GREEN CHEMISTRY AND SUSTAINABLE DEVELOPMENT TEACHING MATERIALS FROM ECoS IN JAPAN

(*KIMIA HIJAU DAN PEMBANGUNAN BAHAN PENGAJARAN LESTARI DARIPADA ECoS DI JEPUN*)

Roslinda Ithnin[a], Teratani Shosuke[b] and Matsubara Shizuo[c]

[a]Pusat Asasi Sains, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
[b]Professor Emeritus,Tokyo Gakugei University, Japan
[c]Toin University of Yokohama, Japan

ABSTRACT

An approach to systematically expose students to the Principles of Green Chemistry is performed by the Educational Co-Research for Sustainability (ECoS) group which was formed in Tokyo, Japan under the program of Grants-in-Aid for Scientific Research "KAKENHI" Scientific Research (B).This group infused the concept of Green and Sustainable Chemistry (GSC) into chemistry education. Aspects of adding GSC issues in the chemistry lesson had produced significant and suggestive opinions from the students. This article describes the activities conducted by the ECoS group including the usage of the special report writing template (Teikeibun)

ABSTRAK

Satu pendekatan untuk mendedahkan pelajar kepada Prinsip Kimia Hijau secara sistematik telah dilaksanakan oleh Kumpulan Penyelidikan Bersama untuk Kelestarian (Educational Co-Research for Sustainability, ECoS) yang ditubuhkan di Tokyo, Jepun di bawah program Grant-in-Aid Penyelidikan Saintifik "KAKENHI" Penyelidikan Saintifik (B). Kumpulan ini memasukkan konsep Kimia Hijau dan Mampan (Green Sustainable Chemistry, GSC) ke dalam pendidikan kimia. Aspek penambahan isu GSC dalam pelajaran kimia telah menghasilkan pendapat yang bermakna daripada para pelajar. Artikel ini menerangkan aktiviti-aktiviti yang

dijalankan oleh kumpulan ECoS termasuk penggunaan templat penulisan laporan khas (Teikeibun).

INTRODUCTION

This paper explores opportunities for schools and universities to advocate safe science. Ideally, learning institutions can contribute to local and regional development processes, apart from classical knowledge transfer within education and lifelong learning. Theoretically, the university-society relationship in regional development processes, involves planning, learning, and implementation theory. Globally, universities are pressured to become change agents for sustainability. There is a need for universities to lead in knowledge transfer and development of generation in regional development processes (Peer and Stoeglehner, 2013). Although provision of knowledge alone is not enough to establish the university as a change agent, "ownership" of knowledge within the communities has to be achieved. The universities that want to act as change agents have to seriously combine research and education in informal learning environments so that knowledge demand, knowledge transfer and knowledge generation can be determined between societies and universities.

According to Dr. Junshi Miyamoto, the past-president of The International Union of Pure and Applied Chemistry (IUPAC; IUPAC Division of Chemistry and the Environment), the increasing knowledge in natural sciences and the application of this knowledge are the driving forces for the development and welfare of mankind. Chemistry plays a central role in this development. Chemistry provides the molecular understanding of physical properties of materials and other matters and thus closely interacts with physics. Chemistry is also closely connected to the molecular understanding of living systems and is the basis for modern biology and medicine. The development of synthetic chemistry has opened new dimensions for materials and compounds to be tailor-made for specific products. The responsibility of IUPAC Division of Chemistry and the Environment is to provide unbiased and timely authoritative reviews on the behavior of chemical compounds in food and the environment. In addition, the IUPAC division is responsible to provide unbiased and timely authoritative reviews on the behavior of chemical compounds in food and the environment. There is a direct relevance of the mission of IUPAC to green chemistry (Tundo, 2000). Green chemistry is defined by IUPAC as follows:

> "The invention, design, and application of chemical products and processes to reduce or to eliminate the use and generation of hazardous substances".

Although there is always a demand for new and efficient processes and chemicals in chemistry, aspects of sustainable and environmentally friendly processes and chemicals have sometimes encountered difficulties. Thus, chemistry should provide the tools for a green and sustainable development. Knowledge in this general area has to be integrated into the planning of all research and development in chemistry. The development of green and sustainable practises, need the input from new technology and novel chemistry.

In 1962, Rachel Carson's publication (Silent Spring) was historically tied to the beginning of the environmental movement. Silent Spring marked the spread of public awareness of the hazards of environmental pollution and pesticides to the environment. By the end of the 1990s, the "Twelve Principles of Green Chemistry" (Anastas, 1998) was published. The guidelines as shown in Table 1 serve as reference for processes and practices to lessen negative environmental impact. The Principles of Green Chemistry provided an initial and still current definition of what we understand as the concept of green or sustainable chemistry and has been implemented by both research and industry worldwide.

Table 1. The Twelve Principles of Green Chemistry (Anastas, 1998).

1	Prevention	A reminder that it is better to prevent waste than to treat or clean up waste after it is formed
2	Atom Economy	Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3	Less Hazardous Chemical Syntheses	Synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

4	Designing Safer Chemicals	Chemical products should be carefully designed to preserve efficacy of function while reducing toxicity.
5	Safer Solvents and Auxiliaries	The use of auxiliary substances (including solvents, separation agents) should be made unnecessary whenever possible and innocuous when used.
6	Design for Energy Efficiency	Energy requirements should be recognized for their environmental and economic impacts and should be minimized.
7	Use of Renewable Feedstocks	A raw material or feedstock should be renewable rather than depleting, wherever technically and economically practicable.
8	Reduce Derivatives	Unnecessary derivatization (blocking group, protection/ deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.
9	Catalysis	Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10	Design for Degradation	Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.
11	Real-time analysis for Pollution Prevention	Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12	Inherently Safer Chemistry for Accident Prevention	Substances used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions and fires. It is important to find alternative starting or raw materials, reagents, solvents as well as catalysts.

The Green Chemistry Program was developed by the US Environmental Protection Agency (EPA) with the goal of preventing or reducing pollution at its source, rather than having to clean it up afterwards. Green chemistry is focused on designing chemical products (and manufacturing processes) such that the use or generation of hazardous substances is reduced or eliminated. Concerns over global environmental issues, such as global warming, depletion of the ozone layer, deforestation, loss of biodiversity, acid rain, and hazardous waste are increasing worldwide. Therefore, many countries are being urged to implement concrete actions and measures to realize sustainable development.

In Japan, the Basic Environment Law, which set out basic principles and directions for formulating environmental policies, was enacted in November 1993. By December, the "National Action Plan for Agenda 21" was submitted to the United Nations while the following year, "the Basic Environment Plan" is adopted. The plan systematically clarifies the measures to be taken by the national and local governments, as well as actions to be carried out by citizens, businesses and private organizations to effectively pursue and uphold environmental policies.

Japan is particularly interested in the Asia-Pacific region because of its location. Countries in this region have been faced with various problems including poverty, accelerated consumption of resources and energy due to population growth, lifestyle changes and deterioration of urban environment. The Environment Agency is striving to preserve the regional environmental integrity and promote intra-regional cooperation through dialogues on environmental policies at the Environment Congress for Asia and the Pacific (Eco-Asia) to help overcome these problems. Environmental problems today are common challenges which affect the future generations. There are cumulative effects of individual environmental problems. Thus, it is vital for central and local governments, enterprises and individuals to cooperate and coordinate actions, both on the international and domestic levels, to effectively respond to these issues.

Green/sustainable chemistry (GSC) can be viewed as a chemical technology for environmentally friendly products and processes. Green chemistry has been defined as a set of principles that reduces or eliminates the use or generation of hazardous substances through the entire life of chemical materials. If one compares the technology with medical care, GSC focuses on precaution (or prevention) rather than diagnosis and cure. Efforts to make the chemical processes more environmentally friendly can be termed as environmentally friendly processes. GSC is a concept developed by integrating these preceding ideas and activities. GSC can be seen as a movement involving various sectors and aims to improve the present chemical industry.

In Japan, GSC is defined as innovations and advances in chemical technologies that can improve human and environmental health. The Green Chemistry Initiative, which was formed in 1998 and comprised of companies, universities, and the government, was intended to encourage technologies that could be used in sustainable development. There have been many successful examples of catalytic technologies in Japan which can be called GSC, but it is rather recent that activities with the name of green/sustainable chemistry started. In the last few years several groups including academic societies organized symposia are directed toward green/sustainable chemistry. In addition, a few new organizations for GSC started. An organization called Green Sustainable Chemistry Network (GSCN), which started in 2000 constitute such esteemed members including Association for the Progress of New Chemistry, Chemical Evaluation and Research Institute, Japan Association for International Chemical Information, Japan Biochemistry Association, Japan Chemical Industry Association, Japan Chemical Innovation Institute (JCII), National Institute of Materials and Chemical Research, The Chemical Society of Japan, The Society of Chemical Engineers, Japan, and The Society of Polymer Science, Japan while IUPAC (Japan) acts as one of the observers. The Green Sustainable Chemistry Network (GSCN) was one of the off-spring from the Green Chemistry Initiative organization.

The GSC Network in Japan is closely related with the “green and sustainable chemistry” and encompasses the innovative chemical technologies for sustainable society. The chemical technologies must acknowledge important objects such as “human and environmental health/safety”, and “efficient utilization of resources and energies”, by minimizing the undesirable environmental influences of chemical products and processes through all the steps of the product life cycle, including selection of feed stocks, manufacture, uses and waste treatments. Continuous efforts must be made with international, inter-industry, interdisciplinary and multidisciplinary between academia, and also between the government and industry to maintain the green indexes. Efforts and achievements must be made visible to the society by establishing good communication between the society and chemistry specialists.

Ideally large, industrial companies should develop innovative and proactive environmental strategies for dealing with issues pertaining to green chemistry. Environmental issues become important issues in the strategic management of the firm once they show a relevant impact on business, influencing industries and their subsequent products and processes of the organisation. Industrial companies started changing attitudes and proactively adopt “greening of industry” due to market opportunities and to get new competitive advantages against competitors (Partidario and Vergragt, 2000).

In Japan, some companies including Panasonic and Nissan seem to gain competitive advantage over their competitors. The Panasonic Green Plan 2018 which was established in 2010, covers five areas: mainly CO_2 reduction and resources recycling, and water, chemical substances, and biodiversity. These areas focus on maximizing the size of contribution in reducing CO_2 emissions, which is an indicator that represents our efforts for CO_2 reduction, to contribute to making net CO_2 emissions from the international community peak and decline thereafter at an earlier timing. Panasonic promotes higher recycled resource utilization ratio and factory waste recycling rate. In addition, with respect to eco-conscious products and businesses, Panasonic is working towards the range of activities to products, services, and solutions keeping strengths in the home appliances field, to provide products and services that create environmental value for our customers. Panasonic promises to deepen the collaboration with various partners across the supply chain and accelerate environmental initiatives to extend better impacts on the society. In October 2011, Nissan announced its Green Program 2016 which focuses on reducing environmental impact of corporate activities and pursuing harmony between resource consumption and ecology by promoting and widening the application of green technologies that were developed earlier. One of the company’s goal is to minimize Nissan's carbon footprint through continuous energy improvements across all areas of its business, and by increasing its use of renewable energy, including wind and solar.

In reality, there are companies everywhere in the world which are taking steps beyond compliance with environmental laws and regulations, and these companies have also organized their activities to prevent possible environmental threats (Partidario and Vergragt, 2000). In addition, Porter and van der Linde (1995) reported that some companies spend too many of their environmental resources on fighting regulations and laws and not enough on finding innovative solutions.

The potential of the scientific and the technological community to make an effective contribution to the decision- making processes concerning environment and development and stressed the role of academia in such an effort Higher Education Institutions have been generally considered significant contributors to the promotion of sustainability. This recognition has been recorded in numerous declarations such as the Kyoto Declaration. The role of Universities and ESD (Karatzoglou, 2013) to approach these issues include:

- A change in the Universities' own management practices including their involvement in recycling schemes, energy efficiency initiatives, or the implementation of an environmental management system.
- Promotion of integration, synthesis, critical reasoning, and system-thinking skills, supporting students and researchers beyond skill development to cope with the future multidisciplinary complex challenges of sustainability;
- The assumption of a leading role in coordinating, promoting, and enhancing the engagement of local authorities and other societal stakeholders to design and implement regional sustainability plans by acting as sources of technical expertise; and
- A new research and teaching agenda for Universities as centers of development of the sustainability science as an innovative scientific field defined by the problems it addresses.

DISCUSSIONS

1. ECoS

The Educational Co-Research for Sustainability (ECoS) group consists of members from the Philippines, Malaysia, Korea and Japan. ECoS was formed in Tokyo under the program of Grants-in-Aid for Scientific Research "KAKENHI" Scientific Research (B). One of the interests of ECoS is for co-operation between its members to increase new and existing knowledge and resources, solve intrinsic research questions and build research capabilities.

Education incorporates two different roles: an individual role and a societal role. The former refers to the increase of one's knowledge whereas the societal role is defined in the institutional role of transferring knowledge to future citizens (Marton, 2006). The learning approach by ECoS shows that it is possible for students and teachers to identify and address problems in a joint effort by using each other's experience and knowledge. From a researcher's point of view, the main importance of the ECoS is that it creates an opportunity for reflection and not just a forum for discussion but also to expose teachers and students to use the idea of GSC in their learning materials. These activities may result in a better understanding of the problems. In addition, the learning network builds strong relationships between individuals and/or groups because of mutual commitment and trust in collaborative efforts.

The International workshops (IWS) attended by members of ECoS, discussed the progress among its participants and these workshops would ultimately develop a framework for international co-research for sustainability. The participants ECoS participants from Japan, the Phillipines, Korea and Malaysia discuss their progress during these annual workshops. The "International Co-research on Sustainable Development (SD) Educational Materials to Be Conscious of the Usefulness of Science and to Foster Scientific Attitude" research is headed by Professor Matsubara Shizuo from the Toin University of Yokohama. This research is in affiliation with the National Institute for Educational Policy Research in Tokyo.

According to Professor Matsubara Shizuo, the Japanese concept or objective behind the development of teaching materials which deals more broadly with SD is the importance of "learning in order to improve the quality of life for us and our descendants". This concept calls for an exploration of ways to improve the quality of life centering on the relationship between science & technology and the environment. Several objectives were put forth which include the dissemination of the duality of benefits and risks, and understand ability to make comprehensive judgements; realizing, appreciating and possess a progressive awareness of science and technology as well as the efforts of scientists and engineers and thus producing responsible citizens, capable of making decisions about social phenomena related to science and technology.

The United Nations declared the years between 2005 and 2014 as a worldwide Decade of Education for Sustainable Development. Education for Sustainable Development is a process of including key sustainable development issues into teaching and learning. These issues include climate change, disaster risk reduction, biodiversity, poverty reduction, and sustainable consumption. It is important to promote teaching and learning methods that motivate and empower learners to change their behaviour and take action for sustainable development. These processes in turn promote competencies like critical thinking, imagining future scenarios and making decisions in a collaborative way. Education for Sustainable Development requires far-reaching changes in the way education is often practised today.

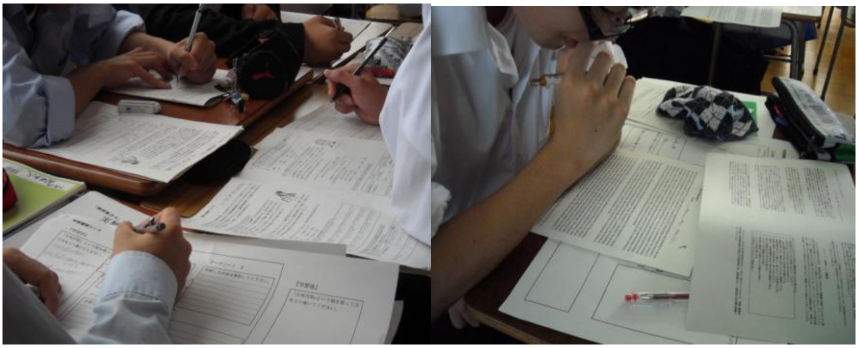
Many have argued that the integration of sustainability issues can be compatible with chemistry education. The Principles of Green Chemistry (Anastas, 1998) provided an initial and still current definition of what we understand as the concept of green or sustainable chemistry and has been implemented by both research and industry worldwide.

Researchers led by Matsubara developed a One Page Report Writing Template with a unique instruction using *TEIKEI-bun* (sentence) to help students write experimental reports. The report writing template is based on the One Page Portfolio Assessment mooted by Hori (2011) to solve three teaching and learning challenges: how to cultivate abilities and competencies in learners; how to validate that this is achieved; and how to help teachers in improving their teaching. The success of TEIKEI-bun instruction suggests that the method can be applied to basic learning objects in science.

Figure 1. IWS activities performed by students as well as IWS participants at various schools in Japan which include writing answers in the worksheets and oral presentation.

Figure 2. Students in Japanese high schools working on the worksheets. The worksheet contains sections on ‘before study’, ‘summary’, “after study’ and “thoughts about the lessons’. The one-page

worksheet challenges students to reflect and write their opinions and answers systematically.

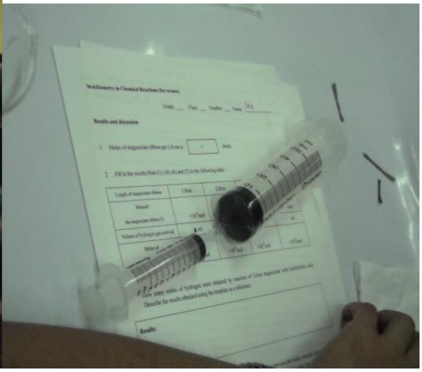


Part of the research objectives is to develop SD educational materials starting with air pollution issue. Another topic which is incorporated into the SD educational materials is electricity. These two topics were already tested in three Asian countries. Two other topics to be included are topics related to water and plastics. These educational materials are expected to be developed, practiced and improved with further collaboration between the ECoS members. Another objective of this research is to develop an Asian version of the SD educational materials through the ECoS co-research network.

2. International Workshops on Sustainability

The International Workshop in Sustainability (IWS) essentially gathers the ECoS members' country reports which involve issues relating to the respective national or regional curriculum. The IWS reports which also concern relations to the local environment try to capture the students' interest as well as scientific attitudes and consciousness. The IWS is also a platform for the participants to exchange ideas about updates, issues and challenges in education. The first IWS was implemented in September 2010 in Tokyo. The second workshop, IWS-2 was also held in Tokyo. IWS-3 as shown in Figure 3, as well as IWS-5 were held in the Philippines while IWS-6 is scheduled in Kuala Lumpur in 2015.

Figure 3. Lab work and report writing during the IWS at various schools in the Philippines.



Topics covered during the workshop concerned environmental issues include environmental pollution caused by acidic substances, sulphur oxides and nitrogen oxides, green chemistry and soda ash industry. An approach to systematically expose matriculation students from Malaysia to the Principles of Green Chemistry was performed with exercises on most of the topics. This exercise infused Green and Sustainable Chemistry into the chemistry education during chemistry lectures.

Aspects of adding GSC issues in the chemistry lesson had produced significant and suggestive opinions from the matriculation student respondents. The respondents comprised of students who are trained for two years at the University of Malaya before venturing to various Engineering courses at the universities in Japan. The session which was conducted during one of the Chemistry double-period lecture started with an explanation regarding the Twelve Principles of Green

Chemistry followed by a brief lecture regarding the specific topic. The students answered the worksheet in groups as shown in Figure 4. The discussions amongst the students were robust and encouraging. Among others, the exercise also introduced to students about risks from pollutants, hazardous wastes and toxic releases. This is important since there is no specific green chemistry program included in the Malaysian matriculation syllabus.

Figure 4. Students from the Centre for Foundation Science, University of Malaya discussing issues from the work sheet.

The GSC lessons were the first of its kind to these respondents. Their lessons normally contain calculations and chemical equations instead of international and economic issues and also application of law the principles of green chemistry. The importance of such lessons and how it fits into their normal chemistry period were revealed to the respondents during the exercise. The respondents were also challenged to write answers in the form of composition. The exercise has been taught in a focused manner so that by the end of 90 minutes, respondents produced coherent answers after realizing that chemistry is not just about equations and calculations. They knew about "eco-friendly" issues but now they are exposed to real cases and to the formal materials of green chemistry and sustainability. Figure 5 shows a student’s response to a simplified version of the Teikeibun template on the topic relating to the environmental pollution caused by acidic substances. This exercise which needed no special instrument nor was it costly should be offered to future batches of students since it raised the students’ interest and consciousness in the GSC matter. The field of chemistry and the industries related to it are also highly related to the global economy. The exercise had been a new and positive learning experience for the students since it is interdisciplinary, promotes critical thinking and decision making and it also involves problem solving. Within 90 minutes of the lesson, students proved that they could appreciate some relevant connections between chemistry and sustainability. Thus infusion of GSC into chemistry lesson at matriculation level is highly beneficial to the students.

3. Report writing template – Teikeibun

The report writing template, Teikeibun, (Matsubara et al, 2012) has been used for participants in schools for the IWS workshops can assist students in several ways. The report writing template, Teikeibun acts as a model for writing experimental results and discussion. The basic and essential format of an experimental or laboratory report would normally include purpose or objective, procedure or methodology, results and discussion, and summary or conclusion. Generally, students who conducted experiments were informed to write a discussion which is supposed to present their own views derived from facts. Students are also expected to provide an explanation for their views. Although there is an importance for students to have both cognitive and expressive ability, when it comes to laboratory or experimental report writings, students tend to omit subjects or verbs or they may write using strings of words that do not form complete sentences. Results and discussions are often mixed up and they may be unable to distinguish between facts and opinions. Thus, this shows a lack in self expression (Matsubara et al, 2012).

Fish (2015) looked at trends that can be symbolized as conflict between “yutori kyoiku,” (roughly translated as a more relaxed education or education some freedom) and the “Action Plan for Improving Academic Ability,” a specific response to the decline of the Japanese academic in the 1990s (ability in math, science, and literacy) compared to their peers in other industrialized nations. The basic outline of Japanese public school education is outlined in a series of documents created by the Ministry of Education, Sports, Culture and Technology (MEXT). The *Gakushu Shido Yoryo*, the Japanese Handbook for Education provides specific guidance to Japanese schools was implemented in 2002. The document determines such important topics as the subjects to be taught and the minimum number of hours to be spent on each subject at each grade level. The *Gakushu Shido Yoryo* responded to these trends and implemented the strongest version of “yutori kyoiku.” The ultimate goal was to revive in students “a zest for learning”.

In Japan, the current Course of Study for Japanese language instruction already include developing abilities of logical expression in the fifth year of elementary school. The Course of Study refers to expressions which describe students having the abilities of “speaking so as to clarify intentions and reasons” and “composing sentences that differentiate facts and phenomena from impressions, opinions and so on”. The Course of Study has generally been revised once every 10 years. The new Course of Study aims to nurture in students the “Zest for life” based on the educational principles expressed in the revisions to the Basic Act on Education. The new Course of Study enrich the content of education and increase the number of classes, with an emphasis on the balance between acquiring basic and fundamental knowledge and skills and fostering the ability to think, make decision, and express oneself. Development of expressive abilities also contributes to development of one’s ability to organize his or her thinking.

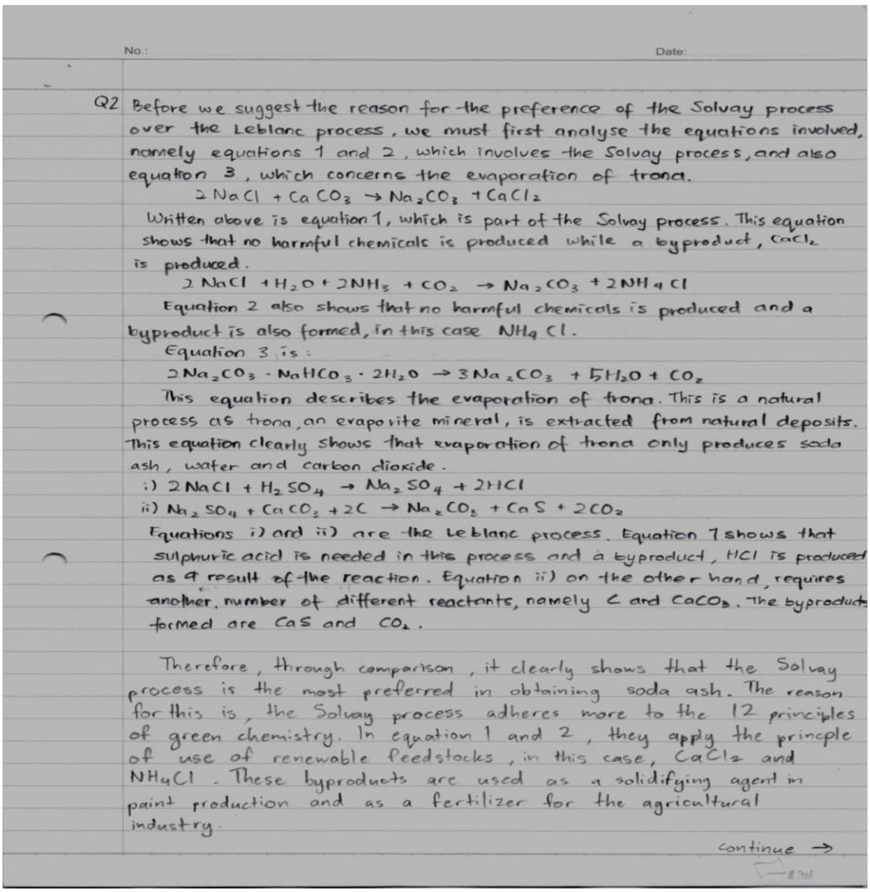
The divergence in science performance, were observed, recorded, and analyzed during lessons in Japanese classrooms by Linn et al (2000). Evidences on Japanese instructional context, curriculum, and policy. structures were also observed. The Japanese students were observed to perform "science activity structures" either individually or in groups, by performing experiments, data sharing, discussion of findings and assessments. These structures were found to contribute to science learning. Student handouts and worksheets for discussions were also distributed as part of the classroom activities. The study also found that the Japanese students conduct experiments or observations to test the hypotheses or predictions just built. The method of investigation may have been designed by the whole class, small group, or individual. There were also hands-on experiment in small group.

Teachers encourage students to reflect on their current ideas and experimental findings in light of their earlier hypotheses or predictions. Teachers may encourage students to repeat the experiment in order to check on their prior hypotheses or findings. To help students gain insights into their own thinking and problem solving. To help students draw conclusions from the findings of their experiment and connect these to their earlier hypotheses.

According to Lewis (1995), Japanese elementary education has been described as "whole person education," with strong emphasis on children's social and ethical development and their capacity to function without teacher-administered rewards or sanctions. Japanese elementary teachers seek to build these student qualities by giving students considerable classroom authority, for example, act as daily rotating class leaders so that students will feel invested in school practices; highlighting social and ethical qualities such as friendliness, responsibility, and persistence as central educational goals; and organizing instruction in ways that meet children's needs for belonging and contributing, and thereby foster students' attachment to school and their disposition to take on the school's values as their own

Japanese elementary teachers collaborate routinely and regularly plan and reflect on lessons and present research lessons *(kenkyuu jugyou)* to colleagues where peer collaboration is emphasized. Teachers who are not expert at teaching science had the chance to express their own ideas and plans to more expert colleagues, and to learn, over time, through discussion and trial of actual classroom lessons. This allows teachers to develop and refine their ideas of what good instruction is, their knowledge of supporting techniques, and their judgment about when to emphasize teacher-directed versus student-initiated approaches. A strong focus on collaboration and personal responsibility during the preschool and elementary years may build skills and attitudes essential to the vigorous, yet respectful conversations likely to promote learning. Another observation (Linn et al, 2000) is the possibility that a set of science activity structures may be implemented systematically and repeatedly over many lessons and many years in Japan, thereby building coherent science instruction. The capacity of Japanese students to work independently, conducting experiments using potentially dangerous materials, may depend on substantial efforts to build personal responsibility and internalized motivation. A science activity structure such as student information exchange or debate may derive support from the long-term social and ethical emphases of Japanese schooling, in which respectful, lively discussion in family-like small groups is nurtured from preschool on Linn’s group (2000) further suggests that, by late elementary school, the Japanese classroom context may differ substantially from that of the United States in many aspects, including student attitudes and skills, opportunities for collaborative learning by both teachers and students, and pressure for curriculum coverage. It should not be assumed, therefore, that science activity structures used by Japanese teachers could be used successfully in United States.

Figure 5. Responds from a Malaysian student regarding his reflections on (the Solvay process over the Leblanc process) by incorporating the Principles of Green Chemistry. The Teikeibun template for report writing challenged the student to reflect upon the lesson and write his opinion apart from writing the standard equation-type answers.



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Q2 Before we suggest the reason for the preference of the Solvay process over the Leblanc process, we must first analyse the equations involved, namely equations 1 and 2, which involves the Solvay process, and also equation 3, which concerns the evaporation of trona.

$2NaCl + CaCO_3 \rightarrow Na_2CO_3 + CaCl_2$

Written above is equation 1, which is part of the Solvay process. This equation shows that no harmful chemicals is produced while a byproduct, $CaCl_2$ is produced.

$2NaCl + H_2O + 2NH_3 + CO_2 \rightarrow Na_2CO_3 + 2NH_4Cl$

Equation 2 also shows that no harmful chemicals is produced and a byproduct is also formed, in this case NH_4Cl.

Equation 3 is:

$2Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O \rightarrow 3Na_2CO_3 + 5H_2O + CO_2$

This equation describes the evaporation of trona. This is a natural process as trona, an evaporite mineral, is extracted from natural deposits. This equation clearly shows that evaporation of trona only produces soda ash, water and carbon dioxide.

i) $2NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2HCl$

ii) $Na_2SO_4 + CaCO_3 + 2C \rightarrow Na_2CO_3 + CaS + 2CO_2$

Equations i) and ii) are the Leblanc process. Equation 1 shows that sulphuric acid is needed in this process and a byproduct, HCl is produced as a result of the reaction. Equation ii) on the other hand, requires another number of different reactants, namely C and $CaCO_3$. The byproducts formed are CaS and CO_2.

Therefore, through comparison, it clearly shows that the Solvay process is the most preferred in obtaining soda ash. The reason for this is, the Solvay process adheres more to the 12 principles of green chemistry. In equation 1 and 2, they apply the principle of use of renewable feedstocks, in this case, $CaCl_2$ and NH_4Cl. These byproducts are used as a solidifying agent in paint production and as a fertilizer for the agricultural industry.

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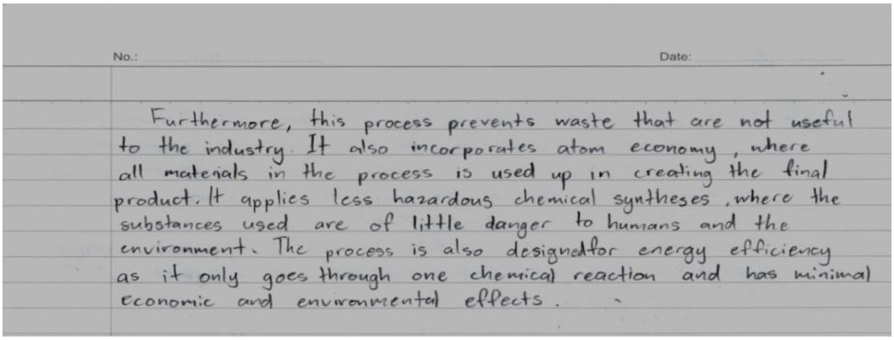

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Furthermore, this process prevents waste that are not useful to the industry. It also incorporates atom economy, where all materials in the process is used up in creating the final product. It applies less hazardous chemical syntheses, where the substances used are of little danger to humans and the environment. The process is also designed for energy efficiency as it only goes through one chemical reaction and has minimal economic and environmental effects.

Peer and Stoeglehner (2013) propose that universities that actively want to engage in Research and Development (R&D) and act as "change agents" for sustainable development might consider going beyond "regular" university activities addressing the diffusion channels "teaching" and "research". Universities can contribute to R&D processes, by showing an active role in sustainable R&D, which can be achieved by customized education programmes, and/ or co-research. If the label "change agent" in the context of sustainable R&D processes is adequate, then perhaps knowledge distribution is not enough to establish universities as change agents. In order to reach this effect, ownership of knowledge within local and regional societies, on the one hand as well as ownership of customized education and co-research by university staff on the other hand has to be achieved. Therefore, universities or groups such as ECoS that want to effectively act in this field have to thoroughly consider collaborative ways of research and education in organized and/or informal learning environments, so that knowledge demand, knowledge transfer and knowledge generation can be negotiated and jointly determined between local/ regional societies and universities.

CONCLUSIONS

There is a global need to make students and educators aware of the importance of safe science. The science activities structures such as the report writing template or Teikeibun in Japanese schools can be adopted elsewhere including in Malaysia to foster students' social and ethical development and the willingness and capacity to express their thoughts and opinions respectfully. Student respondents and participants of ECoS activities benefit from the special lessons. The networking and collaboration should continue to include other environmental issues.

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