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Article

Green Chemistry Education: Towards a Better Understanding of Environmental Knowledge

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Abstract: Measures taken to control the spread of coronavirus disease 2019 (COVID-19) have significant effects on the environment due to increased usage of personal protective equipment (PPE). The haphazard PPE disposal creates environmental burden. In order to reinvent a sustainable future post COVID-19, this paper intended to propose a policy that promotes sustainability by introducing Green Chemistry education in Malaysian curriculum. A previous study has shown that we need education that goes beyond providing basic knowledge and skills, and lean toward awareness, ideas and action that help us advance towards sustainable development. Previous findings indicate that Green Chemistry is an ideal focus for school science education because it can develop the skills that will enable the students to contribute to a sustainable future post COVID-19 through chemistry. The students will learn to apply scientific principles to solve real-world problems., As trainee teachers, we aim to identify suitable pedagogical approaches in teaching Green Chemistry because sustainability concepts need to be incorporated throughout the educational process.

Keyword: Education, Environment, Green Chemistry, Post COVID-19, sustainability.

1. Introduction

Coronavirus disease-2019 (COVID-19) is a new disease that has been declared as a pandemic by World Health Organization (WHO). The rapid spread of COVID-19 from the end of 2019 and through 2021 has impacted lives, economies and societies across the globe dramatically. Attention is now turning to designing recovery packages in many countries. Governments are responding to the crisis by developing an array of policies and recovery measures that cover several sectors and policy types. These recovery packages can also have significant effects on environment-

al goals at a national and international level (World Health Organization, 2021).

The measures taken to control the spread of the virus have also give significant effects on the environment due to the widespread use of disinfectants, hand sanitizers, personal protective equipment (PPE), the haphazard disposal as well as uncontrolled application of other measures that create environmental burden. Unsafe and improper use of these products can lead to toxic effects in people that can be as dangerous as the virus itself (Robert, David & Kate, 2020). WHO recommended alcohol-based hand sanitizers for frequent hand hygiene, which are mainly made up from chemical substances like ethanol, hydrogen peroxides or isopropyl alcohols in different combinations. Increased use of hand hygiene products with alcohols-based formulations are not environmentally friendly and hazardous for human health.

In order to cope with the challenge from environmental crisis, sustainable development goals calls for chemists, engineers and decision-makers to take responsibility solutions. Initial motivation for redesigning chemicals and chemical process came from the pollution prevention legislation in the early 1990s authored by the Environmental Protection Agency (EPA). This legislation clearly articulated a shift toward inherently safer and sustainable chemicals as being the best pollution prevention strategy. However, recognising the concept is not enough as it is necessary to teach the values and views of the sustainability of green chemistry to tomorrow's chemists, engineers and decision-makers during their professional studies. This is to ensure the implementation of the sustainability based on the advancement in of green chemistry (Martin, Mulvihill, & Evan , 2011).

Ideally, green chemistry and discovery in engineering seek to maximize efficiency and minimize health and environmental hazards throughout the chemical production process. Green chemistry intends to accomplish this through the rational design of chemicals and processes according to a set of principles and metrics identified during the past few decades. Education that goes beyond providing basic knowledge and skills that leads to awareness, ideas and action is needed to help us advance towards sustainable development (Jesper Sjöström, Ingo Eilks, et al, 2016). Therefore, this paper aims to propose a policy that promotes sustainability by introducing Green Chemistry education (GCE) in Malaysian curriculum in order to reinvent a better sustainable future post COVID-19.

2. Existing Data

Green chemistry can be defined as the design of chemical products and processes that reduce the use and generation of hazardous substances (Larry, 2017). It seeks to revise inherently safer production and use of chemicals in our society The development of green chemistry has been catalyzed by the formulation of principles and metrics that guide the design of sustainable chemicals. The principles of green chemistry along with other sustainability metrics help identify opportunities for innovation in Malaysia as well as abroad.

2.1 Environmental Education in Malaysia

For now, Green Chemistry Education (GCE) has not fully developed in Malaysia yet. However, there are same component as GCE called Environmental education (EE). EE can be seen as an integral component of future peoples' education in order to allow them to tackle and resolve current and emerging environmental issues. The significance of EE in Malaysia is emphasised in the National Policy on the Environment 2002 and one of the key areas of the Green Strategies highlighted in the policy is 'Education dan Awareness' among people (MOSTE, 2002). Among these strategies are to introduce wide-ranging formal and informal EE integrated the ecosystem and growth into educational activities from school to tertiary institutions, with the development of suitable methods and materials. The promotion of EE in Malaysia is mainly focused on resolving environmental issues such as littering,

water pollution, air pollution and biodiversity depletion.

In terms of formal education, the Ministry of Education has developed an EE curriculum and adopted a variety of teaching and learning techniques to increase knowledge of the environment and integrate the importance of protecting the environment. The aim of these curriculum is to educate people who love and care for the ecosystem in order to think and to be conscious of sustainable development (Mageswary & Zurida, 2012). In schools, EE is infused into each subject, rather than taught as a single subject. This school curriculum focuses on educating society to be more aware and concerned about environmental problems, be educated, competent and committed to solving environmental issues individually or collectively.

By introducing GCE in Malaysia, it allows the students to apply scientific principles to solve real-world problems, demonstrate chemistry's role as an essential science in finding solutions and prepares future scientists for the collaborative interdisciplinary work required. Teaching and learning green chemistry for sustainability education can fully utilize the applied learning models that connect real-world circumstances with the broader human concerns of environmental, economic, and social systems. Education is practiced everywhere. We also study GC executed abroad.

2.2 Green Chemistry in USA

From the context of Green Chemistry (GC), it has already moved over two decades ago mainly started in United Stated of America (USA). Environmental Protection Agency (EPA) is a legislation for redesigning chemicals and chemical processes. A change to inherently cleaner and renewable chemicals was clearly outlined in this legislation as the best option for pollution reduction. The early support of GC came from the U.S. Presidential Green Chemistry Challenge Awards established in 1995, the Green Chemistry Institute founded in 1997 and the publication of the Green Chemistry: Theory and Practice in 1998 (Martin et. al, 2011). GC slowly started to embed in U.S. education system in order to preserve better ecosystem in their country.

Green Chemistry education (GCE) has evolved as a response of traditional chemistry education to Education for Sustainable Development (ESD) and is characterised by the infusion of Green Chemistry Principals, concepts, and practices in science education in several ways (Sjöström et al., 2017). Recently, many companies in U.S have adopted green practices like reformulating materials in response to green market demand, for economic benefits, and because of their dedication to social welfare and the environment, they obtained any GC training for chemistry and science college students to be better prepared for an industrial position. Thus, GCE not only improve the public image of chemistry engineering, but to engage students and people to involve in protecting the environment collaboratively.

3. Analysis of Data Interdisciplinary Green Chemistry in Education

Malaysia initiates GCE to apply more environmentally friendly chemicals and processes to mitigate climate change of anthropogenic origin. Other country such as Brazil has a wider range of characteristics that can enable it to be at the forefront of sustainable chemistry as it is rich in biodiversity and natural resources, with intense solar radiation, plenty of water, and varied climatic conditions throughout the country compared to our nation.

3.1 Similarities and Differences

Based on two types of education policies stated above, there are several similarities that can be observed throughout the process to embed it in our educational system. Both of these policies are more focussing on aligning with the broader sustainability movement and suitable pedagogical approaches to teaching and learning among students. Indeed, Environmental Education (EE) and Green Chemistry education (GCE) can be considered as interdisciplinary of sustainability edu-

cation. Rhoten et. al. (2006), interdisciplinary education can be understood as a form of curriculum design and teaching in which teachers incorporate data and theories from different disciplines to promote and improve the ability of students to create new solutions and reach the current issues. The applied of learning sustainability can be fully utilize and connected real-world circumstances with broader human concern of environmental, economic, and social systems.

Sustainable education is a process of learning how to take decisions that reflect the long-term future of the economy, environment, and social well-being of all communities (McKeown & Hopkins, 2002). The goals of EE are to produce environmentally literate graduate, who is capable of evaluating thinking, making decisions, solving problems and taking responsibility accordingly. Teachers are required to integrate EE principles and components across the curriculum at all levels and to enhance the process, EE Curriculum Guidelines provided primary requirements, elements and EE implementation strategies at pre-school, primary and secondary levels. The ultimate goal of GCE is to foster and improve scientific literacy in sustainability and to develop the corresponding skills among the present and future generations. In addition, GCE promotes and improves scientific literacy in the field of sustainability and develop the appropriate skills for society.

3.2 Strengths and weaknesses

Environmental Education (EE) is considered a key component of the education for future citizens for them all to be able to face and deal with the existing and emerging environmental issues. Through the method of EE, people get an understanding of the concepts of and information about the environment. Moreover, they also acquire values, skills, understanding and the information fundamental to make judgments, take part in decision-making and to require suitable activity in addressing to natural issues dan problems (Salequzzaman & Stocker, 2001). People are empowered to participate in decision making and critically address the issues they might encounter in daily life. Teaching and learning emphasize holistic, multi-disciplinary approach in order to develop information and skills required for maintainable future as well as changes in values, behavior and lifestyles. Hence, the importance of EE in enhancing people's awareness towards the environment is undeniable.

However, after decades of effort to integrate EE in our educational system, studies revealed that Malaysians in general specifically did not reach a certain desired level of commitment towards the ecosystem. The benefits of EE have not been implied due to emphasis and students do not really see the need to practice an enviromental-friendly lifestyle (Nadeson & Nor Shidawati, 2005). A research by Sharifah and Hashimah Yunus (2006) found that Malaysian students still have little apathy to consciously participate in environmental behaviors due to lack of understanding within society. Teachers do not integrate environmental issues even though they acknowledged the benefits of teaching such issues. They cannot effectively address the goals and aims of EE solely by gathering information about environmental issues and concerns. Thus, it is unrealistic to expect people to explore environmental concepts without awareness to protecting our earth.

Based on previous researches, there are only a few reviews on GCE exist in term of its strengths and weaknesses. Andraos and Dicks (2012), published a critical and comprehensive review on GC effective educational practices including teaching resources, emphasizing green organic chemistry. Although their review is the most valuable in GCE but the field is expanding and evolving at such a fast pace, means that their work requires elaboration. Table 1 below shows the strengths and weaknesses of CGE from their opinion.

4. Integrating green chemistry into existing lesson plans

The curriculum has put STEM agenda approach as a core element in the construction and implemen-

Table 1: Strengths and weaknesses of GCE

	Benefits of GCE		Weaknesses in CGE
1	GCE can be implemented with existing courses or be stand-alone	1	More work must be published in subfields beyond Green Chemistry.
2	GCE are both qualitative and quantitative fields that allow green decision making	2	Published paper often lack of experimental detail and concept.
3	GCE became world-wide and relevant in protecting the ecosystem.	3	Only a few courses of Green Chemistry offered and usually electives.
4	Achieve a deeper and critical understanding of chemical engineering		
5	Retain content knowledge and motivated to understand it better.		

tation. Since KSSM and KSSR revision in 2017 is still new, many important steps have to be taken to ensure the smooth implementation of green chemistry in Malaysian curriculum. Among the first steps to strengthen STEM education is through the Malaysia Education Blueprint (2013-2025), namely to increase the interest of students and teachers awareness of STEM education (Suraya Bahrum, Norsalawati Wahid, et. al, 2017). As the Malaysian government has started to show interest in STEM approach to the school level, the government should ensure the implementation of Green Chemistry education (GCE) in the curriculum could meet the characteristics of a clear STEM integration.

To teach GCE, the teachers need to identify suitable pedagogical approaches to teaching and learning green chemistry among college students and preservice teachers by examining the teaching methods that have been used to promote GCE and how these methods have supported green chemistry learning (GCL). A good pedagogical strategy is essential as the laboratory affects students' learning and what they take away from a laboratory course (Mageswary & Zurida, 2011). Understanding how to teach issues in an interdisciplinary curriculum is one of the key factors of interdisciplinary learning. To achieve this objective, a useful approach is student-centered pedagogy, where teaching and learning take place in the field, in interaction with stakeholders, and through participation in civic activities or student-led research. There are a variety of methodologies that can be implemented to facilitate active learning including project-based learning, inquiry-based learning, experiential learning, just-in-time teaching, contextualised learning and cooperative learning. In this way, in addition to cognitive skills, students also learn transferable skills such as the ability to work in teams, to create and to think critically, to communicate and to collaborate when reflecting on complex problems and look for solutions to these problems.

Integrating green chemistry into existing lesson plans will allow students to make more connections between the scientific topics of study and the problems that they face in daily life. In these classes, students learn the protocol that they will take with them to their own labs or industry. Green chemistry principles were applied in the class as the following ways: (i) all waste is recycled and reused, (ii) non-hazardous chemicals are used and (iii) all of the reactants converted to products illustrating atom

economy. Students responded positively to the lab indicating the power of green chemistry as a tool to stimulate learning in high school or college general chemistry. Hence, it is essential that we train our future chemists using green chemistry methods and ideals. By presenting inquiry-based learning opportunities, students can lead their own discoveries, promoting STEM education and critical analysis of the world around them (Martin & Evan , 201).

As we enter the second decade of the 21st century, the Ministry of Education must initiate a curricular vision in GCE that meets a new spectrum of vital interests. If creativity, collaboration, communication, and critical thinking all touted as hallmark skills for 21st century success are to be cultivated, we need to ensure that GCE is drawn closer to the sustainable development of the country especially in post-Covid 19. The professional training in the integration of STEM education in Malaysia should be strengthened, improved, and monitored to establish a competent teacher in knowledge, skills, and attitudes in the context of the integration of green chemistry in STEM.

5. Improvement plan, options and feasibility

Changes to the curriculum of course give huge effects on teaching and learning and assessment in national examinations. Therefore, after the implementation of the new curriculum, the Ministry of Education is recommended from time to time to see the needs of schools, teachers, students, parents, and members of the community and the parties concerned during the implementation of green chemistry in Malaysia curriculum. The process of communication and discussion is important to give a clear picture of the new curriculum and get feedback for improvement in the future to create an inclusive education system for all levels of Malaysian society.

Learners must be engaged with green chemistry at a deep level for the education to be effective. One methodology to contribute towards the achievement of such engagement is for facilitators to employ active learning strategies in a range of teaching environments. Active learning is a teaching strategy where learners are actively participating in the learning process, enabling students to engage in higher order cognitive tasks such as analysing and evaluating. Tons of methodologies that can be implemented to facilitate active learning including project-based learning, inquiry-based learning, experiential learning, just-in-time teaching and cooperative learning. In order to enhance the learning experience such as by facilitating 'flipped' lectures or provision of interactive online content, the use of technology can also be incorporated.

For an interdisciplinary Green Chemistry curriculum, it should be integrated with other science-related courses, such as biology and artificial intelligence, and non-science-related courses, such as psychology, business, ethics and law. Interdisciplinary green chemistry learning can be developed by exploring how cognitive, social, and emotional factors interact with each other to promote an understanding of issues and problems. In implementing these topics, integration of green chemistry with other disciplines problem-oriented perspectives included in "real-world" case studies and laboratory work have been seen to be elective approaches in GCE (Liliana Mammino, 2015). Therefore, an interdisciplinary framework, an interdisciplinary curriculum and interdisciplinary methods should be considered when integrating the sustainable development goals into the GCE.

The suggestions of course teaching methods that can be used by educators are collaborative exploration of case studies and journal articles using open-source software, group concept mapping exercises and delivery of a green chemistry laboratory activity for school children adapted from a classical experiment. This particularly dynamic course not only provides students with a thorough understanding of green chemistry, but also encourages them to contribute to the understanding of a broader audience and therefore providing additional societal benefit.

6. Conclusion

The outbreak of COVID-19 pandemic gives some disruptions in chemical industry which plays an important role in the production of plastic, medicines, packaging and many more. Based on our findings, we can conclude that GCE can be integrated both chemical industry and also in our educational system. By implementing GCE with natural sciences, psychology and philosophy can create a new era of sustainability environment. In addition, integrating GCE with other disciplines can be approached with high levels of thinking skills, creativity and evaluation towards the green process. We are hoping that by integrating GCE, we can make more transformation of our environmental issues. In addition, Green Chemistry education (GCE) is the innovative design, development and processes to educate people for being preserve with our ecosystem. To achieve this purpose, there are links between GCE with other educational domains such as chemistry education that aimed at fostering science literacy and ethic education.

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