SCIENCE AND TECHNOLOGY FOR A SUSTAINABLE FUTURE

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ABSTRACT

Mathematics and science are part of our daily lives. They are also part of STEM (science, technology, engineering and mathematics) education which is considered as one of the the key to fulfilling many of our future challenges. In 1970, Malaysia implemented the first National Science and Technology Registration Policy 60:40, which guarantees that 60 percent of Malaysian students will be enrolled in science with the remaining 40 percent in art. This paper discusses the rise of Malaysia's activities, including those conducted by the National STEM Movement of Malaysia. This movement is an integrated effort that gathers communities to promote STEM education that helps prepare students with the skills to meet science and technology challenges especially with the presence of the Fourth Industrial Revolution (4IR). The Center for Science Studies, University of Malaya supports the STEM Movement. Although the acronym STEM is not a buzz word in the Japanese education system, the Ministry of Education, Culture, Sports, Science and Technology Japan (MEXT) awarded Super Science High School (SSHS) special funding to prioritize science, technology and mathematics. STEM education is in line with the activities conducted by ECoS, a Japanese-based collaborative research group that emphasizes on Sustainable Development and Green Chemistry. This paper also discusses the science activities that is adopted from EcoS.

Keywords: science and technology, STEM education, Green Chemistry

ABSTRAK

Matematik dan sains adalah sebahagian daripada kehidupan seharian kita. Ia juga merupakan sebahagian daripada pendidikan STEM (sains, teknologi, kejuruteraan dan matematik). Pendidikan STEM dianggap sebagai salah satu kunci untuk memenuhi banyak cabaran masa depan kita. Pada tahun 1970, Malaysia melaksanakan Dasar Pendaftaran Sains dan Teknologi Kebangsaan 60:40, yang menjamin 60 peratus pelajar Malaysia akan mendaftar dalam sains dengan baki 40 peratus dalam bidang bukan sains. Artikel ini membincangkan tentang aktiviti di Malaysia, termasuk yang dilaksanakan oleh Pergerakan STEM Kebangsaan Malaysia. Pergerakan ini merupakan usaha bersepadu yang mengumpulkan komuniti untuk mempromosikan pendidikan STEM yang membantu menyediakan pelajar dengan kemahiran untuk menghadapi cabaran sains dan teknologi terutama dengan kehadiran Revolusi Perindustrian Keempat (4IR). Pusat Asasi Sains, Universiti Malaya menyokong Gerakan STEM. Walaupun akronim STEM bukan perkataan buatan dalam sistem pendidikan Jepun, Kementerian Pendidikan, Kebudayaan, Sukan, Sains dan Teknologi Jepun (MEXT) menganugerahkan pembiayaan khas Super Science High School (SSHS) untuk mengutamakan sains, teknologi dan matematik. Pendidikan STEM adalah selaras dengan aktiviti yang dijalankan oleh ECoS, kumpulan penyelidikan kolaboratif berasaskan Jepun yang memberi penekanan pada Pembangunan Mampan dan Kimia Hijau. Kertas ini juga membincangkan aktiviti sains yang digunakan oleh EcoS.

Kata kunci: sains dan teknologi, pembelajaran STEM, Kimia Hijau

INTRODUCTION

Today’s educators have a responsibility of not only making sure students complete their schooling or graduate but also, that the students are well-prepared careers, even though their career choices are as yet undefined. Educators must realize that their students may be involved in future jobs which have not been invented yet and future workers may not involve in the same jobs over a long period of time. Malaysia is in need of scientists, technologists, engineers and mathematicians among others. To ensure that Malaysia can become a developed country, requires firstly human capital that possess critical and innovative thinking which can be nurtured through STEM related subjects in schools: Science, Technology, Engineering and Mathematics.

The key to the success of Japan in education is the traditional belief that all children can be achievements until today where Japan is one of the world's success stories in education. Japan's strong commitment to education leads to rapid economic growth and Japan is currently one of the major players in high technology production and high-value products. Although Japan is one of the most developed, economically and sophisticated industrialized countries in terms of its education system, there is ongoing concern in Japan about the loss of moral standards and the reduction of student motivation. Therefore, Japanese schools need to attract the most talented teachers to the most challenging classrooms, and the most capable principals for schools that need the urge to compete with current challenges. Effective school leadership is needed, together with a stronger emphasis on uncertainty, to allow rapid decision-making, and freedom to act so that educational authorities and local schools can respond to changing circumstances and the surrounding environment. Japan still survives due to the clear and ambitious academic standards of Japan and a coherent delivery chain where curriculum goals are achieved, translated into teaching systems and quality teaching practices as well as effective student learning approaches (Schleicher, 2013).

According to a report by *Shukan Toyo Keizai* (a publisher with experience in politics, economics and business, based in Tokyo), technological advances in Japan have side effects which are economically demanding higher education and higher entry prices. School children struggle to learn while teachers struggle to teach in a more competitive manner. The report also claims that 60 percent of public elementary school teachers are "*karōshi*" (death due to hard work) which means they work at least 60 hours a week, although contracting works for less than 39 hours. In addition to providing lessons, grade assignments, overseeing extra curriculum and counseling activities, they also need to deal with the parents concerned, attend meetings and manage administrative tasks. Toyo Keizai was worried that the schools turned into my burial *kigyō* (black companies) who worked too hard and paid less to the point of neo-servitude. *Toyo Kenzei* is of the opinion that high school and junior high school seem to be moving in that direction.

MALAYSIAN BLUEPRINT

According to Dato’ P. Kamalanathan, Malaysian Deputy Education Minister, some significant progress has been made after the Malaysia Education Blueprint 2013-2025 (MEB) to transform the education system was launched in 2016. The Education Performance and Delivery Unit of the Education Ministry is tasked to drive the progress while also supporting and facilitating the transformation of Malaysia’s education system through the implementation of the six core traits that need to be inculcated into Malaysian students: knowledge, thinking skills, leadership skills, bilingual proficiency, ethics and spirituality, and national identity. The MEB was formed to create an education system that promotes the students' holistic development. Currently Malaysia is at the second main waves of transformation (2016-2020) which is centered on structural changes. Consecutively, the third and final main wave will be from 2021-2025. It is essential that all stakeholders (teachers, students, parents and private sector partners) work together for the success of this noble game-changing transformation Blueprint since education is a means for social mobility and a key to a better future. MEB can aspire Malaysia to be in the top third of countries in terms of performance in international assessments, as measured by outcomes in the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA) within 15 years.

STEM AND STEAM EDUCATION

The acronym STEM was suggested by Dr. Rita Colwell, a bacteriologist who was director of NSF in the 1980s. STEM education is an approach in the teaching and learning process which combines the content and skills in science, technology, engineering and mathematic. Experts in the field of science, business and education believe that the ability of Malaysian nation to compete globally is related to the ability of the Institute of Higher Learning to shape the graduates from the STEM program. Malaysia is envisioned to be a fully developed country by 2020. Looking at the sixth challenge mentioned in the 2020 vision, Malaysia needs to establish itself as a scientific and progressive society that is innovative and forward-looking. Clearly in order to attain this level of achievement, Malaysia needs scientists, technologists, engineers and mathematicians as human capitals. The Ministry of Education for Higher Learning is encouraging all institutions in Malaysia Students are expected to apply STEM in seeking relations with schools, communities, careers and global entrepreneurship.

Just like any other global issues, there are many forums, seminars and conferences which discuss about STEM education as well as STI (science, technology and innovation) in Malaysia. One of the main question is whether by 2020 when Malaysia is supposed to be a developed nation, it is producing the required number of scientists, engineers and mathematicians. Malaysia needs to draw experiences that are relevant to developing countries in developing a sound STEM education program.

What is STEM education program? Can we refer to Japan? According to Kadota (2015) the chosen Super Science High Schools in Japan have been involved in robot education in addition to the regular lessons of mathematics and science. The first batch of Super Science High Schools were awarded in 2002 and these schools received special funds to develop links with universities and other higher academic institutions since the SSHS students are expected to excel as scientists and engineers. In general, Japan high school students do not study technology or engineering. This is part of the reason why the term "STEM education" is not known to many students or teachers in Japan. According to Kadota, another reason that STEM education has not really taken off in Japan is the lack of facilities that should be available in order to emphasize to students on technology and engineering. As a way of involving themselves with the Japanese government's aspiration to make Japan into a technology leading country, it is necessary for schools to spend time for education in '*monozukuri*' where students and teachers are expected to work with a deeper impression of skilled craftsmen. Kadota labeled Tokyo Tech High School of Science and Technology as the only national High School of science and technology in Japan. Tokyo Tech High School has been a Super Science High School since 2002 by maintaining its high standard in its students' quest for science, mathematics as well as engineering and technology. Basically, STEM education is covered in this school, theoretically as well as practically although there is not much of a conscious effort to label it as such. The curriculum which sets Tokyo Tech High School apart from others include curriculum development of robot education and curriculum of machine design course. Clearly these two curriculum are not the emphasis of Malaysian high school curriculum. STEM education will have to take another form.

In his research work regarding comparison studies between STEM education in the USA and in Japan, Kumano et al (2016) listed the definition of technology as “any modification of the natural world made to fulfill human needs or desires”. Engineering is defined as “a systematic and often iterative approach to designing objects, processes and systems to meet human needs and wants”. Application of sciences is defined as any use of scientific knowledge for a specific purpose, whether to do more science; to design a product, process or medical treatment; to develop a new technology or to predict the impacts of human actions”. One of the major difference regarding the STEM education implementation between the USA and Japan, the former country allocates a much higher budget for STEM education activities and issues compared to the latter. Just for the state of Iowa, the governor’s STEM Advisory Council had a total budget of 4.7 billion dollars from its own state funding and the National Science Foundation for the period of 2012-2013. Another observation recorded by Kumano during the comparison studies concerns the new framework of the USA’s science education after 2011 which emphasized on the developmental stages of children and the learning progress. STEM education should begin from an early stage.

While STEM movement began to take shape in 2006, the addition of arts has been made by transforming STEM to STEAM (science, technology, engineering, arts and mathematics). It is claimed that by integrating art and design to various forms with stem subjects, schools are working to strengthen students’ abilities, among others, to be creative and flexible problem-solvers and to communicate well with others. By adopting STEAM, students are also expected to feel driven towards understanding the true meaning of design. The arts integration in schools is expected to improve critical thinking skills and academic achievement. However there are not many studies which address the actual results of STEAM since it is relatively new. Various forms of art including music, dance, sculpture and creative writing will challenge students to explore the human condition and bring empathy to others. Discussions with non-scientists will enrich the emotional, social and cultural aspects of every possible thing when scientists discuss issues among themselves. Institutions must strive to reinforce the ability of students to become creative and flexible problem solvers, to explore different ideas, recognize failure as an opportunity for discovery and communicate well with others. Building this kind of human relationship is what drives true innovation. With the STEAM project, students learn by creating, creating and designing and understanding the true meaning of the design.

Even newer and by far fewer, STREAM (Science, Technology, Religion, Engineering, Arts and Mathematic) education was claimed to have started by several institutions although the real complete curriculum are still vague. Apart from STEM, STEAM and STREAM, we are now on the brink of a fourth industrial revolution (4IR). It is said that students must participate in STEM subjects to meet the demands of its evolving job markets. The 4IR is supposed to represent new ways in which technology becomes embedded within societies including the human bodies. Is our education system converting enough students into modern, high-level professions such as nanotechnologists, bio-engineers and computer scientists?

INTERNATIONAL STUDENT ASSESSMENT

Japan has been consistently among the world's leading systems in the OECD (Organization for Economic Cooperation and Development) Program for the PISA International Student Assessment Program, a competent international test among 15-year-old school students, on the quality of learning outcomes, learning opportunities and value-for-money. Although the current status of STEM education in Japan is of concern for policymakers and society, analyzing policies, strategies and programs, and offering a preliminary assessment concerning their impact and effectiveness. STEM provisions, attitudes toward STEM, participation in STEM in schools and career paths for STEM students are examined in section three along with statistical data and evidence from other sources, including international comparisons of STEM education such as PISA (OECD's Program for International Student Assessment, and TIMSS

(Trends in International Mathematics and Science Study). critical issues pertaining to Japanese STEM education. According to Ishikawa (2013) Japan is trying to focus on four major strategies enhance STEM in four key areas of education: (1) science advocacy programs to generate interest and enthusiasm among the general population, especially among young children; (2) 'elite' science programs to nurture and encourage the brightest talent from high school (upper secondary) to post graduate levels; (3) programs to ensure successful career linkage from university to labor markets; and (4) programs to rectify the under-representation of women in STEM subjects and research as well as workplaces.

FOURTH INDUSTRIAL REVOLUTION

In his book, *The Fourth Industrial Revolution*, Professor Klaus Schwab, Founder and Executive Chairman of the World Economic Forum, describes how this fourth revolution is fundamentally different from the previous three, which were characterized mainly by advances in technology. These technologies have great potential to continue to connect billions more people to the web, drastically improve the efficiency of business and organizations and help regenerate the natural environment through better asset management. The Fourth Industrial Revolution holds unique opportunities to improve human communication and conflict resolution.

Since 2016 with the announcement of 4IR by Klaus Schwab as "emerging technology breakthroughs" in fields such as artificial intelligence (AI), robotics, (IOT) the Internet of Things, autonomous vehicles, 3D printing, quantum computing and nanotechnology, Japan looked to 4IR to reach “impossible” gross domestic product target by 2020 which is the same year as the Tokyo Olympics (Boyd, 2016). The Japanese Prime Minister promotes 4IR by having the public and private sectors collaborate to apply key technologies that are expected to increase Japanese business and industry. At the same time, this will also be part of the solutions to Japanese societal and global challenges. In order for this revolution to happen in Japan, the Japan’s Council for Science, Technology and Innovation (CSTI) suggested that the existing systems and regulations including those at the Japanese national universities must be reformed to achieve the full potential. New sources of funding for research projects are crucial for innovation in topics such as cybersecurity, AI, Big Data Analysis, robotics, Internet of Things, biotech, as well as materials and nanotechnology.

Looking at Japan, Takuma Iwasa, founder of Cerevo's start-up consumer electronics firm in Japan, believes that Japanese organizations have the ability to produce something innovative, but whether the company's management will allow product creation to market use is another matter (Oi, 2016). Iwasa thinks that the larger the company, the company finds it difficult to take risks. He added that globally, large companies succeeded in producing serial innovation (making better versions of the product as it would sell) but less successful to produce new innovations. It can still be proven whether the Japanese government can assist to encourage more innovation. The Japanese government’s promotion of entrepreneurship has helped to boost the country’s spirit. A number of government-to-government and academic collaborations have been promoted through "Abenomics", including the SIP (Cross-Minister Strategic Promotion Program) and Impact (Changing Paradigm Change through Disturbing Technology). At the same time, research and development related to advanced chemistry, incorporating information and communication technology (ICT) will also be further enhanced (Searle, 2016).

DISCUSSIONS

The Malaysian government is facing several major challenges in achieving the goal of strengthening STEM education in its country. The Ministry of Education Malaysia has targeted a ratio of 60:40 for science to non-science students. However, over the years, a huge challenge is the decreasing enrolment of science students at secondary education level. Another challenge is the lagging in science achievement and literacy of Malaysian secondary students in international assessment studies specifically in mathematics. These are worrying trends. By 2050, the population of Malaysia will reach 50 million but will be an ageing population. To ensure that they can live healthy and independently, there is a need to put in place Research & Development to develop robotics and smart devices, infrastructure to accommodate them, designs that support their needs, personalized medicine and remote healthcare monitoring for their welfare. The Malaysian Ministry of Science, Technology and Innovation through Academy of Sciences Malaysia are doing studies to identify ways to position the country moving forward through maximum use of Science, Technology and Innovation by looking at mega trends that would impact Malaysia. This is vital to ensure sustained national development and global competitiveness.

In 1996, a policy had been introduced to teach mathematics and science in English but this policy was reversed in 2012. There have been many discussions dialogues including town hall meetings as well as heated debates regarding the medium of teaching mathematics and science in Malaysian schools at the moment. This issue can be linked to the teaching of STEM in Malaysia. One side of the group thought that Malaysia risks lagging behind unless STEM is taught in English. According to a group of retired high-ranking civil servants, Malaysia may fall behind other Asian countries if the government does not re-introduce the policy of teaching STEM subjects in English. It was argued that the quality of local graduates had fallen. The poor English proficiency means that the graduates cannot interact effectively on the global front.

The opposing group is of the opinion that just like our neighbor in Singapore, English should be the medium for STEM education in Malaysia since English is a currently acceptable language in many countries and in most field of human endeavor. Singapore has repeatedly taken top positions for PISA and TIMSS while Malaysia whereas Malaysia has fared poorly on both. There must be more studies taken to ensure whether the medium of teaching is the main culprit for the success of PISA and TIMMS in Malaysia. According to Hurford (2010), it is important to understand experience by looking at patterns of activity or interest and the relationships between them. It is important to make sense of human learning. Hurford also stated that students who are non-achievers indicate there exist an unsolved problem during their learning process in the classroom. This is also supported by Mullis et al (2012) who observed that the conduct of teaching and learning in classrooms is a dimension that must be studied especially when it relates to students and the teachers who will affect the students’ performance.

What are other methods that can be used to enhanced students’ ability to learn? Stokes (visual literacy in teaching and learning: a literature perspective) stated that using visuals in teaching results in a greater degree of learning. Wileman (1993) defines visual literacy as the ability to read, interpret and understand information presented in pictorial or graphic images. With the advent of 4IR, the students must be able to use computers for this purpose. Wileman also stated that associated with visual literacy is visual thinking, described as the ability to turn information of all types into pictures, graphics, or forms that help communicate the information. This scenario also describes the importance of STEAM education to enhance students’ ability to learn. This is also emphasized by Sinatra (1986) who observed that the active reconstruction of past visual experiences with incoming visual messages to obtain meaning, with emphasis on the action by the learner to create recognition.

Japan like Singapore, has also enjoyed good success in PISA and TIMSS results although the medium of teaching mathematics and science is in their mother tongue and not in English. Thus, one may ponder whether the knowledge of mathematics and science has to be delivered in English in order for students to excel in those subjects. Comparatively, it has been pointed out that Japan’s Honda has adopted English as its official language to survive in the very competitive automotive industry, while India and the Philippines continue to teach science and mathematics in English and have gained success.

The cooperation of all quarters including the stakeholders is vital in instilling passion and creating awareness among students on STEM. Such a cooperation could be implemented via the Malaysian National Blue Ocean Strategy (NBOS) initiative where the relevant quarters in education would work together to plan and carry out activities to achieve the objective. Apart from that, there is now an active organization, namely the Malaysian National STEM Movement which is headed by representatives of several universities in Malaysia as well as those from the Education, Higher Education and Science, Technology and Innovation Ministries. The Malaysian National STEM Movement is currently being chaired by Professor Dato' Dr. Noraini Idris (Deputy Vice Chancellor for Research and Innovation, Universiti Pendidikan Sultan Idris). Idris et al (2014) observed that STEM education can be implemented effectively in Malaysia if properly planned since the teachers' preparedness for STEM education is at a high level while the students' level of readiness in learning STEM education is at a moderate level which can be enhanced even further. Some of the challenges that should be overcome to ensure the success of STEM education include learning materials and infrastructure facilities in schools. In addition, factors such as time constraints, professional training or retaining of teachers and increase in teaching materials should be addressed to ensure that STEM education can be carried out effectively. Idris et al (2014) also observed that students from different background are interested in STEM education and to improve their knowledge including in problem solving and higher order thinking in creativity. Unlike Tokyo Tech High School of Science and Technology, the Malaysian schools are still not ready to implement curriculum such as robot education or machine design course.

In a separate but related movement, the Prime Minister of Malaysia discussed The National Transformation (TN50) at the University of Malaya in January 2017. '*Transformasi Nasional* 2050' or TN50 is an initiative to plan for the future of Malaysia in the period 2020 to 2050. The public's voices and those of 1.5 million youths will be sought to draft the 2050 National Transformation (TN50) policy document in one of the country's biggest policy formulation exercises to date. The TN50 policy document is supposed to outline the economic, social, cultural and environmental targets Malaysia aims to achieve by 2050. TN50 outlines that by 2050, Malaysia is "To become a top 20 nation in economic development, social advancement and innovation". STEM education is part of the issue that is supposed to be outlined in TN50.

Channeling students into STEM subjects represents only the first hurdle in the pursuit of enabling them to take pathways in STEM. The National STEM movement focuses on large scale STEM education events and activities in Malaysia. Members of the National STEM movement not only include the academicians from Malaysian's universities and the Ministry of Education but also IKIM radio station, Malaysian Industry-Government Group for High Technology (MIGHT), *Akademi Sains Malaysia*, National Innovation Agency Malaysia, Petrosains, IBM Malaysia as well as various corporations and NGO (Non Governmental Organization).

The National STEM movement has been regular in promoting and organizing various activities. Monthly meetings at either the Malaysian Science Academy; Petronas Science Centre or local university campuses allow the members to organize and report the outcome of such activities including mentor-mentee gatherings and scheduled science fairs where the activities at these science fairs are injected with cultural themes. Clearly some activities are already progressing towards STEAM where arts and culture elements are part of medium presented during the exhibitions. For all the activities, more parties are invited including the NGO groups. Well-known Malaysian cartoon characters *Upin & Ipin* tend to be invited to promote interest in science amongst the kids at science fairs organized by members of the National STEM movement. The National STEM Movement is also embarking on more exposures of STEM education issues in media. Apart from all these organized activities, there remains a huge task of increasing the number of science students beginning with the Form 4 Science class. The National STEM Movement will have to work together with the education authorities to improve this situation. Another suggestion regarding the STEM education is that there is a need to relook at the courses being offered in STEM areas since there is an inability for some STEM education graduates to gain employment.

Reportedly, 700 out of 2,400 places available for undergraduate science courses at the local Malaysian universities remained unfilled in 2017/2018 session intake (Hamid, 2017). At the tertiary level, one deputy vice-chancellor of a public university informed that he was finding it increasingly tough to fill up the places for science courses at his university. There is just not enough demand, as opposed to social sciences and business administration courses, where there is no shortage of applicants. Could it be that students are no longer interested in STEM programs? Hamid wrote that universities now have to bear the brunt after years of neglect in STEM education (science, technology, engineering and mathematics) at the school level. He also stated that science labs are now a rarity in secondary schools. Is it also true that he teaching of science these days is dry and uninteresting as claimed by some parents? The Malaysian government has, since the 1970s, been giving priority to science and technology education. The first National Science and Technology Enrolment Policy of 60:40, which guaranteed that 60 per cent of students would be enrolled in science with the remaining 40 per cent in arts. Around 69 science secondary schools (*Sekolah Menengah Sains*) and 51 Mara Junior Science Colleges were built as part of the strategy to meet this target.

The Malaysia Education Blueprint 2013-2025 aims at, among others, improving the learning and teaching process of science and mathematics-related subjects to get more students to enroll in science streams. Despite having the 60:40 ratio target of having more students to enroll in science streams since the 1960s, the government has not been able to achieve it. Revamp the way teachers teach science and mathematics in schools. It must focus on developing the students' higher order thinking skills, encourage project-based systems and the use of ICT-based games to make learning fun. There should be more hours allotted to science subjects so that teachers can carry out inquiry-based science approaches. STEM education teachers should be given access to continuous professional development on delivery methods to encourage inquiry thinking.

RESULTS OF SURVEYS AT THE CENTER FOR FOUNDATION STUDIES IN SCIENCE

A survey regarding awareness in STEM education has been carried out at the Centre for Foundation Studies in Science, University of Malaya. The 75 respondents aged between 17-18 years old came from various schools in Malaysia to continue their studies at the Special Japanese Preparatory Program (RPKJ or Ambang Asuhan Jepun) for two years before embarking their undergraduate studies in engineering at universities in Japan.

Only thirteen (13) out of seventy five (75) students have heard of STEM education before they came to RPKJ. Out of the 13 students, only a few have been to STEM education carnivals or STEM education camps. These students definitely have not been able join any of the activities organized by the National STEM Movement since 2016. Is this a concern to Malaysia? Comparatively, Saito et al (2015) believe that Japan still needs evidence that integrated STEM learning will be successful in improving students' knowledge and skills for future sustainability. Saito et al developed and tested a "T-SM-E" instead of a "STEM" template, thinking that teachers may find Technology interesting and better defined than Engineering. The template was tested during a Summer Camp where the learning materials had been labeled as Technology while Scientific and Mathematical activities were conducted during the camp for development of prototypes. Japanese school teachers are unclear of how to implement engineering problems in school lessons. Many questions arise after the STEM education camp. The integration of STEM into daily school lessons are still unclear. It was then suggested that future STEM education research should include design research for teachers' needs as well as for the integration needed in the classrooms.

Another survey was carried out to a group of high school students from Melaka who visited the Centre for Foundation Studies in Science, University of Malaya in July 2017. All 39 of the students wanted to visit the facilities at the center including the laboratories. Only 34% of the students (or 26 out of 39 students) have heard of STEM education even though 100% of them informed that they are interested in science. The students were given briefings about the center's program as well as a short and basic briefing regarding biological life cycle as an introduction to STEM education. At the end of the program all 100% of the students stated that the visit to the center increased their interest in science.

Another survey was conducted on seven science teachers from Kobe Super Science High School, by the Center for Foundation Studies in Science using the same questions. Out of seven (7) science teachers from Kobe Super Science High School, only two (2) of the teachers have heard of STEM education. Only one (1) of the two teachers have had a STEM education activity at his school which involved a project study for students. This survey's result reflects Kadota's (2015) observation regarding the lack of STEM education label in Japan even though science and mathematics are emphasized on the students. Therefore, it is not surprising that all the seven Kobe Super Science High School teachers have not heard of either STEAM or STREAM education.

In a survey conducted by Kumano et al (2016), pre and post questionnaires were given to 40 high school teachers regarding their attitude toward STEM education. As expected, results of the survey shows that most teachers realized that science is more interesting and more exciting when it is connected to STEM. The survey also shows that most teachers realized that mathematics is more interesting and more exciting when it is connected to STEM. However, the survey also shows that the teachers did not improve their attitude toward STEM careers. The teachers cannot relate STEM education with STEM careers. Results of the survey also shows that the teachers identify STEM education as appealing, meaningful, interesting and beneficial. However, the teachers do not find STEM education as active nor easy to understand. Kumano further inferred that although the teachers can identify the importance of STEM education, they may not realize the importance of integrative lessons in science education and they may also not understand the importance of STEM careers in Japan.

Kumano et al (2016) reported that in 2016, there are only a few universities in Japan that have STEM education centers: Saitama University and Tamagawa University. Meanwhile Shizuoka University received a STEM education grant from the Japan Science and Technology Agency to set up STEM innovation for graduate school courses. Kumano also reported that there is a need to develop high quality robotic and radiation protection technologies which can work at severe radiation environment. Therefore, there is a need for Japan to develop a unique model for STEM education for its students.

GREEN CHEMISTRY TOPIC EXPRESSED USING *TEIKEIBUN*

ECoS (Educational Co-Research for Sustainability) members from various institutions in Japan, Philippines, Korea and Malaysia usually meet on an annual basis to discuss teaching materials which focus on risk assessment; green chemistry and teaching material unit on air pollution as well as sustainable development (SD) and development of teaching materials. ECoS which was formed in Japan is currently headed by Professor Matsubara Shizuo of Toin University of Yokohama. Amongst its Japanese members are researchers from the National Institute for Educational Policy Research (NIER) as well as educators from various universities and high schools. ECoS has been supported the program of Grants-in-Aid for Scientific Research. Activities carried out with ECoS have the following objectives:

i. To better prepare students so that they are aware of the issues concerning sustainable development.

ii. To make the students aware of the global pollution which arise from the existing social problems.
iii. To provide a platform for the students to think of ways to make chemistry more environmentally friendly.

One of the topics which are normally discussed during ECoS's annual meeting is usage of using the One Page Report Writing Template (Teratani et al, 2012) which can be used as a One Page Portfolio Assessment (OPPA) to assess students' knowledge on a given subject the Study History Sheet (SHS) allows students to write their prior and gained knowledge, summarization of the lesson learnt as well as impressions on the lesson study. Often times, students are not inquired regarding their impression of the topics which they learnt during lessons. Another section of the SHS requires students to express their frank reflections on the SHS exercise itself. The template which is also called OPPA can help to cultivate scientific expression ability by *Teikeibun* (Report Writing Template). ECoS has been attempting to use the one page *Teikeibun* as a method of propagating Education in Sustainable Development (ESD). This one page *Teikeibun* which acts as a SD educational material has the potential of helping students to become more conscious of the values and benefits that science can offer.

Students at the Center for Foundation Studies in Science, University of Malaya were asked to make use of the Study History Sheet to write down their prior and gained knowledge impression of a specific topic which was Green Chemistry. The format of "before" and "after" GSC lessons adopted from NIER is interesting to the respondents and has raised the respondents' level of awareness regarding Green Chemistry. Responses from students for "before study", "after study" and a reflection study are given in Figures 1, 2 and 3 respectively.

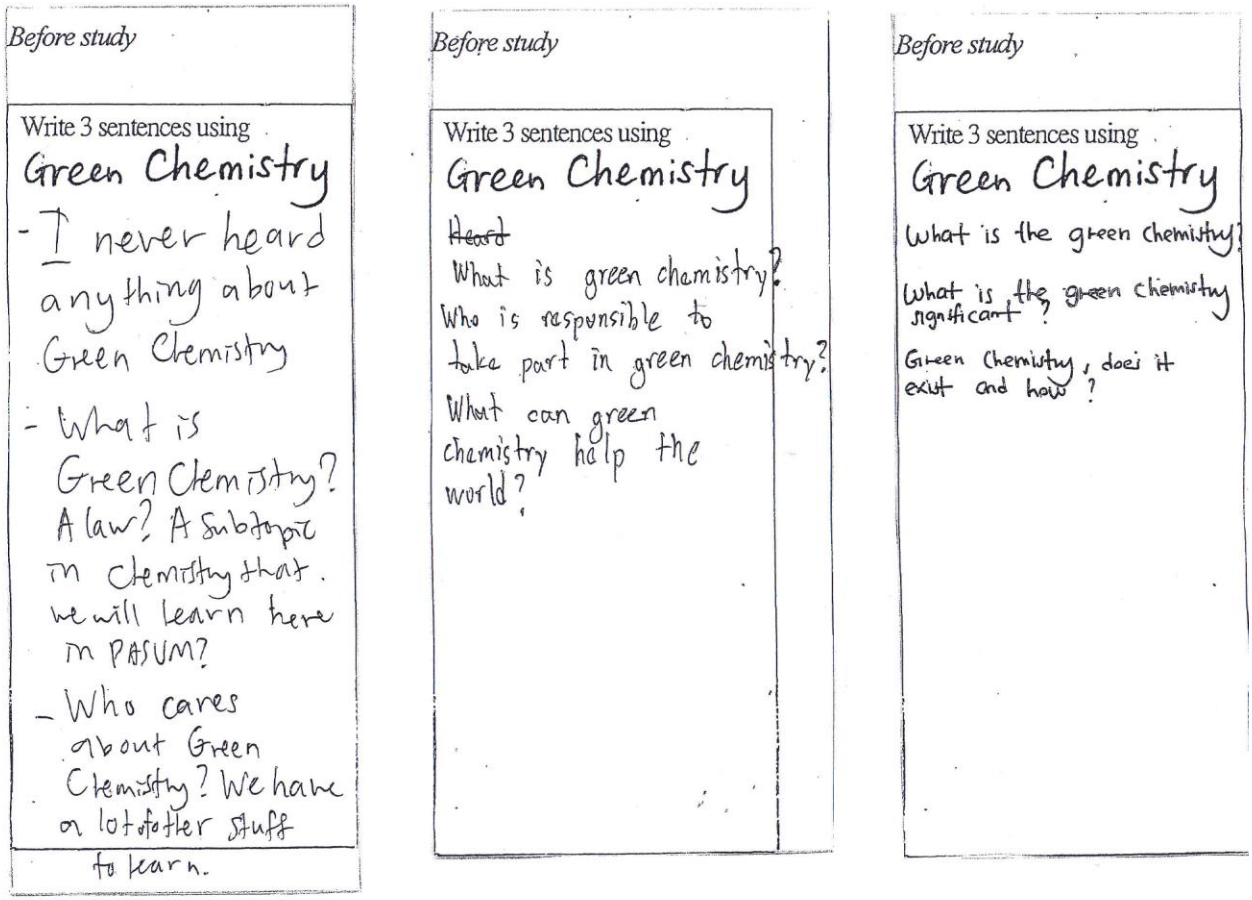
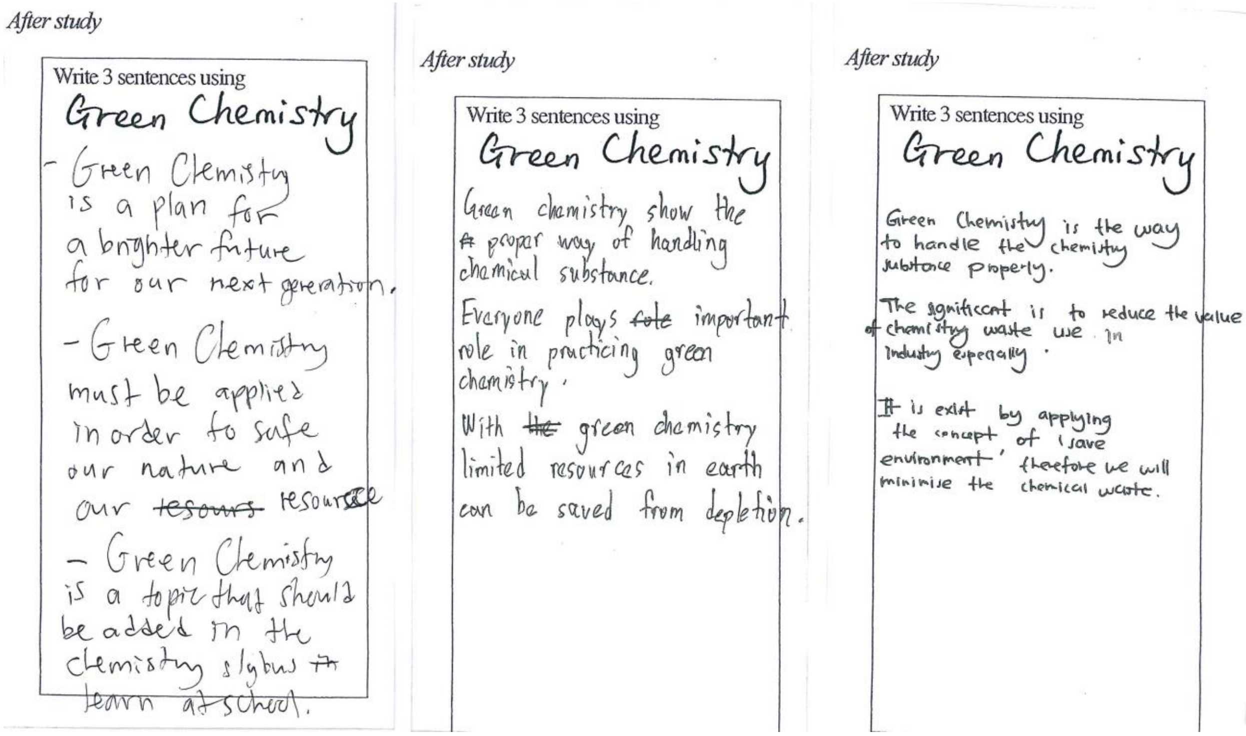


Figure 1. Three chosen responses to the instruction: Write three sentences using Green Chemistry. Most of the responses in the "before study" section are in question form.

The topic of "Green Chemistry" is not included in the Chemistry syllabus at the Center for Foundation Studies in Science even though it is of importance to researchers including ECoS members. The students were given a briefing of the Twelve Principles of Green Chemistry (Anastas, 1998) before being asked to express their thought in the Study History Sheet. Figure 1 shows that most of the sentences regarding Green Chemistry were in the form of questions. All three respondents asked the obvious question "What is Green Chemistry?". Two of the respondents inquire about the significance of Green Chemistry. One of the respondent poses his strong opinion by asking "Who cares about Green Chemistry?". He further explained that "We have a lot of other stuff to learn" which reflects the time constraints and the packed schedule that this student feels at the center.

The responses to the "after study" section shows that the respondents are much more appreciative of the Green Chemistry topic, having realized that this topic shows "the proper way of handing chemical substance", "reduce chemical waste" and that "everyone plays important role in practicing green chemistry" because this is "for a brighter future for our next generation". It can be inferred that Green Chemistry is a topic which can assist students to pave the way for sustainability. The rest of their responses clearly show an awakening regarding the importance of Green Chemistry. The respondent who complained about this additional topic began to realize that "Green Chemistry is a topic that should be added to the syllabus learnt at school".


After study

Write 3 sentences using
Green Chemistry
- Green Chemistry is a plan for a brighter future for our next generation.
- Green Chemistry must be applied in order to safe our nature and our ~~resours~~ resource
- Green Chemistry is a topic that should be added in the chemistry sylbus to learn at school.

After study

Write 3 sentences using
Green Chemistry
Green chemistry show the ~~a~~ proper way of handling chemical substance.
Everyone plays ~~role~~ important role in practicing green chemistry.
With ~~the~~ green chemistry limited resources in earth can be saved from depletion.

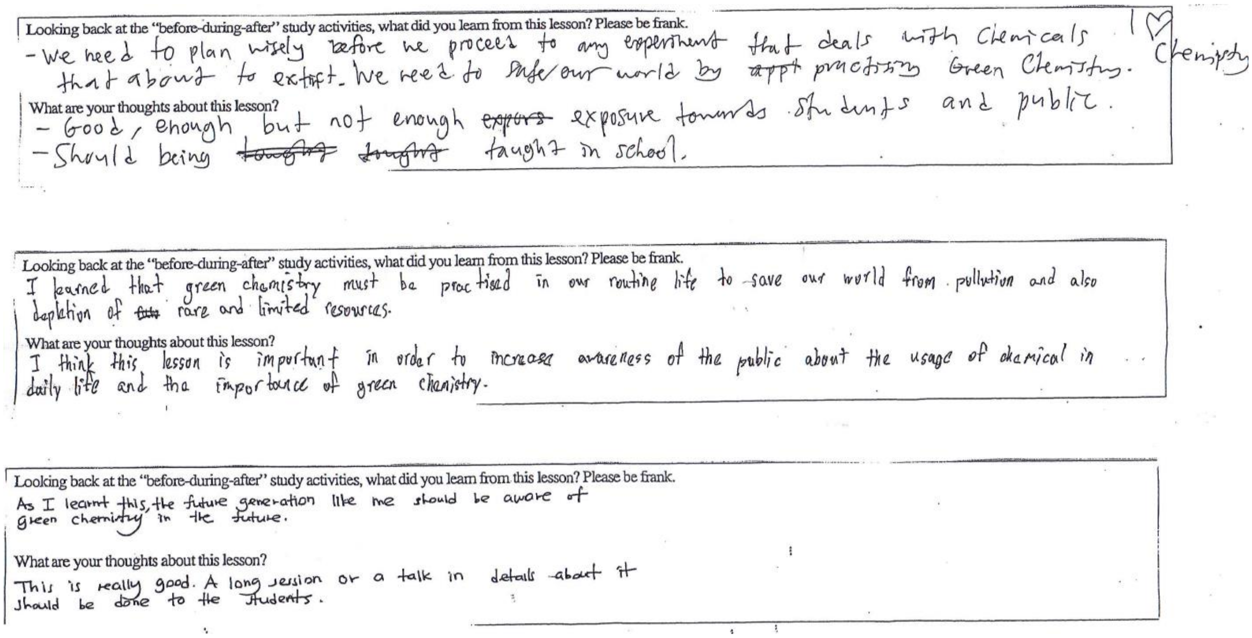
After study

Write 3 sentences using
Green Chemistry
Green Chemistry is the way to handle the chemistry substance properly.
The significant is to reduce the value of chemistry waste we in industry especially.
~~It~~ is exist by applying the concept of 'save environment' therefore we will minimise the chemical waste.

Figure 2. Three "after study" responds by the students concerning Green Chemistry. All the responses are in statement form unlike the response in the "before study" section.

We can infer that the students had benefited from the *Teikeibun* exercise because the realization about the importance of Green Chemistry topic is carried through in their positive responses in the final section of the *Teikeibun* which requires them to frankly look back and ask themselves what they have learnt from the lesson as shown in Figure 3. The students now realized that before they venture into any experiments, it is essential for them to "plan wisely" in order to "save our world" not only from "pollution" but also from "depletion of rare and limited resources". This section of the *Teikeibun* again allows the students to express the importance of the Green Chemistry lesson "to increase the awareness of the public about the usage of chemical in daily life".

Japan has a track record of overcoming the problem of environmental pollution, and in this regard, it has become the world leader in developing solutions to environmental challenges (Searle, 2016). The current Japanese Chemical Association President, who is also the Keidanren (Japan Business Federation) Chairman Sadayuki Sakakibara, emphasized that chemical innovation based on Green Sustainable Chemistry represents the path to Japan's resurgence over the last 20 years as the chemical industry in Japan has grown to be largely Japanese economy. He also pointed out that the development of environmentally friendly products is increasingly important and although the pursuit of wealth and environmental conservation simultaneously is very difficult, but it is not impossible. He urged the public to think of ways to limit the environmental impact while continuing to increase GDP. *Teikeibun* assists in the process of liberating the students' mind from ignorance and allowing their new knowledge of Green Chemistry to be reflected and expressed frankly in a written form. The short lesson using *Teikeibun* regarding Green Chemistry at the Centre for Foundation Studies in Science, University of Malaya has been not only an important but also satisfying reflection on the importance of the topic Green Chemistry for everyone.


Looking back at the "before-during-after" study activities, what did you learn from this lesson? Please be frank.
- We need to plan wisely before we proceed to any experiment that deals with Chemicals that about to extict. We need to safe our world by ~~appt~~ practising Green Chemistry. I ♡ Chemistry
What are your thoughts about this lesson?
- Good, enough but not enough ~~expors~~ exposure towards students and public.
- Should being ~~toughing~~ ~~toughing~~ taught in school.

Looking back at the "before-during-after" study activities, what did you learn from this lesson? Please be frank.
I learned that green chemistry must be practised in our routine life to save our world from pollution and also depletion of ~~the~~ rare and limited resources.
What are your thoughts about this lesson?
I think this lesson is important in order to increase awareness of the public about the usage of chemical in daily life and the importance of green chemistry.

Looking back at the "before-during-after" study activities, what did you learn from this lesson? Please be frank.
As I learnt this, the future generation like me should be aware of green chemistry in the future.
What are your thoughts about this lesson?
This is really good. A long session or a talk in details about it should be done to the students.

Figure 3. This section of the *Teikeibun* shows the students' frank reflection regarding Green Chemistry.

Can the *Teikeibun* exercise on Green Chemistry be part of inquiry-based learning for science? Inquiry-based science (Gibson and Chase, 2002) aims at stimulating greater interest in science and scientific careers. It adopts an investigative approach to teaching and learning where students will investigate a problem, search for possible solutions, make observations, ask questions, test out ideas, and think creatively and use their intuition. In this sense, inquiry-based science involves students doing science where they have opportunities to explore possible solutions, develop explanations for the phenomena under investigation, elaborate on concepts and processes, and evaluate or assess their understandings in the light of available evidence. This approach will challenge students' current conceptual understandings. Several other ways which could assist the inquiry-based science are: schools should be given greater autonomy in choosing textbooks and in implementing the science curriculum and also STEM teachers should have access to continuous professional development on delivery methods to encourage inquiry thinking.

What about inquiry-based teaching? Would inquiry-based teaching be more appropriate for STEM education? Sachiko Tosa (2011) examined similarities and differences in how the USA and Japanese middle-school science teachers teach science through inquiry by measuring how much cognitive scaffolds that teachers provided in order to help students construct conceptual understanding. Tosa observed that little inquiry-based teaching was observed in either of the countries for different reasons: scientific concepts under the classroom discussion were not clearly identified in many of the USA lessons, whereas Japanese lessons often exhibited lack of teachers' support for students in constructing their own understanding of scientific concepts. The study also indicated that majority (79%) of teachers in the 2 countries thought that inquiry-based teaching includes student own explorations of scientific concepts. According to Tosa, the findings imply the importance of student self-directedness in inquiry-based teaching might be acting as an obstacle for increasing inquiry-based teaching both in the United States and Japan. Teachers can gauge the success of their teaching through students' level of engagement with the topic and each other, the scientific language they use to communicate their ideas, and the quality of the work they produce. What types of comments will students make when they have enjoyed participating in science investigations? Inquiry-based science challenges students' thinking by engaging them in investigating scientifically orientated questions where they learn to give priority to evidence, evaluate explanations in the light of alternative explanations and learn to communicate and justify their decisions. These are dispositions needed to promote and justify their decisions. However, there are still many challenges. Can the new teaching and learning will focus on developing our students' higher order thinking skills, allow project-based system and use ICT based games to make the subjects fun? Are teachers and students prepared to create interest simulations and role play apart from the normal experiments and group discussions?

Chemistry is a very important science field and is often known as a central science as it transcends most fields of science and technology. The mastery of the concept of chemistry requires an understanding of macroscopic, sub-microscopic and symbolic levels. Students who have been adhering to the subjects need to master the knowledge of chemistry in order to master the S & T knowledge and subsequently generate S & T innovations as needed to meet the 4IR. There should be variations and changes in chemistry learning for example digital game-based learning (Prensky, 2001) which will also attract and motivate students. Digital games are the preferred medium of current students. This digital learning can be implemented through two learning approaches namely learning through digital gaming or designing digital games. These approaches may be more applicable in order to prepare students for the 4IR era. However, there may be obstacles and challenges for the process as the need for the proper and complete content of a chemical experiment. Not many studies have been made regarding the Japanese science students approach to digital game-based learning in Japan. Bolliger et al (2015) reported that out of 226 Japanese college students' survey results toward the use of digital games in English language learning, most students viewed the potential integration and utilization of digital games as positive. However some students expressed concern that the use of games may not be an effective or efficient method of learning.

Part of the motivation for the advancement of science and technology in Japan is due to the constant natural disasters or hazards in Japan including the Higashi Nippon Giga earthquake, the tsunami and the Fukushima nuclear plant explosion. All this disasters and hazards require a strong reexamination of the Japanese education frameworks. Kitagawa (2014) observed that although disaster education has always been delivered at school since the post-war Japan era, its curriculum has changed over the years from the scientific knowledge model to the civic participation model. There is also a change towards multi-hazard model to the daily life model to suit the current economic, political and social context. There is a need to develop a culture of "everyday preparedness" (*seikatsu bosai*) which is extended beyond the framework of School Safety and therefore the scientific knowledge of disasters and life skills need to be enhanced (Kitagawa, 2014). STEM education could provide some of the essential teaching materials and training for the teachers and students.

SUMMARY

By improving the learning and teaching process of science and mathematics related subjects to get more students to enroll into science streams. Governmental plans such as the Malaysia Education Blueprint which aims to address the weaknesses through various measures should assist to revamp the way science and mathematics are taught in schools. STEM education should be more than just an acronym for science, technology, engineering and mathematics because it is a philosophy when added with arts. *Teikeibun* exercise regarding Green Chemistry topic is an approach and a way of thinking for students to help them integrate knowledge of the Green Chemistry together with the actual reflection regarding the subject and encourage them to increase their awareness regarding a safe environment for the future. Although there has been an increase in STEM education promotion in Malaysia especially with the formation of STEM National Movement Malaysia, many Malaysian students are still not exposed to STEM activities. STEM education activities organized by the movement which include regular and scheduled events such as meetings between academics, NGOs and the community as well as science fairs across Malaysia must be increased and there must be a concerted effort to document STEM education issues. Several of the STEM education activities are progressing towards STEAM in Malaysia. It remains to be seen whether the current STEM movement can reach the target of 60:40 science:non-science. These STEM activities are in line with the activities conducted by the ECoS members. Malaysia has much to learn from other countries regarding STEM education. Apart from the common cause of improving the country's standing in PISA and TIMMS, we need to realize that the emphasis of STEM education may differ from one country to another. It is hoped that the Malaysian education system through STEM education will attract more students to enroll in science courses to meet the daily challenges as well as those of 4IR.

Acknowledgements

The support from the University of Malaya and Grant-in-Aid Scientific Research (B) are highly appreciated.

References

Anastas, P.T. and Warner, J.C. (1998). Green Chemistry: Theory and Practice, Oxford University Press.

Boyd, J. (2016). Forbes Asia Economy, Japan Looks To Fourth Industrial Revolution To Help Reach 'Impossible' GDP Target, 24 July, 2016.

Chew, C. M., Idris, N. and Leong, K. E. (2014). Secondary Students' perceptions of assessments in STEM, Eurasia J. of Maths, Science and Tech Educ., 2014, 10(3), 219-227.

Gibson, H.L and Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. Science education. 86(5), 693-705.

Hamid A.J. (20 August 2017). Why do kids avoid the STEM route? The New Strait Times.
Tackling future challenges in STEM education Academy of Sciences Malaysia.

Hoffman, M. (30 September 2017). The education system still has much to learn. The Japan Times.

Hurford, A. (2010). Complexity theories and theories of learning: Literature reviews and syntheses. Theories of Mathematics Education: Seeking new frontiers (pp567-589), Springer Berlin Heidelberg.

Idris, N., Halim L., Ithnin, R., Abdul Rahim, F., Hashim, N., Daud, M.F., Chew, C.M., Zainol Mustafa, Z., and Mohd Ariff Albakri, I.S. (2014). ERGS Final Report, Developing a high quality education model for STEM.

Ishikawa, M., Fujii, S. and Moehle, A. (2013) STEM country comparisons: Japan, NCVER's international tertiary education research database.

Kadota, K. (2015). STEM education in Japanese Technical High School: Through Curriculum development of the robot education. https://archive.org/stream/Fab11 Paper3/ djvu.txt

Kamalanathan, P. (31 August 2014). Blueprint on track. The Star online.

Kitagawa, K. (2014). Continuity and change in disaster education in Japan. Journal of the History of Education Society, 44(3), 371-390.

Kumano, Y. (2016). Status study on the US STEM education innovation. Report of Japan Society for Science Education, 30(9), 57-62.

Malay Mail (26 March 2017). Cooperation vital to instil interest in STEM education, Bernama.

Malay mail online (6 September 2013). Highlights of the Malaysia Education Blueprint 2013-2025. Bernama

Mullis, I.V.S., Martin, M.O., Foy, P. and Arora, A. (2012). Findings from IEA's trends in international mathematics and science study at the fourth and eighth grades. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Oi, M. (2 March 2015). Rebooting innovation in Japan, Business Section, BBC News.

Prensky, M. (2001) Digital natives, digital immigrants. On the horizon, 9(5), 1-6.

Saito, T., Gunji, Y. and Kumano, Y. (2015). The Problem About Technology in STEM Education: Some Findings from Action Research on the Professional Development & Integrated STEM Lesson in Informal Fields, K-12 STEM Education, 1(2), 85-100.

Schleicher, A. (2013). "Lessons from PISA outcomes" in OECD Observer, No 297 Q4.

Searle, R. (2016). Green Chemistry Blog on Tokyo International Conference on Green and Sustainable Chemistry (July 5 to 8, 2015 at Hitotsubashi Hall, Hitotsubashi University2015). Royal Society of Chemistry.

Sinatra, R. (1986). Visual literacy connections to thinking, reading and writing. Springfield, IL: Charles T. Thomas.

Teratani, T., Goto, K., Nouchi, Y and Matsubara, S. (2012). Education Co-research for sustainable development in Science, Report on Second International Workshop on Science Education, Toin University of Yokohama.

The future of jobs: employment, skills and workforce strategy for the fourth industrial revolution, World Economic Forum, http://hdl.voced.edu.au/10707/393272.

Tosa, Sachiko (2011) Comparing U.S. and Japanese Inquiry-Based Science Practices in Middle Schools, Middle Grades Research Journal, 6(1) p29-46.

Wileman, R.E. (1993). Effect of metaphoric (visual/verbal) strategies in facilitating student achievement of different educational objectives. International Journal of Instructional Media, 26(2), 205-211.