Use of the Chemical SWOT Methodology to Enable Students to Analyse and Discuss the Socio-scientific Issues in the Classroom

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Abstract: One of the challenges that science teachers face is the lack of strategy/method to train students in data collection and developing analytical skills, which are pre-requisites to resolve socio-scientific problems and an important element in scientific literacy. In this activity, the SWOT analysis proposed by the Stanford Research Institute in the United States is modified and carried out in a class of university students to teach them how to analyse data and make decisions in the context of socio-scientific issues related to the use of parabens and triclosan, which are chemicals with potential adverse effects that are widely used in everyday products. The participants consist of 31 students, who are enrolled in the environmental and analytical chemistry programme at Universiti Malaysia Terengganu in Malaysia. Data is gathered from the essays submitted by the students to the course coordinator at week seven of their lessons. The findings show that students have positive response towards the implemented activity. After weighing all strength, weakness, opportunity and threat attributes, most students seem to support the use of those chemicals despite their risks and implications to health and the environment, albeit with greater awareness and prudence. This SWOT activity may potentially be used as an alternative instructional tool to promote discussion and resolution of socio-scientific issues in the classroom.

Keywords: Organic chemistry, controversial chemicals, socio-scientific issues, SWOT analysis.

1. Introduction

For decades, it has been extremely difficult to provide a definitive meaning to the term "scientific literacy". This is evident as numerous definitions have been put forth by various researchers (Holbrook & Rannikmae, 2007; Laugksch, 2000). A report published by the United Nations Education, Scientific and Cultural Organisation (UNESCO) in 1993 stated that it was appropriate to relate scientific literacy to a person who is not only scientifically and technologically literate, or simply a scientist in a workplace, but also one who can function in society (Holbrook & Rannikmae, 2009; Jain & Luaran, 2020). However, scientific literacy as observed today is only aligned to the understanding of science lessons in classrooms

or laboratories. According to a report, students merely regurgitate what has been taught to pass examinations without being able to distinguish the underlying theories (Felder & Brent, 2005). It seems that the syllabus of science studies is being given more emphasis by teachers and thus, it is described as "short-term" scientific literacy (Maienschein, 1998). However, in the long term, scientific literacy can play a major role in equipping the future generation with skills to adapt to a fast-changing world. For this, scientific literacy should be aligned with the development of life and reasoning skills in a social context, which can be incorporated into lessons to train students to become responsible citizens (Zulinda Ayu, Mohamad Mubarrak, Norezan & Siti Fairuz, 2020). As such, there is a need to incorporate analytical and decision-making skills in science education (Holbrook, 1998).

From the perspective of science educators, this type of civic scientific literacy should encompass the teaching of topics or situations that are relevant in the students' daily life, such as application and practicality, which will then make the learning process more meaningful. However, a survey on the students' perspective has found the learning of some science topics and subjects to be irrelevant (Osborne & Collins, 2001). The students did not find the knowledge gained in the classroom to be useful in everyday life, hence making the lessons a boring and monotonous experience, which may have been taught in vain. In science, many students have developed a particular image on how scientists conduct their research, but they seldom see the development of informed views in decision-making of socio-scientific issues (SSI) and the creation of knowledge, which is an important component in scientific literacy (Marchlewicz & Wink, 2011).

In this paper, to provide the relevance of studying organic chemistry and training to sharpen decision-making skills to resolve SSI, we invited a class of undergraduate chemistry students of a local university in the state of Terengganu, Malaysia, to participate in a strength, weakness, opportunity and threat (SWOT) analysis on the use of controversial chemicals in consumer products. The SWOT analysis is used to determine the advantages and pitfalls of a particular subject of study. Previously, this type of analysis has been used to study the implementation of a new protocol (Jetoo & Krantzberg, 2014), school programme (Balamuralikrishna & Dugger, 1995) and scientific method (Posthuma-Trumpie et al. 2009). However, none of the reports used a similar approach in the teaching of SSI.

In this activity, students were asked to play the role of consumers and discussed the use of parabens and triclosan in consumer products, and whether they should support the use of these ingredients. Parabens and trichlosan are controversial chemicals that have been reported to cause adverse effects on humans and the environment (Jualiano & Magrini, 2017). However, as their practicality and low cost outweigh the effects, they continue to receive widespread use among industrial manufacturers, Students were asked to write and submit their thoughts on the issue. Undoubtedly, writing is an effective tool to organise, express and clarify ideas, and thus, the students may be induced to reflect on their learning experience (Cha et al., 2016; Kan et al., 2015). Finally, the students were also encouraged to comment in their essays on what they have learnt in the SWOT analysis. The research questions explored in this study are listed below:

1. What are the empirical elements presented by students when participating in the discussion of the controversial chemicals in the SWOT analysis?
2. What are the students' perceptions towards the implemented activity?

2. Methodology

2.1 Participants

A total of 31 students who enrolled in the basic organic chemistry course in Universiti Malaysia Terengganu, Terengganu, Malaysia, in Semester I 2018/19 were recruited. Throughout the course, the students attended two one-hour lessons per week and were taught for a total of 14 weeks.

2.2 Procedure

At the beginning of the semester, the course instructor facilitated the activity by asking students to choose between two organic chemicals (parabens and triclosan) that are active ingredients in many consumer products, such as hand wash, body wash, shampoo, detergent, hand cream and body lotion, as a topic to analyse and discuss in the SWOT analysis. They were asked to conclude whether or not they should continue supporting the products that use these active ingredients. Parabens and triclosan were chosen as topics for analysis because the students had studied these benzene derivatives as part of their coursework. Students were required to write an essay as a form of giving their feedback and analysis. They were encouraged to discuss the topics with each other when performing their analysis, and their essays were collected at week seven. All the students' essays and feedback were carefully reviewed and categorised by two authors. Consent on the categorisation was obtained from all authors and, in the analysis of the students' qualitative data, the percentage of agreement between the coders was calculated at 97 per cent.

2.3 SWOT analysis

Students were requested to discuss the strength, weakness, opportunity and threat attributes when using parabens and triclosan in consumer products according to the method developed by the Stanford Research Institute (SRI) to assist in strategic planning and businesses management (Panagiotou, 2003). The current and future impact of using those chemicals were taken into consideration and examined in detail, which involved an "internal scan" to identify the strengths and weaknesses possessed by these chemicals. The external environmental scan was important to determine whether there were any external opportunities that could be harnessed, or threats that might become a hindrance in using these chemicals.

In this activity, the original definition of SWOT analysis was slightly modified in the context of using controversial chemicals and reformulated as "chemical SWOT analysis" (*Figure 1*). Students were briefed on this matter, whereby strengths referred to the advantages possessed by the chemicals, which were used for retainment purposes as ingredients in consumer products. Meanwhile, weaknesses referred to the unambiguous elements or potential risks of the chemicals to human health that might lead to their withdrawal/discontinuation of use in consumer products. Opportunities referred to the alternative ingredients that the students could think of to replace the controversial chemicals as an ingredient in consumer products to give positive outcome to safety and the environment. Finally, threats referred to the adverse effects on the external environment or aquatic life forms brought on by the use of these ingredients in consumer products.

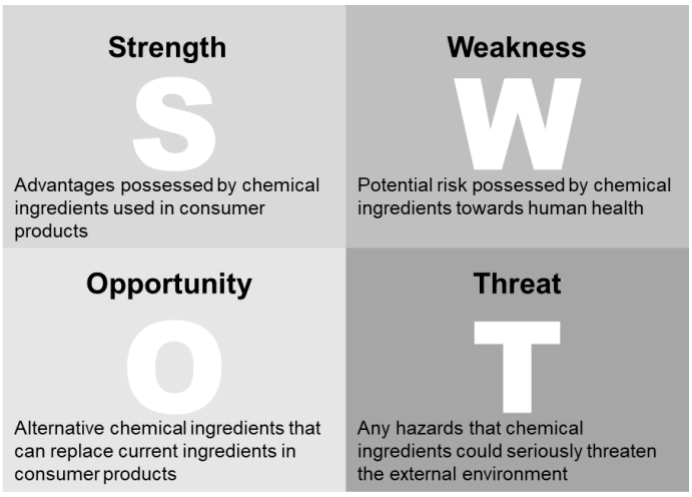

Fig.1 Chemical SWOT analysis framework

3. Results and Discussion

3.1 Students' analysis

Figures *2* and *3* summarise the empirical elements provided by students during their discussions in the SWOT analysis. In the case of parabens (Figure *2*), five students stated anti-bacterial properties and low cost of the chemical as strong points, while six students said its potential as a breast cancer carcinogen was a major threat. A total of 17 students said the major threat was environmental contamination of the soil and water. Last but not least, several students suggested natural ingredients as an alternative to parabens, such as neem oil (seven students), caprylyl glycol and phenylpropanol (five students), potasium sorbate (five students) and rosemary extract (four students). Even though the students were only taught about parabens and triclosan in week five of their course, they seemed to understand the implications of using such chemicals.

The students revealed that they knew triclosan possessed beneficial properties, such as anti-gingivital to maintain oral hygiene (three students), antibacterial properties for cleaning (three students) and as hand sanitiser (one student), lotion to wipe out impetigo (one student), as preservative in cosmetics (one student) and skin cleanser (one student). Additionally, students noted that the weaknesses of using triclosan included its ability to cause allergies, asthma and eczema in children (three students), increasing the risk of *Staphylococcus aureus* colonisation in the nasal passage (two students), potential in causing breast cancer (two students) and possibility of having birth defects and miscarriage (one student). In the SWOT analysis, two students noted that essential oils extracted from thyme and flavanoids, respectively, as well as the use of nano-particles (five students) could potentially replace triclosan as an active ingredient in consumer products. Finally, students stated that the threats of using triclosan were its toxicity to aquatic life (four students), potential cause of muscle impairment as shown in a research on fish and mice (three students) and ability to react with chlorine in water to form chloroform and other chlorinated by-products (two students). Overall, students who participated in the SWOT discussion on triclosan as an active ingredient in consumer products had used the empirical data provided and the examples in each element of SWOT analysis.

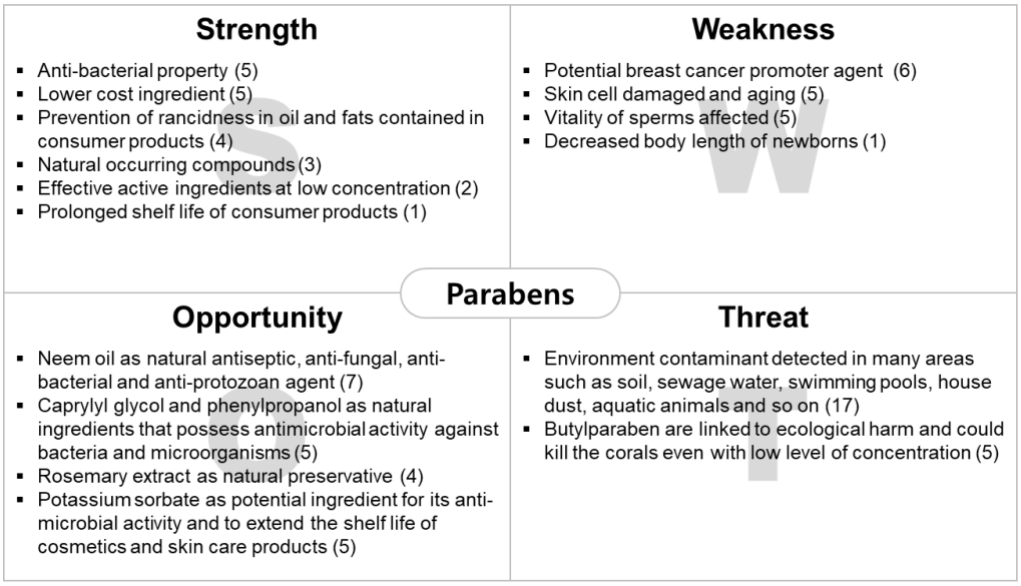

Fig. 2 SWOT analysis of parabens as active ingredient in the consumer products (The number of student commentaries is represented in brackets).

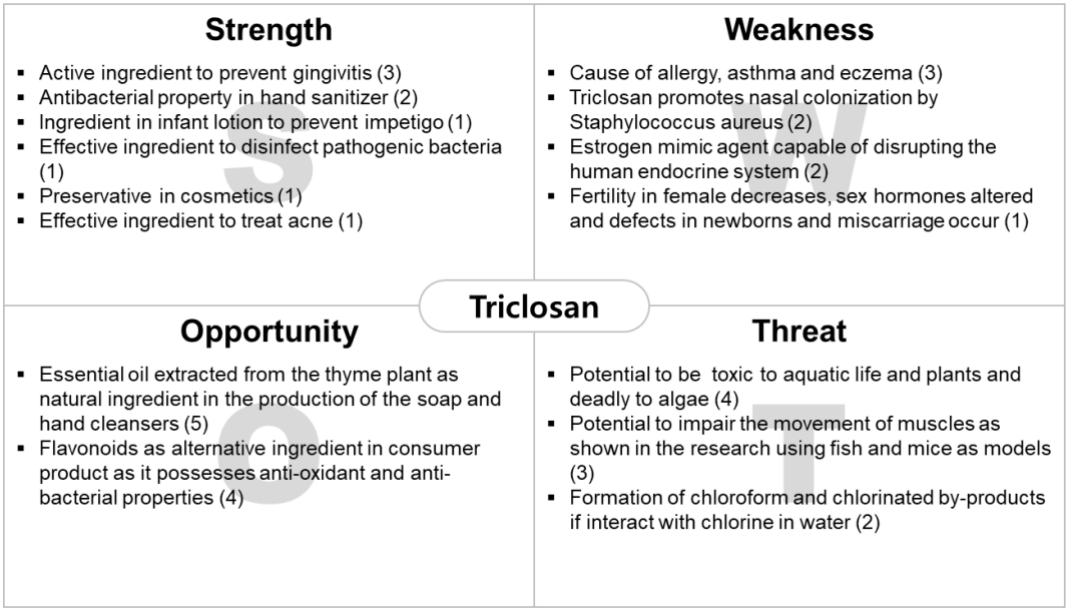

Fig.3 SWOT analysis of triclosan as active ingredient in the consumer products (The number of student commentaries is represented in brackets).

In the data shown in Figure 4, students' points of view seemed to be heterogeneous in deciding the use of parabens and triclosan in daily life. Sixteen students supported and five were against the use of parabens in consumer products.

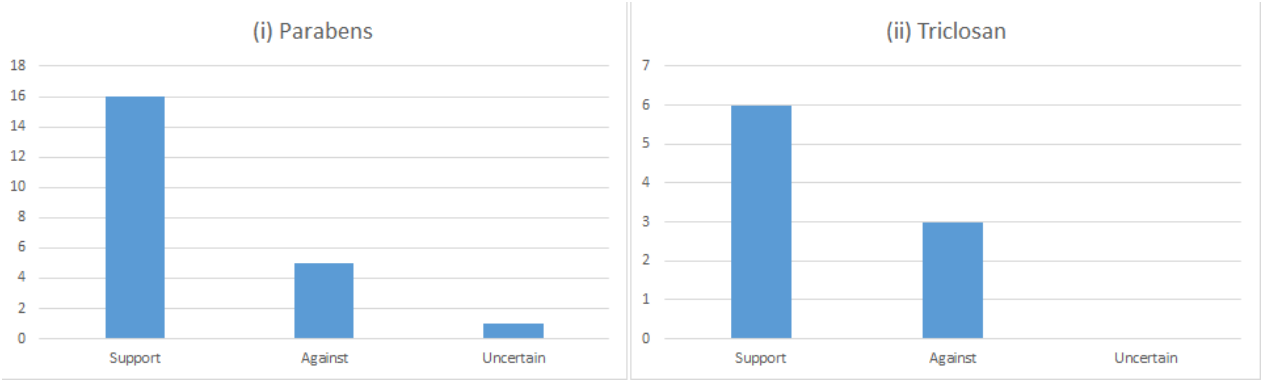

Fig. 4 Students' position on the use of parabens and triclosan as ingredients in consumer products

It was noteworthy that state that one student was uncertain in making a stance due to the lack of one final answer and frustration. Overall, most students referred to empirical data in supporting the use of parabens in consumer products. One student who voted against it justified his decision by referring to scientific data (Janjua, 2007). This student's comment is stated below.

> *"At the beginning of this activity, I thought that parabens are not hazardous because it may be 100 % metabolised and eliminated by our body. However, after searching the literature, I found that the esterase level in our body is unable to hydrolyse parabens thoroughly due to their absorption*

> *in our body. This condition will lead to the accumulation of parabens in our body and eventually brings side effects. This is the reason why I am against the use of this ingredient.* [Student 16]

In the case of trichlosan, six students supported its use in consumer products. On the contrary, three students believed that this ingredient was dangerous to humans, living organisms and the environment, thus they were against its use. Common knowledge on triclosan, such as its mimicry of estrogen and the formation of chlorinated by-products, had led the students to take this position against the use of this ingredient. All students also referred to scientific evidence to support or object the use of triclosan in consumer products.

3.2 Students' perception of chemical SWOT activity

In this activity, students were invited to reflect on the implemented activity through essay prompt. Some of the representative samples of students' quotes are shown below. Overall, students learned about the chemical ingredients which they would encounter in daily products, but never been exposed before in the classroom as reflected in one of essay quotes below.

> *"From this activity, I have learnt that parabens are the most common preservative, but I never knew it before this course. It was a surprise to know that almost 70 to 90 % of our consumer products contained parabens.*"[Student 20]

It was interesting to note that two students (Student 5 and 6) displayed keen interest to learn more about the chemicals that were relevant to their daily life the moment they received this assignment as evidenced in their reflective journals.

> *"I started to analyse the issues of using parabens that have become a controversial topic and I really enjoyed it".* [Student 5]

> *"When I typed triclosan and clicked 'search' on the Internet, I saw a lot of information about the chemical, which turned on my attention to search and read about it. Throughout my search on triclosan, a lot of interesting facts appeared."*[Student 6]

In addition, one student commented that this activity had given him the opportunity to critically analyse and make his own conclusions on the issue, as told by the course instructor during the briefing session of this assignment.

> *"My lecturer made it clear to us that rather than just offering description on the issue, it is all about personal inferences that really matter in this activity."* [Student 11]

Finally, a student revealed that this activity had made him and his peers to be more aware about the chemicals used in the consumer products and their safety implications, which had helped them to be more discerning in using those products.

> *"From this activity, I have learnt that we need to become a discerning consumer because, sometimes, we do not know that some consumer products we buy everyday may contain undesired chemicals."*[Student 28]

On the whole, the students showed in their essays that this activity could relate to their daily life and relevant to the science content studied in the course. This chemical SWOT activity was also capable of training students in various skills, such as data gathering, analysis, inferencing and relating the knowledge gained to make their own decisions. The only limitation identified was the relatively small number of students participating in this activity. As a consequence, the students' perception and attitude had changed towards SSI, which cannot be felt by a larger group of students. In future, the SWOT methodology had the potential to be utilised in other courses as an instructional tool to facilitate student discussion and teaching of SSI in the classroom.

4. Conclusion

The purpose of implementing the chemical SWOT activity was to enable students to know how to evaluate the quality of data and, at the same time, allow the course instructor to train them in decisions-making, which was an important component in scientific literacy. This chemical SWOT activity is a potential tool to train students in data collection and analytical skills, a pre-requisite in decision-making on some of the socio-scientific problems in our society. As such, this activity provided students with an opportunity to reflect on their thoughts and values in assessing social issues, an element which is often missing in the field of science education. Science teachers might face challenges in finding a strategy/method to train students in decision-making and data collection. This activity had the potential to be used as a teaching tool, as part of the inquiry-based instruction for future educators, to teach and train students in decision-making in resolving SSI.

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