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Green Approach for Chemical Education in Chemistry Lab

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Abstract In this work we reported Green procedures for chemistry lab experiments and evaluated it as a benign approach for chemical education in chemistry for chemistry undergraduate students. The improved Experimentation represented new, facile, less hazardous, high atom efficiency, and environmentally benign advance in practical chemical education. The newly designed greener procedures were carried out and the advantage over the conventional one was evaluated through a comparative study. The greener experimentation obviously demonstrated the superiority of the greener practice over the conventional one and largely increased the learning outcomes about Green Chemistry and Sustainability for the individuals participated in the study.

Keywords Green Chemistry, Sustainability, Chemistry Education, Benign Lab, Green Experiments

1. Introduction

Green Chemistry is defined as invention, design, development and application of chemical products and processes to reduce or to eliminate the use and generation of substances hazardous to human health and environment [1].

The challenges in resources and environmental sustainability require more efficient and benign scientific technologies for chemical processes and manufacture of products. Green chemistry addresses such challenges by opening a wide and versatile research scopes, thus allowing the invention of novel experimentations that can maximize the desired products and minimize the waste and byproducts [2]. Therefore, it is essential to direct research, education, and development efforts towards a goal that will constitute a powerful tool for fostering sustainable innovation [3, 4]. Green chemistry alone cannot solve the pressing environmental concerns and impacts to our modern era, but applying the twelve principles of green chemistry into practice will eventually help to pave the way to a world where the practice is greener [5, 6]. Exploration of alternatives with minimal side products or waste, and elimination of the hazardous materials will be the main thrust area in all aspects of life [7].

Sustainable development is now accepted by governments, Academia, industry and the public as a necessary goal for achieving societal, economic and environmental objectives. Within this, chemistry has a key role to play in maintaining and improving our quality of life [8, 9].

Green chemists should assure about the things that they do, they should not only do chemistry, what they were supposed to do, but also they should do it safely [10, 11]. This means that it is not only important how chemists make something, it is also important that what they make isn't harmful. In green chemistry, function is not related to hazard, making safe, and non-toxic products and processes is the goal [12, 13]. Thus, designing, green and sustainable experimentation in lab and classroom, is a central demand to make chemistry interesting, attractive, and environmentally benign [14].

Our work is a successive approach to apply Green Chemistry and sustainability in laboratory, classroom, academia, manufacture, and finally, the surrounding environment. Our objectives is to conceptualize Green Chemistry and sustainability in education, to change our Chemistry practice to be greener, to reassure the importance of green Chemistry and sustainability, and to design Greener and sustainable Chemistry practice instead of the conventional one.

2. Results and Discussion

Our study focus on simple chemistry lab experiments, that involve the identification of chemicals via a given reagent and the observation is color change. These types of experimentation were conventionally incorporated in all educational study plans from primary schools to universities. The problem with such conventional experiments was the terrible environmental impact that increased the bad tenure of practical chemistry.

Initially, open discussions between participant groups about exchange ideas, share experiences, and best practices

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that help embed green chemistry and sustainability in academic programs were also conferred.

Remarkably, the conventional procedures of such experiments were well known with its bad reputation and extra cautions due to the high risk as well as the presence of hazardous materials. Also carrying out such procedures in lab, will not be free from accidental hazard. Moreover, at the end, we will face, how and where to dispose the liquid chemical waste?, Figure (1).

On the other hand, the green practice solved the problem through simplicity, usage of less material, safety during procedure, presence of the high environmental impact, nearly absence of liquid chemical waste. In the green procedure, materials were minimized to microscale and the liquid chemical waste was prevented, since the waste will be colored paper discs, that were reused in green lab decoration. The environmental impact was high and the student clearly understand the meaning of green chemistry and sustainability in practice, Figure 2.

During practice, Students were asked to individually answer the Test Questions about green chemistry and sustainability, one time before starting the practice, and another one after ending the practice. A comparison between the results, (in percentage), of the Test Questions declared that, the differences in the learning outcomes before and after the practice were highly significant as shown in (table 1). The significance of the study was obviously noticed from the increased percentage of the answered Test Questions after practice for all individuals comparing with that before. It was obvious that the study practice enabled the students to increase their knowledge about green chemistry and sustainability, thus, increasing the percentage after practice more than before.

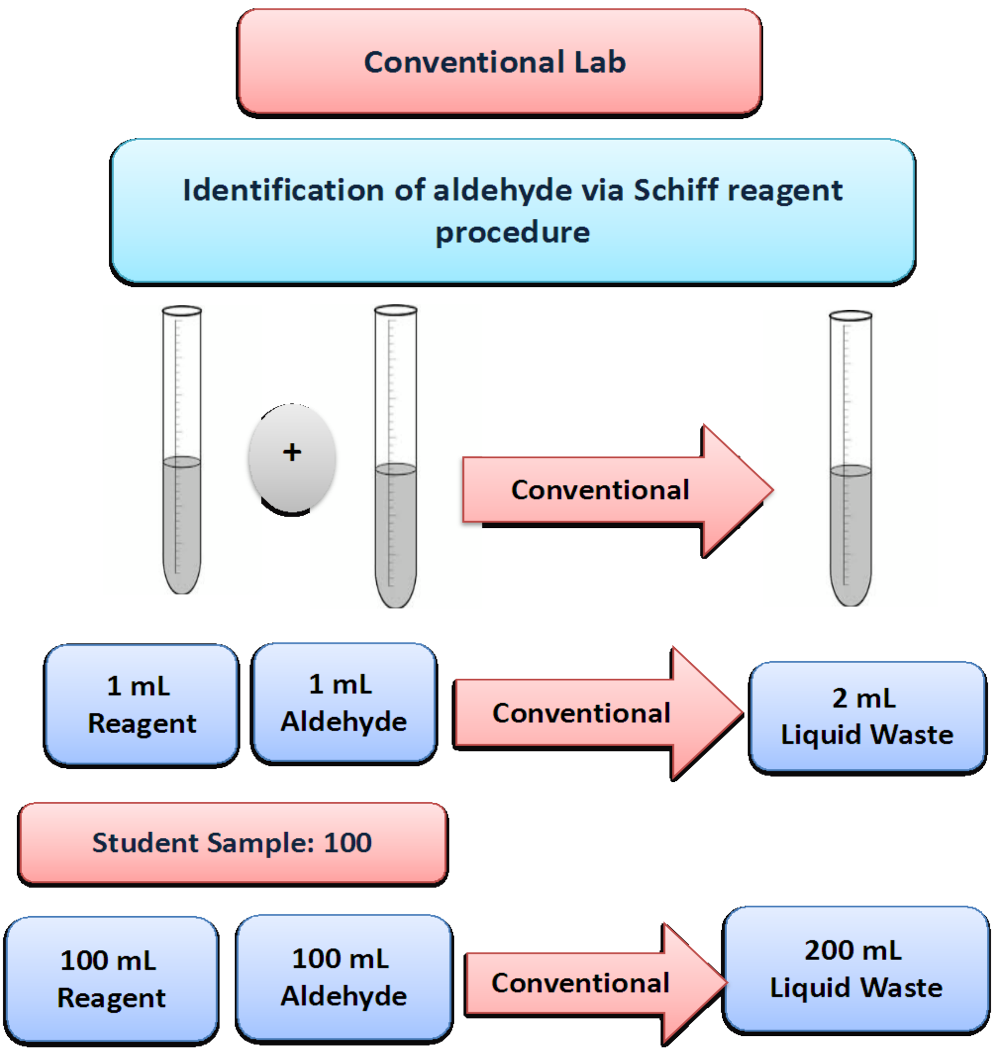

Figure 1. Graphical representation of Conventional Lab experimentation

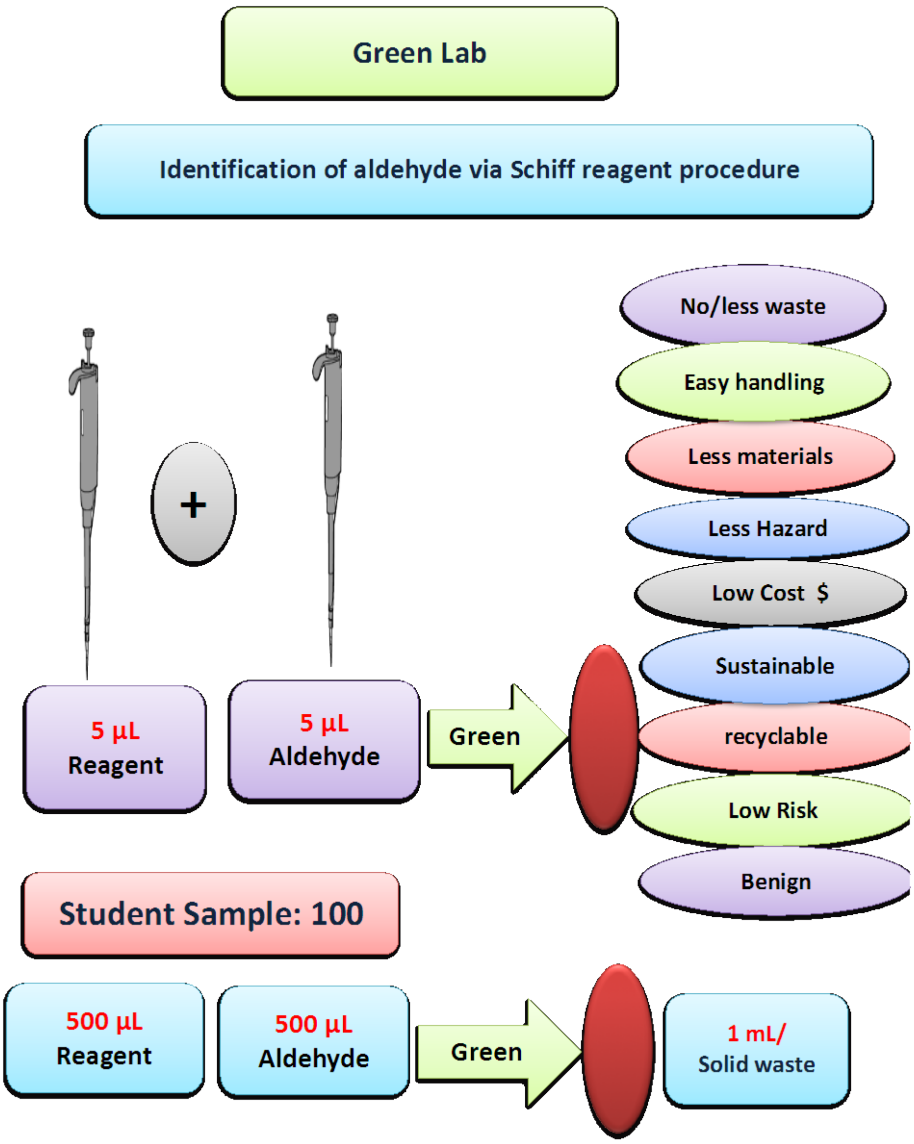

Figure 2. Graphical representation of Green Lab experimentation

Table 1. Comparison between the results (in percentage %)

	Question	Before practice		After practice	
		Yes	No	Yes	No
Q1	Have a general idea about the aims of green chemistry and sustainability	20	80	95	5
Q2	Relate green chemistry with a new and safer way of doing chemistry which prevents hazards and pollution;	10	90	80	20
Q3	Realise that green chemistry encourages critical thinking and careful planning of chemical reactions and processes;	20	80	70	30
Q4	Understand that green chemistry is not only theoretical but is also practical	30	70	90	10
Q5	The important role of green solvents to minimise waste and safeguard human health and the environment.	20	80	90	10
Q6	Did you have any idea about 12 principles of green chemistry	10	90	90	10
Q7	Did you know the microscale meaning	20	80	90	10

*total number of students = (100 students/4 groups)

Figure 3. Graphical representation of procedure of Green Lab experimentation

The students' comments in the standard lab reports were highly reproductive, and recommended the green procedure over the conventional one due to high atom efficiency, ease of handling, low cost, nearly absence of probable risk and hazardous, waste reuse, and the environmentally benign practice. Also, through discussion groups, the student encouraged such practices that embed green chemistry and sustainability courses in study plans for all levels of education to publish these practices in all aspects of life, labs, classrooms, manufacture and finally the surrounding environment.

3. Experimental

This study has been carried out with the participation of under graduate chemistry students, (100 students/4 groups), who studied these experiments via the conventional procedure. Firstly, the students were oriented about the study and accepted all the terms and condition of the study. The students were asked to answer a Test Questions about green chemistry and sustainability. The students requested to carry out both the conventional and the green procedures for each experiment using the given lab manual and report their observation and comments for each experiments. Finally, the students were asked to answer another copy of Test Questions about Green Chemistry and Sustainability. The two copies of Test Questions for each student were corrected and the results (in percentage) were compared to evaluate the learning outcomes and education impacts of the study about green chemistry and sustainability.

Conventional procedure: Both the reagent and the identification compound solution was prepared and its physical characterization was reported. Two clean dry test tubes and two 5 mL pipette were placed.

Procedure: In two dry test tubes, Equal volumes (1 mL), of both the reagent solution and the Identification compound were taken and mixed in one tube. The color change after mixing was observed and compared with that before mixing. These procedure was repeated twice to insure observation. The liquid chemical waste was measured and kept in the waste bottle. The observation was reported and the environmental impact of the conventional procedure was outlined.

Green procedure: For each Experiment, three filter paper discs, 0.5 cm diameter, were impregnated with 5 µL/disc by the given reagent solution via means of micropipette and were introduced as reagent kits for the given experiment on Identification Sheet Figure (3). The identification compound solution was prepared and its physical characterization was reported.

Table 2. Data of Some Experiments incorporated in the current study

Exp.	Identification Compound	Reagent	Color Change	
			Before*	After**
1	Aldehyde (Formaldehyde)	Sciff	White	Red
2	Salicylic Acid	$FeCl_3$	Pale yellow	Violet
3	Benzoic Acid	$FeCl_3$	Pale yellow	Light brown
4	Bases	Ph. Ph.*	White	Pink
5	Acids	Methyl orange	Yellow	Red
6	Quinol	$FeCl_3$	Pale yellow	Green
7	Formic acid (format salts)	KMnO4	Violet	White
8	Na_3PO_4 (Phosphate ion)	AgCl	White	Yellow

*, The reagent disc color BEFORE addition of identification compound
**, The reagent disc color AFTER addition of identification compound

Procedure: On the Identification sheet of the given experiment, about 5 μL of the identification compound solution was added via micropipette to two discs of the reagent kits leaving one clear for comparison. The color change of the disc after addition was observed, compared with that of the reagent and recorded in Table (2). The observation was reported and the environmental impact of the green procedure was outlined.

Recycle and Reuse: At the end of the work, the students were invited to practice reusing and recycling by collecting the colored paper discs and make nice GreenLab decoration.

4. Conclusions

The work clearly conceptualized the practice meaning of green chemistry and sustainability in education. The green procedure was advantageous, and take superiority over the conventional one. Also it has the applicability to wide variety of lab experimentation with the mission to promote greening of Chemical education. The study recommended embedding greener experimentation in chemistry lab since the green chemistry and sustainability practice in education increased the learning outcomes of the individuals. The study opened research window to encourage benign and sustainable research on educational practice, and to activate embedding green chemistry and sustainability practices in study plans of all education levels.

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