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INCLUSION OF ORGANIC CHEMICAL BASED SOCIO-SCIENTIFIC ISSUES AND ACTION-BASED ACTIVITY TO PROMOTE SUSTAINABILITY IN THE BASIC ORGANIC CHEMISTRY COURSE

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Abstract: Although there is overwhelming concern among scientists on the idea of a sustainable future, however, early motivation and classroom experience about sustainable development (SD) in undergraduate courses are still very low. As majority of the science curriculum are meant to prepare students to become the next generation of scientists, there is a need for them to learn about SD so that they can contributre responsibly without compromising the environment. At Universiti Malaysia Terengganu, the students gained classroom and non-classroom experiences on SD by participating in an activity that involved studying socio-scientific issues and basic organic chemistry content. In that activity, students take turns to present literature regarding the organic chemical-based socio-scientific issues and their real-life solutions to address problems. Based on a survey and feedback, the students showed an increased familiarity about organic chemical based Socio-Scientific Issues (SSI), which involved the use of organic compounds, and they expressed a high degree of satisfaction towards the implemented activity.

Keywords: Education for Sustainable development, socio-scientific issues, basic organic chemistry, interest, learning.

Introduction

Education for Sustainable Development (ESD) is an effort established by the United Nations (UN) to promote sustainable development by improving the capacity of future citizens to address developmental issues that affect the environment (Holden *et al*., 2017). According to the ESD, students or future citizens should be able to actively participate and shape their current and future society in a sustainable manner, based on the concept of Sustainable Development (SD) (De Hann, 2006). In this respect, all stakeholders, especially schools, are anticipated to play a vital role in ESD (Burmeister *et al*., 2012).

In general, the school chemistry education is playing a pivotal role in achieving SD. From the ESD perspective, chemistry may be used to create awareness among students on proper stewardship of our natural resources, and enables the evaluation of chemistry-related business and products based on a balanced, multi-perspective and carefully reflected fashion (Hofstein *et al*., 2012). In addition, as viewed from the lens of socially-relevant science education, chemistry has full of potential points of contact in fostering ESD, which plays a central role to maintain the current quality of life and, at the same time, bettering the future economy.

Examples of school chemistry activities that are in line with ESD are debates on the use of consumer products and their effects on human lives (Marks & Eilks, 2010), alternative energy and their uses (Feierabend & Eilks, 2011), climate change (Feierabend & Eilks, 2010) and use of plastic in modern society (Cook, 2014). The ESD-related activities mainly occurred within the classroom. There are also other forms of ESD learning for undergraduate students, which takes place outside the classroom, one of which is the practice of green chemistry laboratory work.

Examples include green synthesis of 4-bromoacetanilide from aniline (Biswas & Mukherjee, 2017), green epoxidation of soybean oil (Barcena *et al*., 2017), green nano-particle synthesis (Amaris *et al*., 2014), green Wittig Reaction (Morsch *et al*., 2014), ionic-liquid mediated synthesis of (3-Methoxycarbonyl) coumarin (Verdía *et al*., 2017), and the introduction of mechano synthesis in chemistry laboratory teaching (Wixtrom *et al*., 2014). The motivation for implementing sustainable practices in university chemistry education reflects the increasing consciousness of stakeholders towards global climate change and environmental problems, and how they are seeking opportunities to use science to address the needs of our changing world.

In general, we agree that learning "about" and "for" sustainable development are important for transforming students into civic-minded citizens. But, we must be aware that chemistry education should also go beyond teaching of theories and SD knowledge. As such, the incorporation of chemistry lessons into an individual action-based pattern of living is of great importance, which suggests that students should participate actively in their local environment, school and society in light of ESD teaching (Wals *et al*., 2014). The scientific community sees a greater need to promote SD knowledge in undergraduate courses to create early environmental and societal familiarity that encompasses every citizen's responsibility to look after the earth.

In order to create a synergy between chemistry education and sustainable education learning, herein, we like to report on an activity which provides an alternative instruction for educators that can lead students to engage, gain new knowledge and take action to address the socio-scientific issues (SSI) and sustainable challenges faced by society today. At the same time, it may provide an alternative instruction for organic chemistry teaching. Many chemistry issues, such as the use of alternative fuel, are feasible in SSI-based chemistry learning. This activity implores students to think critically to analyse and produce evidence-based scientific information (Mamlok-Naaman *et al*., 2015).

Infusing the concept of sustainable development into organic chemistry lessons is important as students will be exposed to advantages of green techniques in organic synthesis, besides learning to minimize the production of by-products, solvents and reagents that are harmful to human and environment. The SSI activities will enable students to discuss the issues and find possible solutions that they may already be aware of, which is also part of the pedagogical framework in learning about sustainability. In addition to preparing future citizens who are aware about sustainable development, equipping future scientist and/or engineers who will deal with chemicals and/or materials must be considered in terms of green chemistry and sustainability as well.

In this study, participants are required to read and present a peer-reviewed journal about organic chemical-based SSI. The use of SSI approach as a topic for students' discussion not only allows the explicit learning of chemistry, it also enables them to discuss about the development of chemistry using all aspects of the sustainable dimensions (Marks & Eilks, 2009; Burmeister & Eilks, 2012). In this way, the learning of organic chemistry is tied to the living world and make the learning process more meaningful (Mamlok-Naaman *et al.*, 2015). Moreover, organic chemistry has been recognized as one of the leading fields to incorporate ESD under "green chemistry" (Hamidah *et al*., 2017). As such, the purposes of this study are i.) To evaluate students' understanding and solution in response to their proposed organic chemical based SSI issues; ii.) To examine students' familiarity on the organic chemical-based SSI issues before course, mid-term and end of semester using a five-point Likert scale questionnaire; and, iii.) To investigate students' experience and satisfaction on the current activity based on their reflective essays.

Methodology

The activity involved 27 participants who took the basic organic chemistry course during semester II 2016/17 in Universiti Malaysia Terengganu, Kuala Nerus, Terengganu, Malaysia. The basic organic chemistry course consisted of two one-hour lessons per week for 14 weeks. There were two stages of presentation involved during this activity and only the end semester presentation was evaluated using a rubric ("Sustainable energy project rubric", 2019) adapted from previous literature. At the beginning of semester II 2017/17, participants were required to present their topics of interest regarding the organic chemical based SSI, based on a peer-reviewed journal. At the end of semester, students were required to conduct a final presentation that included their proposed solution, in which they think they could make contributions in daily life in response to these organic chemical based SSI. Besides, students' familiarity on the organic chemical based SSI issues were also surveyed using a five-point Likert scale at week two, seven and 12. Additionally, students were required to submit a reflective essay regarding their experience towards the implemented activity. The submitted reflective essays were carefully examined by two authors. Upon consensus on the overall analysis, the descriptive data were confirmed and shown in this manuscript. The students' familiarity on SSI in using six controversial compounds (polyethelene, naphthalene, phthalates, triclosan, PABA and BPA) was measured three times — before the course, at mid-term, and at end term. The test items consisted of six items about SSI associated with the discussed topics, and mean scores were calculated for each item. At the end of the course, students' attitude towards the implemented activity was also surveyed with four questions. Frequencies and means of each item were calculated. Much environmental concern had been raised over the detrimental effects of the six controversial compounds, which were vital ingredients in many consumer products.

Results and Discussion

I. Students' Understanding and Solution

At the beginning of the course, the students were enthusiastic when they were briefed on this activity. This was evident when many of them met the lecturer for detailed discussions on their chosen topics. And students became more confident in this activity as the semester progressed. Table 1 shows the topics of interest along with the number of students involved in the presentations.

Table 1: The number and topic of interest chosen by students

Topic chosen	Number of students
Polyethylene in plastics manufacturing (Eriksen *et al*., 2014)	20
Napthalene as insect repellant (Sudakin *et al*., 2013)	1
Phthalates as plasticizer (Olaniyan *et al*., 2016)	1
Triclosan in consumers products (Meeker *et al*., 2009)	2
Para-aminobenzoic Acid (PABA) (Gago *et al*., 2011)	1
Bisphenol A (BPA) in plastic manufacturing (Groff, 2010)	2

Based on the reflective essays, students showed understanding about the organic chemical based SSI and gave their feedback about the potential issues caused by these organic compounds. Table 2 shows some of the representative quotes extracted from their reflective assignments. In addition, the rubric provided in this activity had also played an important role that guided students along their presentation preparations. Table 3 shows the rubric that was adapted from literature and used to assess the students' final presentation ("Sustainable energy project rubric", 2019).

In this activity, students were not only exposed to information on organic chemical based SSI, but by taking an action, one's study solution could be translated into action

Table 2: Representative quotes of students' understanding about the organic chemical based SSI in reflective essays

Representative quotes extracted from students' reflective essays
A Student's reflective essay on polyethylene: "*It was estimated that about 5.25 trillion pieces of plastic in the ocean and this will make the ecosystem unbalance, if some of the sea creatures die as a result of consuming this large amounts of waste*." [Student 7]
A Student's reflective essay on mothballs: "*The danger of this product should be aware by consumers as acute over-exposure of naphthalene can cause hemolysis*." [Student 23]
A Student's reflective essay on triclosan: "*The unscrupulous disposal of triclosan containing products may threaten human lives and our environment.*" [Student 19]
A Student's reflective essay on phthalates: "*The most concerning effect about the exposure of phthalates by knowing or without knowing is the reproductive health problem in male.*" [Student 2]
A Student's reflective essay on PABA: "*PABA sunscreen product may cause DNA damage in human*" [Student 26]

Table 3**:** Final presentation rubric

Sustainable chemicals project criteria	Below basic standard (1 point)	Meets basic standard (2 points)	Exceeds basic standard (3 points)
1. What are organic chemical based SSI driving questions involved?	Identified question does not address an issue about organic chemical based SSI.	Identified question somewhat address an issue about organic chemical based SSI.	Identified question address an issue about organic chemical based SSI.
2. What is the proposed solution?	Proposed solution lack sufficient steps or details.	Proposed solution contain sufficient steps or details.	Proposed solution contain easy-to follow steps or details.
3. What is the science behind your proposed solution?	The details of science concept is not adequately described.	The details of science concept is adequately described.	The details of science concept is comprehensive and adequately described.
4. How well the presentation is conducted?	The presentation is disorganized and unclear. No eye contact between presenters and audience.	The presentation is organized and clear. Maintain eye contact between presenters and audience.	The presentation is well organized and creative. Maintain eye contact between presenters and audience.

by changing or remedying existing issues. To this end, the important question was deciding how and what action to be taken. Apart for this, students also needed to explain why their proposed solutions were more environmentally friendly than current ones. In the reflective essays, several potential solutions had been raised and these solutions could be attributed to the 3R concept, namely the Reduce, Recycle and Reuse (Figure 1).

Undoubtedly, the concept had been a priority policy that was outlined during the World Summit on Sustainable Development (WSSD) as one of the approaches to achieve sustainable consumption and production (Elliot, 2006). So far, the implementation of 3Rs in waste management had achieved considerable success in developed countries. Yet, its accomplishment in developing countries had yet to be seen (Kam *et al*., 2016). As such, the implementation of the current activity was relevant as it promoted SD, as well as the familiarity towards the 3R concept. The details of potential solutions suggested by the students in response to organic chemical based SSI were summarized in Figure 1, and their solutions could be categorized into the 3R concept as shown in the following sections.

Reduce the Usage of Hazardous/Controversial Chemicals

In order to reduce the amount of hazardous waste in the environment, the first thing that one could consider is to reduce the generation of the source at first hand. In this activity, about six participants (Students 2, 10, 12, 14, 21 and 25) provided feedback that the effective method for reducing the use of these controversial compounds was through adjustment in the usage of products. In their reflective essays, a change of lifestyle and demand for goods that were less hazardous to humans and the environment might drive the world towards SD. For example, Student 2 had decided to buy a recyclable bag for future shopping. According to her reflective essays, this student stated that plastic bags contained high proportional of phthalates and thus, she would like to reduce her reliance on plastic bags, which further minimized the use of phthalates.

Besides, some students had chosen topics that dealt with controversial chemicals, which are ill-defined and multi-perspective. Examples of these were showcased in the submitted essays of Students 4 and 19, who commented that the use of triclosan was dangerous as it might be converted into a toxic compound when exposed to sunlight, Furthermore, triclosan could react with chlorine in tap water to form chloroform, which was a potent carcinogen. In an effort to use less toxic detergents, Students 4 and 19 had replaced their triclosan-containing products with home-made organic detergents.

Meanwhile, Student 23 used pandan leaves (*Pandanus amaryllifolius*) as an alternative to mothballs (Figure 2a). This alternative

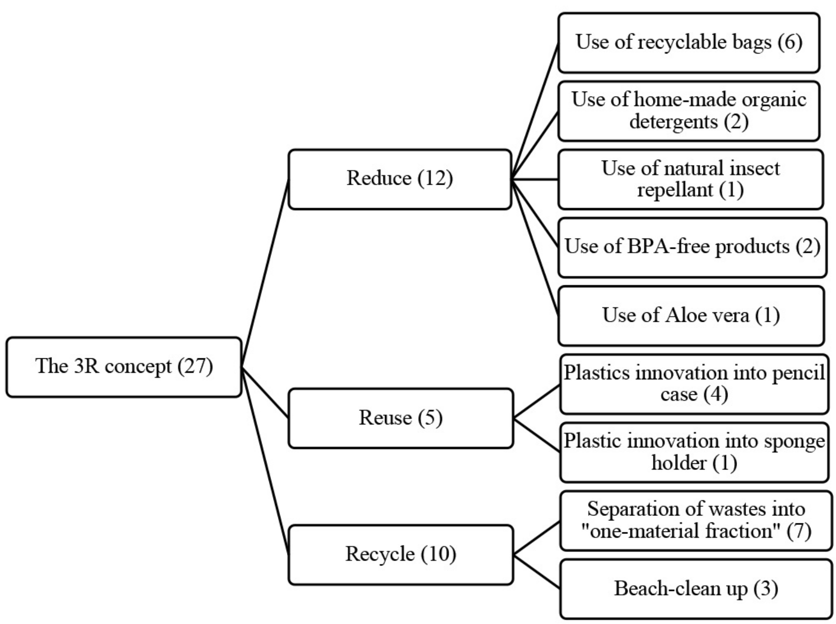

Figure 1: The network diagram shows the students' possible solution to some of the controversial compounds in the current activity. The number of commentaries was given in brackets

avoided the use of naphthalene, which was also a potential carcinogen. Student 26 wrote about using *Aloe vera* as an alternative to PABA, in which the latter compound in sunscreens had been linked to DNA damage. Finally, Students 11 and 22 stated that they had started using BPA-free bottles over health concerns (Figure 2b).

Reuse of Waste Materials

The next strategy for waste management is to reuse it whenever possible. The cost of waste management and disposal of might be reduced if some of these wastes could be re-generated into useful products. In regard to this, five participants (Students 5, 7, 15, 18 and 24), who had chosen the topic on polyethylene, mentioned in their reflective essays that the there was a high chance of sea turtles accidently eating the plastics floating in the ocean. In addition, the act of burning used plastic bottles might deteriorate the environment as the act could release carbon monoxide and toxic smoke into the atmosphere. In an effort to minimize the disposal of waste bottles, these students proposed recycling plastic bottles and converting them into useful products, such as pencil cases and sponge holders. Figure 2c shows an innovation of how used plastic bottles might be converted into a sponge holder (Student 7).

Recycle of Waste Materials into "One-material Fractions"

Recycling is to ensure that waste is separated before disposal and this strategy has been a standard practice in developed countries, as it reduces energy consumption and pollutants from the growing demand on raw materials (Masanet & Horvath, 2007). Most participants (Students 1, 3, 13, 16, 17, 20 and 27) admitted that they did not practise recycling in their daily lives. Hence, they resolved to begin the effort. In relation to plastic waste on beaches, Students 6, 8 and 9 had decided to take part in a beach clean-up to collect and recycle discarded plastic bottles to minimize the waste from being ingestion by marine life, which could result in fatality for the animals.

Figure 2: A proposal by students to address the organic chemical based SSI through the 3R concept. (a) Using non-toxic pandan leaves (*Pandanus amaryllifolius*) as an alternative to the mothballs by Student 23. (b) Using BPA-free bottlesby Students 11 and 22. (c) An innovation to convert used plastic bottles into a sponge holder by Student 7

Students' Familiarity on the Organic Chemical Based SSI Issues

Participants were asked to convey their understanding about organic chemical based SSI and possible solutions to the audience or faculty by making a presentation. Assessments before, mid-term and after the implemented activity using a five-point Likert scale survey form revealed that the current activity was effective in increasing students' familiarity about organic chemical based SSI in the current developments of chemistry. Based on Table 4 and Figure 3, mean scores of six topics were less than 3.0 before the course. They gained one point at mid-term, and finally increased to more than 4.0 at the end term. This showed students had become more aware about the societal issues associated with the discussed topics. The current survey result was also in agreement with a previous study that indicated the employment of blended-mode learning could lead to enhancement and relevance in students' science education (Ruiz-Gallardo *et al*., 2013). There were several limitations in this study. First, the sample size was relatively small. As a result, the impact of students' attitude changes towards the raised issues could not be reflected in a larger group. This activity had benefited students by creating awareness and nurturing them to think creatively and innovatively for solutions to SSI. However, it did not guarantee that they would continue to practise sustainable practices in their lives.

Table 4: Students' familiarity on the SSI as feedback in the survey form

Topic	Rate*($N = 27$)		
	Before course (mean ± SD)	At mid-term (mean ± SD)	At end (mean ± SD)
Polyethelene	2.9 ± 0.31	3.6 ± 0.65	4.6 ± 0.18
Napthalene	2.4 ± 0.44	3.7 ± 0.36	4.7 ± 0.64
Phthalates	2.0 ± 0.56	4.3 ± 0.37	4.4 ± 0.39
Triclosan	2.2 ± 0.34	3.2 ± 0.54	4.4 ± 0.83
PABA	2.2 ± 0.62	3.1 ± 0.48	4.5 ± 0.63
BPA	2.1 ± 0.87	3.5 ± 0.63	4.2 ± 0.45

*Likert five-scale; 1 = None; 2 = Limited; 3 = Somewhat familiar; 4 = Familiar; 5 = Very familiar

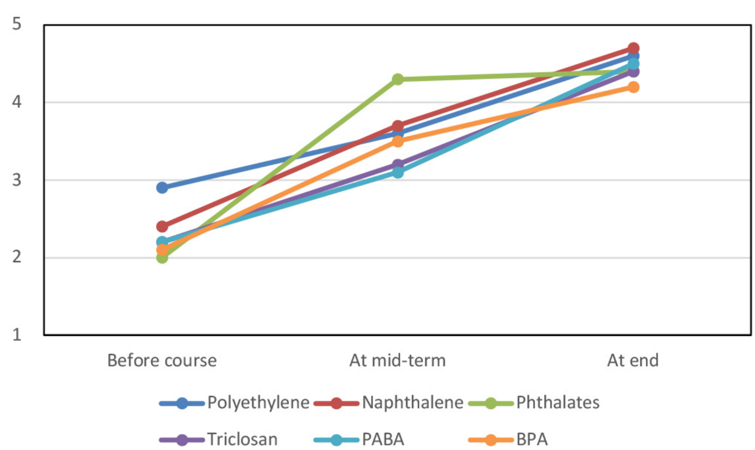

Figure 3: Students' familiarity change on SSI

Students Experience and Feedback on the Current Implemented Activity

The purpose of the current implemented activity is to enhance students' interest in the basic organic chemistry course by incorporating the element of SSI to provide an applicable method of ESD teaching. Besides, students were required to think critically about a sustainable solution that could potentially resolve SSI problems. Nevertheless, the current activity was directly related to SD, where it involved the topics of green chemistry and societal issues. Also, by taking advantage of SD issues, the current activity had provided an opportunity to move away from the traditional way of studying basic organic chemistry.

As seen in Table 5, the response towards the current implemented activity was found to be highly positive. Overall, students agreed that this activity was intellectually challenging (M = 4.70), which was indeed needed in today's curriculum to nurture thinking capability and reasoning skills (Kan *et al.,* 2015). In terms of knowledge, it was evident that students were able to learn more about the principles of basic organic chemistry through SSI content, and the implemented activity (M = 4. 52). The mean score for autonomy learning was high (M = 4.78), which revealed that this activity was capable of training students to develop personal skills. Finally, the result of the feedback survey showed that the current activity enabled the learning of basic organic chemistry course to be more effective (M = 4.48). The results of this survey demonstrated the potential of including action-based activity in other courses that emphasized SD.

At the end of the course, students expressed their level of satisfaction towards the implemented activity in reflective essays. Some of the individual's comments are as follows:

This activity is very challenging, especially when come to think about solution to current SSI problems.

I understood well about the SSI topics now than before.

This activity has provided a good platform for learning societal issues and organic chemistry. We credits the course lecturing by you.

The effort in this activity might seem little but if ever citizen of the world play their role, our planet can last for a longer time.

Table 5: Students' feedback towards the implemented activity for semester II 2016/17

Question	Rate* (*N* = 27)					(*N* = 27) M (SD)
	1	2	3	4	5	
Rate the intellectual challenge of this activity.	0	0	0	8	19	4.70 (0.47)
Rate the effectiveness of the current activity in accessing principles in basic organic chemistry.	0	0	3	7	17	4.52 (0.69)
Rate whether the current activity promotes autonomy learning.	0	0	0	6	21	4.78 (0.42)
Rate whether the current activity enables students to study effectively in the organic chemistry course.	0	0	4	11	13	4.48 (0.74)

*Likert five-point scale; 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = Agree; 5 = strongly agree

Conclusion

The current activity was employed as an alternative instruction for students to learn about SD, by incorporating the SSI content into the basic organic chemistry course. The implication of this research showed that students felt intellectually challenged, were satisfied with the learning principles and it promoted autonomy learning to study effectively. Besides, students felt familiarized with the SSI topics on controversial compounds. In addition, this activity could serve as an alternative method for teaching SSI in organic chemistry, and to train future scientists to make environmentally-responsible decisions. In future, there would be greater need to promote SD knowledge in all undergraduate courses. This study also showed that some students were capable of thinking and proposing solutions. Hopefully, the current activity could inspire more research on more SD learning activities that could be incorporated into undergraduate courses, with the aim of nurturing civic-minded citizens towards the environment.

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