., (1982) students must first become dissatisfied with their existing conception through experiences which show that their existing conceptual ideas cannot solve problems. Secondly, they must have access to a new conception that is intelligible or make sense to them. Thirdly, the new conception must appear to have ability to solve problems. Finally the new conception must be fruitful and it must be able to solve future problems for the students.According to Posner et al. (1982), all students come into the classroom with prior knowledge; that is, every student has some idea of a concept, regardless of whether they have had any formal education about the topic or not. Learning occurs when students accept new information into their existing conceptual framework, which is a process of assimilation. (Posner et al., 1982).

Science Writing Heuristic (SWH) consists of a teacher template, which offers suggested activities which will engage students in meaningful thinking, reading, writing and learning. (Keys et al, 1999; Akkus et al., 2007; Yore, 2003). According to Posner's model the students come with personal explanation or prior knowledge to the laboratory with beginning questions and ideas. In the second stage, the students are provided with a handout that includes a brief introduction and researchable questions to answer as well a list of materials that can be used during the investigation. This will encourage the students to negotiate their ideas against their existing conceptual understanding through interactive discussion during every step of instructional design of SWH. Students are required to design and implement their own method to gather and analyse data, communicate and justify their ideas with others during interactive session. Each group writes their questions and from those questions the teacher frames the laboratory activities deciding on the variables to be tested. The laboratory activities embedded with green chemistry activities and SWH encourage students to be active learners in the laboratory as utilizing investigative experiments are done rather than using instruments for confirmations which allows students to build critical thinking skills essential for scientists when evaluating a problem.

Purpose of the Study

The primary aims of this study is to investigate the effect of Green Chemistry experiments integrated with Science Writing Heuristic (SWH) in changing matriculation students' understanding of chemistry concepts.

Research Questions

What is the effect of green chemistry experiments integrated with science writing heuristic in improving students understanding of chemistry concepts?

Hypothesis

H_{05}: There is no significant difference between control group and experimental group in the mean scores of understanding of concepts in chemistry post test mean scores after controlling the pre-test scores.

Contribution of the Study

The findings and the manual of the experiment through this study can be used by the curriculum planner and policy maker among matriculation colleges throughout Malaysia. In this study green chemistry with science heuristic writing (SWH) demonstrates that it basically provides the required knowledge and awareness that could be incorporated into the existing curriculum that will enhance students' understanding towards the impact of the chemical usage towards environmental and ways of prevention. It will increase the level of environmental literacy whereby the students of matriculation will be venturing the field of science and technology. Furthermore, students would enter the professional world with knowledge of the weaknesses of current industrial process, coupled with the positive attitude to overcome the weakness of current industrial process based on green chemistry principles in an interdisciplinary environment.

Understanding of Chemistry Concepts

Concepts are like mental representatives in their simplest form that can be expressed in a single word. Concepts may also represent a set of ideas that can be described in a few words. Through the use of language individual concepts can be connected to build more complex representational structures, at other times two concepts can be combined to form a third representational structure. Concepts can thus act like building blocks of more complex and even abstract representations. (Carey, 2000). It is proven that chemistry is a difficult subject for many students because chemistry topics are generally related to structures of matter. Chemistry curricula incorporated with many abstract concepts are important as further chemistry concepts cannot be understood if these underpinning concepts are not sufficiently grasped by the students. (Sirhan, 2007; Orgill & Bodner, 2004). Moreover learning requires much intellectual thought because the content is filled with many abstract concepts which are meaningfully linked (Abraham et al., 1994; Nakhleh, 1992).

Kozma (2003) supports the assertion that thinking about chemistry requires learners to see beyond the symbols and make connections among the different levels when describing an observation or explaining a process. According to Meyer (2005) despite the claim that introducing and emphasizing the particulate nature of matter (sub-microscopic level) during chemistry classes can help the students to link the particulate nature of matter to other levels (macroscopic and symbolic level) but this is rarely a practice during chemistry classes (Gabel, 1993). Integration of different kinds of information from different levels (representational) allow the information to be coherently structured and permits the understanding, for example understanding single concepts such as oxidation and reduction into more complex concepts such as redox reactions is built coherently based on few underlying concepts. Through the use of language or writing an individual concept can be connected to build more complex representational structures, two concepts can be combined to form a third representational structure.

Green chemistry experiments are designed in accordance with the latest research findings of how students learn science most effectively (Eilks & Rauch, 2012). Most of the activities are designed based on guided inquiry experiences that help students to think about the ideas underlying laboratory work, construct concepts to answer open ended questions and engage in independent thought (Whelan & Zare, 2003). This is in line with the claim that student centred instructional programs are designed based on a number of strategies that form the core of contemporary thinking about science education reform which consisted of constructivist approach, hands-on

inquiry approach and context-based approach significantly improved overall students' understanding of chemistry concepts (Kozma et al., 2003).

In the context when green chemistry integrated with SWH further enhances the nature of inquiry and constructivist based learning. SWH offers instructional strategies where the learners are required to design the experiment, proposed a hypothesis, employ the experiment to test the hypothesis, collect data, observe trends, and make connections between observations and principles (Rudd et al., 2001; Gunel & Hand, 2007). SWH experiences help students to think about the ideas underlying laboratory work, construct understanding on concepts to answer open ended-questions, and engage in independent thought (Nakhleh, 1994). When a writing task is structured to promote the development of conceptual understanding rather than recalling facts, knowledge transformation can occur (Hand et al., 2004); that is, the concepts about which the student is writing are transformed into a new and more enriched version than before the writing. The act of writing becomes one of learning process when learner purposefully links new ideas to prior knowledge to build understanding of the chemistry concepts which are being studied (Driver & Odham, 1986; Ebenezer, 2002; Danili, et al., 2004).

Methodology

In this study quasi-experimental design involving two groups will be employed. For measuring the understanding of chemistry concepts, understanding chemistry concept test (UCCT) consists of 30 multiple choice questions given to both groups and the questions will be specified accordingly to Blooms Taxonomy Classification (Bloom, 1956). A pre and post quantitative survey will be administered before and after the treatment for the both the groups to measure the changes students' understanding of chemistry concepts. Out of 210 students, 120 students will be randomly assigned as experimental group (N= 120) and the rest will be assigned as control group (N=90). After completing each green chemistry experiment, students will be required to submit a laboratory report using SWH for experimental group whereas formatted laboratory report for control group. The students from the experimental group will be using the same green chemistry manual as the control group and will be writing laboratory report based on SWH (see Appendix 1). The students from the control group will be using the same green chemistry manual as the experimental group and will be writing laboratory report based on the standard format (see Appendix 2).

Table 1. The quasi-experimental design

Group	Pre-test	Treatment	Post test
Intervention	O_1	X_1	O_2
Control	O_3	X_2	O_4

O_1 and O_3: Pre test
O_2 and O_4: Post Test
X1: Green chemistry integrated with SWH
X2: Green chemistry with formatted laboratory report

Findings and Discussion

An ANCOVA was performed to find out the effect of green chemistry with SWH on matriculation student's understanding chemistry concepts. As shown in table 4.8, there is significant main effect for the groups ($F(1,204) = 99.549$, $p < 0.05$ partial eta squared =0.335). This results shows that the changes in the post test probably could be due to the treatment received by students. A partial eta squared = 0.335 indicate that 33.5% of the total variance in the post test attitude scores were due to the treatment. According to Cohen (1988) the eta squared value of 33.5% indicate relatively large effect of the treatment on the post results. Therefore statistically significant difference has been obtained that signifies the advantage of green chemistry with SWH in improving the students' understanding chemistry concepts.

Table 2. Analysis of co-variance for mean understanding chemistry concepts

Source	SS	Df	MS	F	p	Partial Eta Squared
Pre-test	3.210	1	3.210	1.027	0.312	0.005
Group	331.305	1	311.305	99.549	0.000	0.328
Error	637.941	204	3.127			
Total	50793.469	207				

This statistical evidence called for the rejection of the null hypothesis that there is no significant difference between control group's and experimental group's in the mean scores of understanding of concepts in chemistry post test mean scores after controlling the pre-test scores.

Descriptive Statistics

Table 4.10 includes the outcome of descriptive analysis. The results indicate that both the groups have shown some improvement after the treatment. The experimental group exhibited decrease in the mean values in the post test (M_{exp}= 16.59; SD_{exp} =1.556) compare to the pre-test mean value (M_{exp}=12.38; SD_{exp}=1.988). Similarly, increase in mean value also noticed in the mean value of the pre-test ($M_{control}$= 12.05; SD_{exp} =2.619) and post-test (M_{exp}= 14.09; SD_{exp} =2.016) among the control group student. Increase in the mean values shows that after the treatment students have better understanding of chemical concepts than prior to the treatment.

Table 3. Descriptive statistics of understanding chemical concepts

Groups		Mean	Standard Deviation	N
Exp Group	Pre-test	12.38	1.988	118
	Post-test	16.59	1.556	118
Ctr Group	Pre-test	12.05	2.619	89
	Post-test	14.09	2.016	89

From the quantitative analysis on understanding chemistry concepts among the matriculation students reveals that there is a significant change in understanding chemistry concepts ($F(1,204) = 99.549$, $p < 0.05$ partial eta squared =0.335 which favours the experimental group. These results revealed that the green chemistry with SWH can enhance the understanding of chemistry concepts among matriculation students. Thus hypothesis H_{01} to be rejected.

Conclusion and Recommendations

In the context of this study while engaged in the science writing heuristic, the students were exposed to hands on activities whereby experimented and manipulated real world objects. These hands-on activities with SWH significantly improved students' chemistry understanding. Green Chemistry with SWH perceived to help to prepare students by providing them with understanding concepts of chemistry and skills. The outcome of this study shows that Green chemistry with SWH can overcome barriers and geared towards creating and implementing effective programs which can enhance the understanding of chemistry concepts.With the commencement of this research, green chemistry with SWH would be fruitful if project based activities are carried out to other colleges too. This could be done by providing training to the in-service teachers probably as a professional development courses.

References

Abraham, M. R., Williamson, V. M. & Westbrook, S. L., (1994). A Cross-Age Study of the Understanding Five Concepts, Journal of Research in Science Teaching, 31(2), 147–165.

Akkus, R., Gunel, M., & Hand, B. (2007). Comparing an Inquiry-based Approach known as the Science Writing Heuristic to Traditional Science Teaching Practices: Are there differences? International Journal of Science Education, 29(14), 1745-1765.

Ayas, A., & Demirbas, A. (1997). Turkish Secondary Students' Conceptions of the Introductory Concepts. Journal of Chemical Education, 74(5), 518.

Bloom, B. S. (1956). Taxonomy ofeducational objectives. New York: David McKay, 356, 1998-1999.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. Journal of chemical education, 63(10), 873.
Carey, S. (2000). The origin of concepts. Journal of Cognition and Development, 1(1), 37-41.
Coll, R. K., & Treagust, D. F. (2001). Learners' mental models of chemical bonding. Research in Science Education, 31(3), 357-382.
Danili, E., & Reid*, N. (2004). Some strategies to improve performance in school chemistry, based on two cognitive factors. Research in Science & Technological Education, 22(2), 203-226.
Driver, R. a. O. (1986). A constructivist approach to curriculum development in Science. Studies in Science Education., 13(105-132).
Ebenezer, J. V., & Fraser, D. M. (2001). First year chemical engineering students' conceptions of energy in solution processes: Phenomenographic categories for common knowledge construction. Science Education, 85(5), 509-535.
Eilks, I., & Rauch, F. (2012). Sustainable development and green chemistry in chemistry education. Chemistry Education Research and Practice, 13(2), 57-58.
Gabel, D. L. (1993). Use of the particle nature of matter in developing conceptual understanding. Journal of Chemical Education, 70(3), 193.
Gott, R., & Duggan, S. (1995). Investigative Work in the Science Curriculum. Developing Science and Technology Education. Open University Press, Celtic Court, 22 Ballmoor, Buckingham, England ,United Kingdom
Gunel, M., Hand, B., & Prain, V. (2007). Writing for learning in science: A secondary analysis of six studies. International Journal of Science and Mathematics Education, 5(4), 615-637.
Harrison, A. G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. Science Education, 84(3), 352-381.
Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. Journal of Computer Assisted Learning, 7(2), 75-83.
Keys, C. W., Hand, B., Prain, V., & Collins, S. (1999). Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. Journal of research in Science Teaching, 36(10), 1065-1084.
Kiboss, J. (2002). Impact of a CBI in physics on students' understanding of measurement concepts and skills associated with school science. Journal of Science Education and Technology, 11(2), 193-198.
Kiboss, J. K., Ndirangu, M., & Wekesa, E. W. (2004). Effectiveness of a Computer-Mediated simulations program in school biology on pupils' learning outcomes in cell theory. Journal of Science Education and Technology, 13(2), 207-213.
Kozma, R. (2003). The material features of multiple representations and their cognitive and social affordances for science understanding. Learning and Instruction, 13(2), 205-226.
Martine, & Rijlaarsdam, G. (2006). Literary reading activities of good and weak students: A think aloud study. European Journal of Psychology of Education, 21(1), 35-52.
Morgil, I., & Yoruk, N. (2006). Cross age study of the understanding of some concepts in chemistry subjects in science curriculum. Jornal Turkey Science Education, 3(1), 15-27.
Nakhleh, M. B. (1992). Student's Models of Matter in the Context of Acid-Base Chemistry. Journal of Chemical Education, 71(6), 495.
Nakhleh, M., (1992). Why Some Students Don't Learn Chemistry: Chemical Misconceptions, Journal of Chemical Education, 69(3), 191-196.
Nicoll, K. (2001). Radiocarbon chronologies for prehistoric human occupation and hydroclimatic change in Egypt and Northern Sudan. Geoarchaeology, 16(1), 47-64.
Orgill, M., & Bodner, G. (2004). What research tells us about using analogies to teach chemistry. Chemistry Education Research and Practice, 5(1), 15-32.
Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211-227.
Ravialo, A., (2001). Assessing Students' Conceptual Understanding of Solubility Equilibrium, Journal of Chemical Education, 78(5), 629–631
Rudd, J. A., Greenbowe, T. J., Hand, B. M., & Legg, M. J. (2001). Using the science writing heuristic to move toward an inquiry-based laboratory curriculum: An example from physical equilibrium. Journal of Chemical Education, 78(12), 1680.
Sirhan, G. (2007). Learning difficulties in chemistry: An overview. Journal of Turkish Science Education, 4(2), 2-20.
Treagust, D. F., Chittleborough, G., and Mamiala, T. L., (2003). The Role of Submicroscopic and Symbolic Representations in Chemical Explanations. International Journal of Science Education 25: 1353–1368.
Whelan, R.J. & Zare, R. (2003). Teaching effective communication in a writing –intensive analytical chemistry course. Journal of Chemical Education, 80(8), 904–906.
Yore, L., Hand, B., & Prain, V. (1999). Writing-to-learn science: Breakthroughs, barriers, and promises. Washington, DC: US Department of Education. ERIC Doc. Rep. No. ED441688.
Zoller, U. (1990). Environmental education and the university: the "problem solving-decision making act" within a critical system-thinking framework. Higher Education in Europe, 15(4), 5-14.