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The green chemistry and Filipino approach to high school experiments in Saint Paul College Pasig

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Abstract

This paper is a call for teachers to initiate measures in improving the quality of high school chemistry education in the Philippines and that is by going back to practical laboratory work. The experiment presented in this paper is a proof to the possibility of tailor-made experiments that integrate principles of green chemistry. Integrating green chemistry concepts in the design of high school chemistry experiments makes students aware of the responsibility that goes with the use and production of chemicals. Moreover, the experiment was designed to consciously integrate aspects of Filipino culture, values, and traditions. Such enculturation of chemistry by giving it a Filipino flavor aims to make the students own the science and not view it as something that is highly foreign. When students can relate to the chemical concepts illuminated in their culture they become more appreciative and receptive of the science giving them meaningful and lasting learning.

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Keywords: High school chemistry experiments, green chemistry, Filipino enculturation of chemistry, practical work, chemistry education in the Philippines

1. Introduction

1.1. Chemical education in the Philippines and the challenges it face

While chemistry and the other sciences are being promoted in the Philippines as experimental subjects and practical works are, therefore, emphasized, actual practice does not meet this objective (Padolina & Magno, 2003). The minimal practice and application of science in actual laboratory setting points to other perennial constraints in the advancement of chemical education in the Philippines like insufficient laboratory

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rooms and equipment, inadequate budget for chemicals and other materials, big classes and crowded classrooms.

Being aware of what's happening in a national and even in an international level (Kimel et al, 1998), teachers are therefore responsible in complementing the directives of the Department of Education (DepEd) and the Department of Science and Technology (DOST) in promoting quality chemical education by also establishing means to contribute to the solution. If we only rely on government's initiatives and become merely spectators to the struggling state of chemical education then we can expect very slow development.

1.2. The study and its significance

This paper is a response to the need for teacher-initiated measures in improving the quality of secondary school chemical education in the Philippines. This project is generally aimed to design high school chemistry experiments that:

- a. do not require inaccessible and expensive chemicals and instruments.
- b. promote the value of responsible stewardship by applying the principles of green chemistry in the design.
- c. emphasize the chemical nature of common place materials like plants, medicines, cooking ingredients, food stuffs, beverages, condiments and the like by using them instead of laboratory chemicals in the activities to make the obvious linkage of chemistry concepts in the lives of the students.
- d. time-bound and do not require too much time before results are observed.
- e. exhibits chemical phenomena that can be used as springboard, application, or "meat" of the class discussion that would eventually minimize the use of lecture and chalk-talk type of teaching.
- f. can be performed outside the laboratory, even without standard laboratory equipment and glassware.
- g. requires minimal preparation on the part of the teacher.
- h. infuses aspects of Filipino culture in the activity as a way of promoting and enriching it.

The chemistry experiment designed in this project will hopefully contribute in the betterment of chemistry and science education in Saint Paul College Pasig and the Philippines. This project was conceived all in the effort to promote practical chemistry laboratory work even when constraints are existent. If it is impossible to eliminate them totally, then teachers and all stakeholders of science education should do the necessary adjustments and be creative enough to address them.

This project also challenges chemistry teachers to start initiating moves to veer away from traditional, comfortable, convenient but unproductive methods of teaching by implementing tailor-made experiments suited to needs of the students, resources of the school, and available substitutes that may be tapped.

2. Theoretical background and literature review

2.1. Green chemistry

There is a growing and evolving interest among chemists, chemical practitioners and educators in using green chemistry principles in their practice. There had been a number of organizations, conferences, journals and workshops that were devoted in the promotion of green chemistry, evidence to this emerging field of chemistry.

The International Union for Pure and Applied Chemistry (IUPAC) with its establishment of a sub-committee on green chemistry, and in collaboration with many other agencies like the American Chemical Society (ACS) and the Green Chemistry Institute (GCI) are major stakeholders in promoting the concept and practice of green chemistry around the world.

2.2. The guiding principles of green chemistry

What makes green chemistry a promising field and tool in the practice of chemistry and chemistry education?

Anastas and Warner (1998), proponents of green chemistry in their seminal work entitled “Green Chemistry: Theory and Practice” defined green chemistry as the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products.

Green chemistry is not a new independent branch of chemistry nor an isolated field on its own, but it penetrates through all of the classical branches of chemistry. It is a chemical philosophy – a way of looking at how things should be done in the practice of chemistry.

Green chemistry is founded on twelve principles as presented by Anastas and Warner.

Table 1. Twelve principles of green chemistry green chemistry theory and practice (1998)
Anastas and Warner

Principles	Explanations
Prevention	<i>It is better to prevent waste than to treat or clean up waste after it has been created</i>
Atom Economy	<i>Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.</i>
Less Hazardous Chemical Syntheses	<i>Whenever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.</i>
Design Safer Chemicals	<i>Chemical products should be designed to effect their desired function while minimizing their toxicity</i>
Safer Solvents and Auxiliaries	<i>The use of auxiliary substances- solvents, separation agents, and others- should be made unnecessary whenever possible and innocuous when used.</i>
Design for Energy Efficiency	<i>Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.</i>
Use Renewable Feedstocks	<i>A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.</i>
Reduce Derivatives	<i>Unnecessary derivatization- use of blocking groups, protection/deprotection, and temporary modification of physical/chemical processes- should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.</i>
Catalysis	<i>Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.</i>
Design for Degradation	<i>Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.</i>
Real-time Analysis for Pollution Prevention	<i>Analytical methodologies need to be further developed to allow for real-time, in process monitoring and control prior to the formation of hazardous substances.</i>
Inherently Safer Chemistry for Accident Prevention	<i>Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.</i>

In the design and presentation of green chemistry experiments, these principles may be indicated to facilitate its integration in the discussion of the chemical topics. Kichhoff and Ryan (2002), in the book “Greener Approaches to Undergraduate Chemistry Experiments” clearly presents the practice of including green chemistry topics together with the chemical topics in the experiment presentation.

3. Experimental

The following section describes the protocol that was designed, tested, and refined in the laboratory for the proposed green chemistry experiment for high school students.

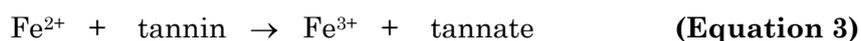
Bayabas decoction was prepared by boiling five to ten fresh guava leaves in 200 mL water (after washing them with water and cutting them in pieces). The source of heat was removed upon observation of brown coloration in the mixture. Guava leaves were removed from the decoction.

Four tablets of *fersulfate* (325 mg/ tablet) were soaked in water to remove the brown coating. The de-coated tablets were dried using absorbent tissue paper then pulverized using a mortar and pestle. The pulverized *fersulfate* was dissolved in 50 mL hot water and filtered. The filtrate was collected in a clean Erlenmeyer flask then poured into the brown guava decoction. The resulting mixture was finally observed.

4. Results and discussions

This section discusses the observations and data gathered in performing the designed chemistry experiment. Here, chemical concepts are stressed to support observed chemical phenomena. The green chemistry principles at work in the designed experiment are also explored in this section.

Mixing the bayabas decoction and the fersulfate solution resulted to an immediate color change from brownish to bright black. Such color change indicates that a chemical reaction has occurred. The reaction may be described as an oxidation-reduction reaction, wherein Fe^{2+} is oxidized to Fe^{3+} and the tannin is reduced to tannate.



Iron(II), Fe^{2+} , serves as a reducing agent and the tannin serves as an oxidizing agent. The oxidizing power of tannins in guava decoction makes it a good disinfectant in cleaning and healing wounds. The oxidizing power of tannins kills microorganisms that cause infection.

Precipitation was observed in the reaction flask as seen in the layering of the mixture if left standing for a long period of time. Precipitation is another indication of a chemical reaction. The black precipitate is primarily iron(III) tannate. It is mentioned by Cobb (2001) that when iron(III) tannate gets in contact with oxygen, it becomes more black, such may be explained by the oxidizing power of oxygen. When iron(II) ions that may still be present in the mixture are oxidized to iron(III) there will be a more intense the change in color.

4.1. Green chemistry concepts

The experiment promotes the following green chemistry principles: prevention, less hazardous chemical syntheses, use of renewable feedstock, and inherently safer chemicals for accident prevention.

The experiment uplifts the green chemistry principle of finding alternative feedstock (as Anastas and Warner would put it) or starting materials in trying to produce a chemical substance. Anastas and Warner promote the use of alternative feedstock or starting materials in chemical synthesis by using agricultural or biological feedstock instead of petroleum materials.

The goal of the experiment is to see how iron(II) reacts with tannin. The use of guava leaves, an agricultural feedstock as a source of tannin is one way of getting rid of the use of tannic acid – a known carcinogen.

The use of guava leaves in the production of iron(III) tannate still realizes the same effect of using tannic acid as a reactant. The only difference is that the use of guava leaves is much safer and cheaper. The bayabas decoction may spill on the students handling it without posing any harm as compared to spilling tannic acid.

5. Conclusion

This project is a call for teachers to initiate measures in improving the quality of science education in the Philippines and that is by going back to practical laboratory work- the most effective method of teaching science.

While there may be constraints in using practical work as a teaching tool, teachers through their creativity may design experiments that are cost-efficient yet of high pedagogical value. Experiments that are designed carefully leading to the understanding not only of chemical concepts but of their implications in the student's daily living.

The experiment that was presented in this paper is a proof to the possibility of tailor-made experiments that integrate principles of green chemistry – the growing and evolving philosophy of responsible stewardship in the context of doing chemistry. Integrating green chemistry concepts in the design of high school chemistry experiments makes students aware as to the responsibility that goes with the use and production of chemicals.

Moreover, the experiment was designed to consciously “inculturate” chemistry. Aspects of Filipino culture, values, and traditions may be infused in the design of experiments so as to make the students own the science and not view it as something that is highly foreign. When students can relate to the chemical concepts illuminated in their culture then that is a lasting learning for them.

It is a hope that more and more teachers realize their potent role in uplifting the quality of science education in the Philippines. The government and other institutions may prod teachers to improve on their competence and teaching styles, but still, the magnitude of change in the educational system would always rely heavily on the motivation of teachers – seeing worth in what they do.

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