Understanding the Basics of STEM Education Through Zero Waste Project

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Abstract:

The new millennium has brought with it many educational terms and their acronyms too. Among which are 21st Century Learning Skills, STEM Education, and Sustainable Development Goals. These educational terms often exert undue pressure and challenges on practising teachers to be competent in implementing them in their classrooms. This study attempts to assess the Thai teachers' conceptions on STEM education based on the Zero Waste Project that they are diligently involved with in its implementation. A total of 36 science and mathematics teachers participated in a focus group discussion in clarifying the strategy and approach in conducting STEM education based on their chosen strand in the Zero Waste Project. The said project is made up of 13 strands. However based on the group classification in the workshop, only six stands of specific subjects were used for the focus group discussion and presentation. From the deliberation, it could clearly be concluded that teachers have high level of awareness that STEM approach is designed to revolutionize the teaching of subject areas in science and mathematics by incorporating technology and engineering into a single multi-disciplinary curriculum. However, this study found that one of the challenges to transform teacher-centredclassroom by introducing a curriculum that is driven by problem-solving and project-based learning was the lack of clarification between 'technology' and 'engineering' aspects in the curriculum.

Keywords: *STEM education, Zero Waste Project, multi-disciplinary approach*

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1. Introduction:

This article would like to begin by tracing the origins of 'STEM' and 'zero waste'. STEM is the acronym for science, technology, engineering and mathematics. This, we all know. Traditionally, they are four distinct academic disciplines taught in schools and colleges. However, what many people, teachers and educators included, are uncertain or even fail to comprehend the wider meaning of STEM education. The acronym STEM might have surfaced with the emergence of the new millennium, but the first explicit mention of STEM seems to be in 2005, when the US Congress "set up the Science Technology Engineering and Math, or STEM, caucus" (Heitin, 2015).By 2008, STEM was gradually gaining global attention, and subsequently the acronym becoming a common educational term.

The Term *Zero Waste* was derived from a commercial company, Zero Waste Systems Inc. (ZWS), which was founded in the mid-1970s in Oakland, California. The mission of ZWS was to collect (buy) and redistribute (resell) excess chemicals used in electronic industry. The company soon expanded its services in many other directions. For example, they accepted large quantities of usable laboratory chemicals which they later resold to experimenters, scientists, companies and tinkerers for half price. ZWS pioneered many other reusing and recycling projects to salvage resources to go into landfills or incinerators (Wikipedia, 2017).

Today *zero waste* encompasses the broad concept that Earth's resources and its products can be recycled and reused. Hence, philosophically, there would not have any trash that needs to be sent to landfills or be incinerated. In this connection, the Zero Waste International Alliance (ZWIA) advocates itself working towards a world without waste through public education and practical application based on a principle that all resources could be reused in nature (ZWIA, 2015).

2. Conceptual Understandingof STEM Fields in Education :

Science, technology, engineering, and mathematics are traditionally four seperate and discrete school subjects each with its own distinct curiculum. Together they form the acronym STEM, which, encompases the distinct perspectives of each of its academic disipline but incorporates other connotations.*Science*is defined as the systematic study of the nature and behavior of the material and physical universe, based on observation, measurement and experiment, leading to the formulation of laws to describe these facts in general terms (Collins English Dictionary, 2017a). While technology is the branch of knowledge that deals with the creation and use of technical means and their interrelation with life, society, and theenvironment, drawing upon such subjects as industrial arts,engineering,applied science, and pure science (The Free Dictionary, 2017). Put it in simpler terms, *technology* is the application of scientific knowledge to help us to do work, and the use of specific methods or know-how to use materials and devices to solve practical problems in our daily life, but particularly in commerce and industry, for examples, such as in car and aerospace technologies. *Engineering*, is seemed as the art or science of making practical application of the knowledge of pure sciences, such as physics or chemistry, as in the construction of engines, bridges, buildings, mines, ships and chemical plants (Dictionary.com., 2017).In other words, engineering uses scientific knowledge to design, construct and maintain engines and machines or structures such as roads, railways, and bridges (Collins English Dictionary, 2017b). The key words associated with engineering is therefore designing and constructing. *Mathematics* is the study of number, quantity, shape, and space and their interrelationships by using specialized notation (Collins English Dictionary, 2017c). The related areas of study include algebra, geometry, trigonometry, and calculus. Figure -1 below illustrates the simplified conceptual frame of STEM fields.

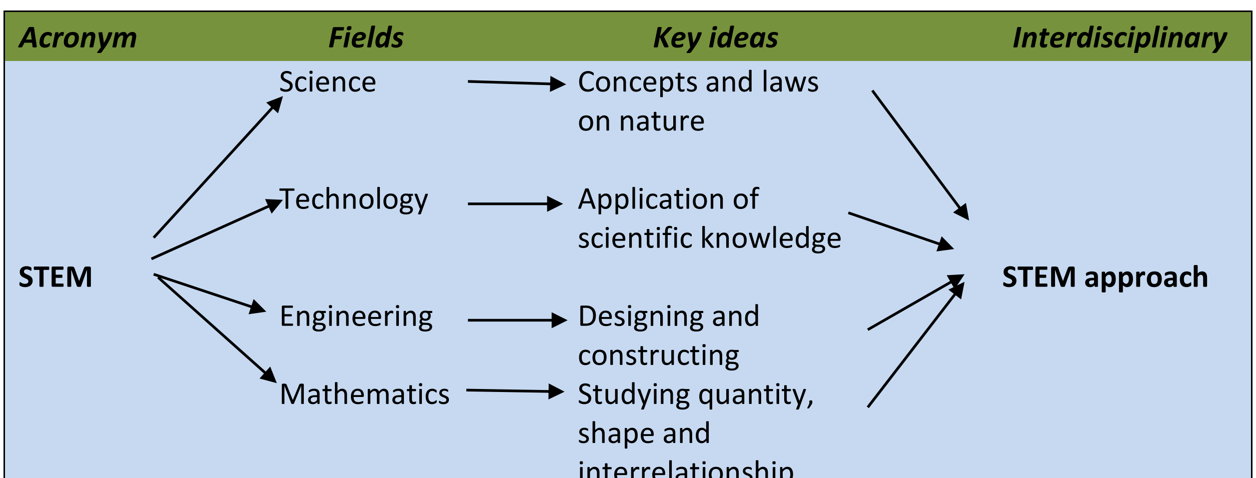

Figure - 1: Conceptual framework of STEM fields

However, STEM can be viewed from different perspectives, such as an amalgam of several school subjects, as a pedagogical approach, or as a set of practical skills (CDD, MOE Malaysia 2016). As an amalgam of traditional school subjects, STEM encompasses all science and technology subjects including science, mathematics, information communications technology (ICT), engineering and agriculture. These subjects may be clustered or packaged together and offered to students to prepare them for their choice of a STEM career. STEM as a pedagogical approach refers to a strategy of teaching and learning which applies STEM knowledge, skills and values to solving problems in the context of everyday life, community and societal issues. This approach requires students to inquire, explore, solve problems, and make decisions to develop all-round STEM knowledge and skills. STEM knowledge comprises facts, ideas, concepts, principles and theories in STEM disciplines, for examples, science concepts and mathematical theorems are examples of STEM knowledge. STEM skills include science process skills, science manipulative skills, computational thinking skills, mathematical process skills, engineering design thinking skills, ICT skills and other specific technical skills that are related to acquire the abilities and competencies to explore, investigate and solve problems, and to design and produce products. Stem values and ethics consist of the ethical guidelines, scientific attitudes and moral values. Examples of STEM values and ethics are rational thinking, objectivity, precision, risk-taking, persistence, commitment and adherence to laboratory rules and safety measures(IBE-UNESCO, 2017). The focus of STEM education is to engage students on scientific investigation and exploration as well as problem solving and innovation. Emphasis is on the importance of establishing classroom learning with real-world connections.

3. Challenges of Implementing STEM in Classroom Teaching :

In the STEM fields, Science and Mathematics are most recognizable in their curricula which most people can relate to in terms of academia. However, “E” and “T” in STEM, that is, Technology and Engineering are the fields that are most underrepresented as school subjects, having gaining their importance only in the recent modern era. Many educators, certainly most of the classroom teachers, who are not in the fields of Engineering and/or Technology are intimidated with processes that are associated with them. Although Engineering is a recognizable terminology that most educators and teachers can somewhat relate, many who are not in the field(s) are not sure what engineers actually do in terms of education. Many consider Technology as just a computer related field (White, 2014).

In STEM education, the four disciplines are integratedinto a single curriculum adopting an interdisciplinary and applied approach. Amalgamation of STEM provides a cohesive learning paradigm based on real-world applications. However, the challenge to the classroom teachers is: how do they interpret and integrate STEM into their instructions? And, in this study, to what extent a zero waste project in a Thai school can help its teachers comprehend better the STEM approach in classroom instruction? This Zero Waste Project will have to narrate from King Bhumibol's 'Sufficiency Economics' theory.

4. Thai King's 'Sufficiency Economics' Theory

In 1997 when Thailand suffered its worst economic crisis, the late Thai King Bhumibol Adulyadej came up with 'Sufficiency Economics' theory, based on Buddhist principles to help alleviate the suffering of his people. His Royal highness initiated more than two thousands development projects aimed at improving the living conditions of his subjects, particularly those in the remote rural areas. His theory is basically on land management and the development of water sources for agricultural purposes. The 'New Theory' is a simple formula of'30-30-30-10'. Under this theory, a plot of land is to be divided into four portions, namely 30 percent for a water source, 30 percent for a rice field, 30 percent for mixed crops such as fruit trees and vegetables and 10 percent for residence, animal farms and rice barns (Lim, 2016).Farmers who followed the 'theory' found the plan could be implemented without much complication and did not have to use costly technology. Consequently, large sections of the farming communities tried and produced satisfactory results, and became self-sufficient and self-reliant. This was what the King suggested that a self-sufficient economy would enable all Thais to live a life with enough to eat, while relying on their own economy. In a sufficient economy, in line with Buddhist values on 'simplicity', generation of material wealth is not the ultimate aim in life. Instead the final goal is to create environmentally healthy, self-sufficient communities in which basic human needs are met through local natural production methods (Lim, 2016). For example, in an area where soil quality was poor with little nutrients and too dry to provide growth potential for crops, the farmers started land revitalization project by creating environmental structures that retained natural water resources, namely from mountain springs and rain water. The rainy season was capable of providing sufficient water resources to support the needs of both a thriving forest ecosystem and local agricultural practice. As soil moisture increased, there was significant increase in farming harvests. The success of land revitalization convinced the rural communities that regeneration of soil nutrients do not necessarily depend on the use of expensive chemical fertilizers. These rural folks realized that natural fertilizers could be derived from, previously discarded, farming wastes such as dry leaves and decaying organic materials. By reusing and recycling these matters in the farming systems, nothing will be gone as wastage.

5. The Definition and Philosophy of Zero Waste:

The definition of zero waste commonly used is stated by the Zero Waste International Alliance as follows:

> *"Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health"*(ZWIA, 2014).

Briefly, Zero Waste advocates to maximise recycling, minimizes waste, reduces consumption and ensures that products are made to be reused, repaired or recycled back into nature or the marketplace. A 'whole system' approach must be adopted to eliminate the vast flow of resources and waste through human society (GRRN, n.d.). Recycling is apparently a powerful indication of Zero Waste on excessive consumption, waste, corporate irresponsibility, and the fundamental causes of environmental destruction. Zero Waste poses a fundamental challenge to 'business as usual'. But, the ultimate aim of Zero Waste is to eliminate rather than manage waste. As such, industrial and business systems must redesigns the current, one-way into a circular products modelled on Nature's successful strategies and not to 'use too many resources to make too few people more productive'. Zero Wastes should provide guideline to help communities achieve a local economy that operates efficiently, sustains good jobs, and provides a measure of self-sufficiency (GRRN, n.d.).

6. The School's Zero Waste Project:

The Zero Waste Project, which is the focus of this study, is situatedat the back of a school in a plot of land of about 1 hectare in size. The land is demarcated into 13 zones or stations, each showcasing a specific strand of 'zero waste' as shown in Table 1.

Table-1: The 13 stations in a school's Zero Waste Project

Station	Project strand	Purpose	Zero waste methodology
1	Studying Herbs (e.g. lemon grass, Asiatic pennywort, garlic…)	Cultivating several local herbs showcasing use for basic medicine and energy-saving in producing medicine	No chemical insecticides are used in the cultivation. Producing health drinks sold to students and visitors.
2	Organic Farming	Using organic fertilizers from dry leaves, grass and left over food for growing vegetables.	Learning teamwork and management skills. Gaining skills and experience in planting and caring of plants.
3	Feed the Soil and Let the Soil Feed the Plants	Feeding the soil and let the soil feed the plants by covering the soil with dry leaves, grass, and hay to preserve the moisture in the surface of the soil. Decomposing of organic matters become useful organic fertilizers of the soil.	The practice reduces and reuses natural organic wastes from dry leaves and grass, at the same time, recycle them through decomposition.
4	Growing Three Kinds of Plants	Showcasing three kinds of trees (names not available) that yields 4 benefits: preserving soil water, producing fruits, firewood and economic wood for construction.	Reduce expenses, reuse and recycle tree products.
5	Sufficiency Economy	Planted with different fruit trees, e.g. durian, chilli, tomato, basil, eggplant,	Practicing 3 Rs, reduce cost of buying food, organic matter reused as

		and onion.	fertilizer and recycling excessive or unsold fruits and vegetables as dry products.
6	Fertilizers using HRH Princess Sirinthorn's Formula and Application	Decomposing animal manure, dry leaves, and vegetable leftovers to serve as fertilizers.	Using animal manure and plant materials as fertilizer.
7	Triple Waste Water Treatment Plant	Three ponds collect waste water from canteen and other parts of school buildings. The clean water produced is use for watering the plants in the project area.	Reduce cost of water bill, waste water is recycled, and clean water is reused to water the garden.
8	Biogas Station	Gas produced by the decomposition of organic substances and anaerobic organisms.	Reduce methane gas emission to atmosphere, so help to reduce global warming. Reuse animal manure for alternative energy. Recycle animal manure as animal feed after extracting the methane gas.
9	Organic (enzyme) Water	Using lemon grass, basil and neem leaves to produce organic water to make insecticide.	Reduce the use of chemical insecticide. Reuse harmless plant parts sprayed with organic water, for example, use banana leaves as cups or food containers. Recycle organic water can also improve fertility of soil.
10	Cultivating Mushroom	Learning how to grow food. Gain supplementary food or income.	Reduce expenses to purchase mushroom. Reuse leftover mushroom as food for earthworms. Recycle leftover mushroom as fertilizer.
11	Feeding Earthworms with Organic Waste	Cultivating earthworms and at the same time get ridof organic waste.	Reduce organic waste (e.g. fruit peels) by feeding it to earthworms. Reuse excessive fruit peels to produce EM (effective microorganism) water.
12	Recycled Waste Bank	Separating different types of waste into specific categories.	Reduce throw-away garbage to landfill. Reuse materials to create new products or useful things. Recycle some materials to re-generate products.
13	Charcoal Kiln	Making charcoal from tree branches.	Reduce wasting natural materials. Making charcoal from tree branches as fuel.

Source: Zero Waste Project, Saint Joseph Thare School, Thailand (unpublished report)

7. Research Methodology and Sample :

This research study adopts focus group's interview method to collect shared understanding and views on STEM education from several individuals in specific groups based on the various components of a school zero waste projects. The process is not just between interviewer and the group of interviewees. Rather, the reliance is on the interaction within a group who discuss a topic supplied by the researcher yielding a collective rather than an individual view (Morgan, 1988: 9). In the formative stage, the participants interact with each other rather than with the interviewer, so that the view of the participants can emerge. In other words, it is from the interaction of the group that leads to data and outcomes, usually on a specific issue, theme or topic (Cohen, Manion & Morrison, 2011).However, for the data generated from the focus groups to be useful and reliable, the interaction between individuals must lead to a shared understanding of the question(s) posed by the researcher. Hence, when conducting focus groups it is important to ensure that all participants have their say and to nurture a group agreement to take turns, that is, participants should understand that the focus group is a group-sharing activity ad not something to be dominated by one or two participants (Gay, Mills & Airasian, 2012).A researcher can pose questions to the group and encourage all participants to respond, use a structured or semi-structured interview schedule. To provoke active responses from the group member, the researcher may adopt the 'basketball' or 'pingpong' questioning style, that is, ask the question, elicit a response, and pass it off to another participants (i.e. basketball); or ask the question, accept the response, and ask another question (i.e. ping-pong). Either way, the researcher must ensure that all group participants have an opportunity to respond (Gay, Mills & Airasian, 2012). Since the data are collected from the insights and shared opinion of the group, participants should be empowered to speak out in their own words (Morgan, 1988). In this study, the thirty-six teacher participants are divided into six groups of six members each. Each group was free to choose a station in Zero Waste Project site to investigate how the particular site practice 'zero waste' strategy to conserve natural resources by means of 3Rs (Reduce, Reuse, and Recycle) approaches. The researchers posed two *research questions* to each group as follows-

(1) What are the STEM components that can be identified in the specific station of the Zero Waste Project site?
(2) How do you propose to use the specific station in the project site to conduct a typical STEM lesson?

Every group then visited the project site and chose a specific station for their investigation. They studied the station of their choice and also enquired the students on duty about how each station was operating. After diligently observed the station and engaged in situ discussion to clarify and interpret in the connotation STEM education, the participants then came back to the workshop venue, seated together and cooperatively drafted a poster displaying diagrammatic presentation of their shared perception of STEM education. Each presentation was typically consisting of three parts in this focus groups discussion (Fraenkel, Wallen, & Hyun,2015) inclusive of question-response session. The oral presentation process is illustrated in Figure 2, and Figure 3 provides two photographs to illustrate the presentation process.

1 Opening part
- Focus group facilitator/researcher welcomes the group, and explain that purpose of the presentation is for the group is to share their perception of STEM education based on the station (that they had studied) at Zero Waste Project .
- Group coordintor introduces members of the group.

2 Middle part
- Participants in the group collectively, but speaking individually, to answer the main research questions.
- They may complement each other in presenting their shared conception to other participants.

3 Closing part
- Group coordinator inviting questions from the floor for further deliberation and clarification.
- Workshop facilitator thanking the group and debriefing workshop participants or even inviting comments from the floor.

Figure- 2 : Procedure for the oral presentation of shared perception in focus groups discussion

A) **Focus group on Sufficiency Economy**

B) **Focus group on Waste Water Treatment**

Figure- 3 : Focus groups engaging in group-sharing presentations

8. Data Analysis and Summary :

The diagrammatic presentations by the six focus groups on their respective perceptions and understanding of using the a particular station or strand in the school's Zero Waste Project for incorporating into STEM approach in their classroom instruction is summarized in Table 2. The table also encompasses each group's views verbally expressed during the interview and discussion.

Table- 2 : Summary of data presented by each focus group

Group	Science	Technology	Engineering	Mathematics
A **(Station 1: Herbal plants)**	Cultivation of herbal plants- uses and application	Sprinklers and bamboo frames	Station construction.	Saving time, space, money and others
B **(Station 11; feeding the soil with organic fertiliser)**	Culturing earthworms, type, anatomy, soil, food and temperature	Research data from Internet, YouTube, Google; create manual showing benefits	Design bedding, barn and transferring mucus and urine.	Waste from cow, coconut fiber, waste from fungus concentration; calculation of volume and area.
C **(Station 2: Ground cover)**	Soil cover with dry leaves, grass, and hay, plus vermin-compost and water. Reduce waste.	Organic fertilizer from decaying matter and vermin-compost. Sell fertilizer online.	Clear surface weeds and loosen the soil, add water and vermin-compost, cover surface with organic matter	Save-cost calculation
D **(Station 5: Sufficiency economy)**	Explore plants that can coexist or complementary in soil fertility conservation	Using organic fertilizer	Package products and create attractive logos	Calculating market price and profit.
E **(Station 12: Waste bank)**	Concepts of reuse, reduce and recycle. Examples of each: cloth bags, plastic bottles and recycling old papers	Selling used materials online (e.g.old papers)	To make different designs and uses of the materials	Calculations to show the cost-saving advantages of 3Rs comparing to using new materials.
F **(Station 7: waste water treatment)**	Water treatment ponds and role of each of the three ponds	Applying concepts of sedimentation, aqua planting and reservoir	Designing and making 3-pond system and improvised aeration (old bicycle parts)	Volume of water recycled; cost-saving in recycling water.

9. Results Interpretation and Discussion:

Looking at Table 2, it can be seen that Group F had attained meaningful understanding of multi-disciplinary approach in STEM education by integrating science, technology, engineering and mathematics into one subject in harmony. Scientific knowledge of waste water treatment, whether using chemicals (not in this project) or microorganisms and aquatic plants(used in this project), is applied in the technological method in cleaning waste water in the carefully designed and constructed 'digestive' ponds based on engineering principles. Mathematics was an integrated component in calculating size and quantity of water being to be treated and effort in cost-saving. Groups A, C and D exhibited basic understanding of technology in STEM education, whereas Groups B and E viewed technology as the software and hardware of digital inventions. In the engineering components, all the groups, except Group D, had regarded it as to 'design' and 'construct', albeit short of elaboration to indicate deeper comprehension of the term. However, the contrived nature of focus groups interview is both their strength and weakness. Since discussion is very focused on a specific issue, the outcome of which is limited, yielding definite insights (Creswell, 2005). Hence, this study could yield limited responses. Furthermore, in this study limited time was allocated to collect information, and thereafter group members had to quickly discussed and agreed on a common understanding.

10. Conclusions:

This study showed that all the focus groups were generally able to identify the STEM components in their respective stations in the Zero Waste Project, although some groups were not definitive about *technology* aspect, overlapping with the area on *engineering*. However, all the focus groups were aware that STEM education necessitates the integration of science, technology, engineering and mathematics in multidisciplinary approach in classroom instruction. In the focus groups interview, they attempted to explain the use of the various components of the specific station in the project site that could be adopted to conduct STEM lesson. As such, it appeared that the Zero Waste Project was beneficial in gaining basic understanding of STEM education. However, since *STEM education* and *zero waste* are rather new terminologies borne out of recent times, they are not necessary the best in a correlated study as in this research. Nevertheless, it might be interesting to do a comparative study of using other projects that could promote STEM education

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