STEM Education Teaching approach: Inquiry from the Context Based

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Abstract. This study aimed to develop theoretical framework for STEM teaching strategies in school setting. The paper clarified what the worldwide leaders and educators’ beliefs, focuses, and actions of STEM education; what the conceptions of STEM education should be provided for teachers; Suggested STEM education teaching in aspect of practicing knowledge in real world through STS approach, concept of technology and engineering reserved for STEM education; the implementation of Yuenyong (2006)’s STS approach for enhancing students’ applying scientific and other knowledge for designing the solutions in real-world problems. Based on these literatures, this paper will propose the practical idea of STEM education teaching approach which integration key concepts among problem based, project based, inquiry, design, and a real world problem solving as STS. The paper, therefore, propose the theoretical framework of STEM education teaching approach as inquiry from the context based. The teaching approach consists of 7 stages. These include (1) Identification of social issues, (2) Identification of potential solution, (3) Need for knowledge, (4) Decision-making, (5) Development of prototype or product, (6) Test and evaluate the Solution, and (7) Socialization and completion decision stage. The paper discussed more details of each stage.

Keywords: STEM education, pedagogy, context based

1. Introduction

STEM education has been pushed to improved education in the early twenty-first century. Obviously, international concerns for advancing STEM education have increased in recent years. Not only educators but also policy developers, non-government organization, and business and industry organization are stressing the urgency for improving STEM skills to meet current and future social and economic challenges. There are many concerning with the STEM education in shaping innovation and development. Innovation and production of agriculture, industrial, military, and consumer products are the strength of the nation economics. This push the policy of many countries continues under the orientation of STEM education. In the USA for example, the 2013 reported from the Committee on STEM Education stressed that “The jobs of the future are STEM jobs,” with STEM competencies increasingly required not only within but also outside of specific STEM occupations [41]. This showed the needs of developing competencies in the STEM disciplines. To do so, the goal of education systems have driven to prepare the future STEM workforce. Another reason of pursuing STEM education is being emphasized is because of the lack of student achievement in STEM subjects [22], as determined by their low rankings on TIMSS (Trends in International Mathematics and Science Study) assessments (IAE 2011) [20]; [46].
However, the leaders and educators in each country held the varied beliefs, focuses, and actions of STEM education. These included [7]; [8]; [10]; [23]; [26]; [31]; [46]; [48]; [54]:

- STEM educational reform,
- preparing for STEM workforce and STEM literacy,
- structuring STEM as a track of school curriculum,
- providing a broad range of content and practices such as:
  - specific STEM subjects – integrative STEM,
  - integrate STEM into single courses,
  - merging the content of science and technology education,
  - the development of engineering programs into schools,
  - integrating engineering content into science, technology, and mathematics education,
  - additional applications of computer science into the K-12 curriculum
  - Adding art to form STEAM
  - a STEM project-based,
- exploration of different teaching strategies for STEM such as:
  - STEM team teaching
  - Teaching STEM through a real-world problem solving,
  - proposed a national STEM education strategic approach,
  - exploration of new curriculum and methods for delivering STEM concepts,
  - communications about careers needing different levels of STEM knowledge and abilities
- teacher preparation for STEM education teaching approach such as:
  - STEM education teacher training
  - providing materials for STEM teachers
  - Partner organization for STEM in primary and secondary school levels

Internationally, there are some movements for STEM educational reform. There were found that many foundations have been established by government, schools, and enterprises to foster STEM education and communications. The new ways of integrating content and practices among technology, engineering, science, and mathematics were organized. This generates the principles to enhance student learning of complex concepts. The hands-on nature of this school subject has allowed for learning to become conceptualize knowledge for students and brings it into real world uses. It has much to offer to the STEM educational reform efforts. In France, for example, the La Main à la Paête program (asking for collaborative hands-on work) is an inquiry-based project that aims to teach young students scientific concepts and procedures using innovative STEM teaching methods. The Sciences à l’École (Science at School) project is another supported by the French government. It has worked to encourage project-based learning programs and scientific subjects at the post-secondary levels (colleges, vocational schools, and preparatory classes). It developed multidisciplinary programs to promote educational innovation to increase linkages with scientific vocations. These initiatives have become core activities to promote STEM educational reform in France. Its programs have focused on the cultural dimensions of science in the curriculum, connecting knowledge within societal contexts, and establishing linkages between real-life problems and industry [46]. In England, STEM education reform has been aligned to two main objectives: (a) the flow of qualified people into the STEM workforce and (b) STEM literacy for the general population [18]. In Scotland, the Science and Engineering Education Advisory Group (2012) offered recommendations for STEM educational reform. The advisory group has focused attention on the separate STEM subjects. A report from Australia revealed establish national STEM education policies and curriculum programs in Australia and some strategies of Australia’s STEM educational reform [31]. Like Thailand movement, many government organizations (e.g. IPST and OBEC), schools, universities, and private sectors provided some teacher training and materials for STEM education. STEM education have developed strategic national STEM policy framework which provide positive conditions for variety of activities. These
included centrally driven and funded STEM programs of MOE, IPST, and others; and initiatives and partnerships and engagement (Chevron, EGAT, and others) that link STEM activities in schools, vocational and higher education with industry, business and the professions [24]; [33]; [14]. This could conceptualize also STEM educational reform [61].

The preparations of STEM workforce and STEM literacy were developed. STEM education should not focus only on students who are going to choose STEM careers but also all needs to interact natural and material setting with at least a set of knowledge, skills, and attitudes involving STEM. The preparation for STEM workforce involves multidimensions of students, STEM concepts, skills, ways of thinking, the 21st skills, and attitude towards STEM careers. [12]; [40]. For example, in England, the curriculum provided clear vision of STEM as two main objectives (1) the flow of qualified people into the STEM workforce and (2) STEM literacy for the general population. Some countries hope to increase the number of students who elected to study STEM majors while in college and then transition into the future STEM workforce, while others hope to improve the methods teachers use to present STEM subjects to their learners and increase students’ understanding and use of this knowledge. In Taiwan, science and technology was combined as a learning area for junior high schools. This was done to help students experience the relationships between science and technology and how this knowledge is integrated in business and industrial practices [46].

The view of studying science and technology research have emphasized on the integration among disciplines for decades. The key driver of the future economy and concomitant creation of jobs will be innovation, largely derived from advances in science, technology, mathematics and engineering (STEM) [40]. The STEM workforce is a powerful component of this innovation pipeline. The jobs of the future are integrally STEM driven and the foundation of STEM knowledge student receive has been directly linked to the prosperity of the country [50]. Structuring STEM as a track of school curriculum is another issue that some countries tried to prepare STEM workforce and action on the STEM education. For example, in the Philippines, the department of education approved the K-12 track series in year 2013. There are four tracks including Academic, Sports, Arts and Design, and Technical-Vocational-Livelihood tracks. Four different strands fall under the Academic track: Accounting, Business and Management (ABM) strand, Science, Technology, Engineering and Mathematics (STEM) strand, Humanities and Social Sciences (HUMSS) strand and the General Academics strand (GAS). Through the STEM strand, students will get to learn the basics of STEM-related disciplines such as Calculus, Biology, Physics and Chemistry. Students will get an overview of the foundation of most STEM fields which basically deal with several branches of physical, Earth and life sciences, and pure and applied mathematics. And, a future career of students in STEM stand is about bio researcher, engineer, microbiologist, statistician, programmer, software developer, database administrator [57].

It seems that the concept of STEM education covers a broad range of contents and practices. Literatures suggested that STEM can become a multidisciplinary approach to learning that can be used to integrate knowledge from the separate STEM subjects into existing science, technology and engineering, or mathematics instructional programs using project-based learning, engineering design-based studies, or problem-based learning strategies. Many policy discussions of STEM have focused on the improved teaching of separate subjects, especially those of science and mathematics [10].

It is believed that developing engineering programs or integrating engineering content into science, technology, and mathematics education will enhance students’ learning and interest in STEM subjects. Some countries have experimented with the development of engineering programs for their schools in an effort to bring context to science, mathematics, and technology content. Other nations are integrating engineering content into technology education curriculum (e.g., Canada, Sweden, United States). For examples, the Next Generation Science Standards (NGSS) has integrated engineering design concepts and activities into its structure for future K-12 science education programs [42]. Project Lead the Way (PLTW 2014) courses were designed to promote engineering careers and STEM learning at the K-12 levels. Engineering by Design, which was developed by the International Technology and Engineering Educators Association’s STEM Center for Teaching and Learning, is a
standard-based curriculum for technology and engineering education, which integrates mathematics and science standards content into technology and engineering courses for the K-12 levels [46]. Another example in Thailand, IPST and OBEC enhanced teachers to provide the engineering design process into science, technology, and mathematics education in order to support students to learn STEM education [61].

In some cases, STEM has incorporated technology and engineering into its framework as a means to show how scientific applications can be incorporated within science and mathematics lessons [54]. Some countries have merged the content of science and technology education (e.g., France, Israel, The Netherlands; [35]). And, Thailand also just merged the content of science and technology education in the year of 2018 [25]. In Taiwan’s most recent planning for K-12 compulsory education, technology education will be separated from science in the curriculum. In the new plan, technology education will be combined with information technology, thus creating a new learning area [39]. The Israeli government is encouraging additional applications of computer science into the K-12 curriculum. It established a 260-h course for all students and an in-depth study (450-h course) for those who express interest in further study of computer sciences. The Israeli curriculum includes both theoretical material and hands-on applications within their computer science courses [2]. The Korean education system combined the subjects of science, technology, and home economics as one learning area in 2011. The arts were added to STEM to restructure the Korean curriculum and it now encompasses these subjects to form STEAM [26].

And, some see it taught as a new integrative subject labeled as STEM. In this interpretation, educational practices would use multiple STEM subjects and integrate these into single courses. This is known as integrated or integrative STEM [38]; [47].

Internationally, there are explorations of strategies for STEM teaching such as communications about careers needing different levels of STEM knowledge and abilities, teaching STEM through a real-world problem solving, proposed a national STEM education strategic approach, exploration of new curriculum and methods for delivering STEM concepts, and STEM team teaching. In UK, for example, the ASE website provided some information and activities to communicate STEM careers. These include providing information of rotes into STEM careers, career profiles and interviews with STEM professionals, STEM learning careers posters, STEM ambassadors, STEM insight and so on [5].

There are many proposed STEM education strategic approach. In Australia, the Australian Academy of Technological Sciences and Engineering developed an innovative STEM program (The Science and Technology Education Leveraging Relevance) that addresses the problems within secondary school level science and mathematics education. Meanwhile, the Office of the Chief Scientist (2013) also proposed a national STEM education strategic approach. This approach emphasizes four essential elements (Education, Knowledge, Innovation, and Influence) in STEM education [31]. In UK, the National STEM Centre in the United Kingdom was established to provide a wide range of high-quality support materials for STEM teachers and to explore new curriculum and methods for delivering STEM concepts to students [7]. In France, proposed the STEM education programs which focused on the cultural dimensions of science in the curriculum, connecting knowledge within societal contexts, and establishing linkages between real-life problems and industry [46]. In Thailand, some government and non-government agency proposed some STEM strategic approach. They provided some strategies of inquiry or solving problem with a little bit different steps of teaching. For example, IPST proposed the engineering design process including Identification, Related Information Source, Design, Planning and Development, Testing, Evaluation and Design Improvement, and Presentation. And, the EDP of OBEC STEM consists of 9 steps including (1) Identify the problem, (2) analyzing five capitals, (3) explore information, (4) knowledge sharing, (5) model solution, (6) planning and development, (7) testing and evaluating the solution, (8) present the solution, and (9) reflection and revise [61].

Some cases organized the integrated learning activities as the ideas of STEM team teaching. For example, in China Beijing’s Yew Chung International School teachers provided team teaching. The
team teaching includes classes in science, mathematics, geography, and other subjects. Strategies used for teaching mathematics have one teacher explaining step-by-step procedures in English, while the second teacher shows students shortcuts for solving the same problems through the Mandarin language. These strategies have resulted in better understandings by students and higher student test scores [2].

Teacher preparation for STEM education has been also considered. For example, in UK schools, Bell (2012) found that STEM has not had the impact that was planned. Many teachers are unaware of the existing STEM endeavors and are unsure of the contributions they can make for students to better understand and learn STEM subjects. Some organizations and ministries of education have developed educational materials to assist teachers in instructing from a STEM perspective. The ASE (2010) provided the STEM learning website which suggested good resources and ideas of STEM education. The ASE suggested resources of science learning and practicing through the SATIS revisited version. This version was has updated and revitalized the groundbreaking SATIS (Science and Technology in Society) units from the 1980's and 90's. The units provide a wide range of strategies to cover the program of study for How Science Works and the wide spectrum of science. Materials consist of bright stimulus visuals, student activities including research, discussion, role plays, quizzes and board games with background information sheets to suit a wide range of student interests and abilities. They also contain guidance for teachers and an overview of the science considered. Another example, in Thailand, the government organizations have pushed the projects to prepare STEM teachers across the nation. The STEM professional development projects have been provided for in-service teachers by many organizations such as the institute for the promotion of teaching science and technology (IPST), the office of basic education commission (OBEC), the ministry of energy, the Electricity Generating Authority of Thailand (EGAT), the chevron enjoy science project, and the schools and universities STEM education projects. These projects could provide approximately 5,000 teachers (in the year of 2017) who could generate the learning activities through integrating knowledge, concepts and skills systematically as STEM education [61]. There are some suggestions of partner organization for STEM in primary and secondary school levels. The Partners in Research (PIR) has also broadened its programs to implement science, technology, engineering, and mathematics education at primary and secondary school levels [27].

As above mentioned about a boarded view of perceptions, beliefs and actions on STEM, this paper may share some ideas based on those STEM education review. This paper will share an approach for STEM teaching and learning. But, the paper will focused on how teachers may provide some kinds of STEM learning activities in the single subjects as the integrated STEM. The paper will propose the framework of STEM pedagogy. The ideas of proposing STEM teaching approach are about enhancing students’ to apply science, mathematics, technology, and other knowledge for finding solutions or products through inquiry from the context based. In order to provide some theoretical framework, the concept of STEM teaching and learning and suggested ideas for literatures about related to STEM will be clarified.

2. Suggested ideas of STEM teaching and learning
What should the conceptions of STEM education be provided for teachers? It found that descriptions of what comprises STEM content and practices and what STEM conceptions look like range in the literature, especially conceptions of STEM education [9]. However, there are three consensus issues of discussion about STEM education including (a) instructionally (b) as a set of integrated or interconnected disciplines, or (c) as more dependent on the stakeholders or context in which it is viewed or conceptualized. For this study, we will hold Moore et.al. [36] definition of STEM education for enhancing teachers. They define it as “the teaching and learning of the content and practices of disciplinary knowledge which include science and/or mathematics through the integration of the practices of engineering and engineering design of relevant technologies.” To them, five characteristics distinguish integrated STEM instruction from other teacher pedagogy: (a) the content
and practices of one or more anchor science and mathematics disciplines define some of the primary learning goals; (b) the integrator is the engineering practices and engineering design of technologies as the context; (c) the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through design justification; (d) the development of 21st century skills is emphasized; and (e) the context of instruction requires solving a real-world problem or task through teamwork. This conceptualization of STEM is grounded in learning research [61].

It seems that the engineer design process was widely recognized for STEM education. Engineering can act as a connector for meaningfully learning the content of mathematics and science [37]. Engineering design has been treated as a pedagogical strategy to bridge science and mathematics concepts in use of solving ill-defined (open-ended) problems, developing creative thinking, formulating solutions and making decisions, and considering alternative solutions to meet a variety of constraints [53]; [56]. Engineering requires the use of scientific and mathematical concepts to address the types of ill-structured and open-ended problems that occur in the real world [52]. Using engineering design as a context for these problems is a natural way for students to learn through STEM integration. Using engineering contexts as spaces for students to develop real-world representations can be the catalyst for developing related scientific and mathematical concepts through using multiple representations (concrete models, pictures, language, and symbols) and facilitating translations between and among them [37]. The engineer design process was also introduced in Thailand by government agencies. For example, the EDP of OBEC STEM consists of 9 steps including (1) Identify the problem, (2) analyzing five capitals, (3) explore information, (4) knowledge sharing, (5) model solution, (6) planning and development, (7) testing and evaluating the solution, (8) present the solution, and (9) reflection and revise [61]. In Malaysia, the application of engineering design process in the module is based on the five cycles as; (1) ask, (2) imagine, (3) create, (4) test, and (5) improve. The application of STEM content knowledge during the design processes will be the key component of students’ learning in solving engineering-based problem. The context of instruction requires solving the real-world problem or task through teamwork [50].

Another conceptualized idea of teaching and learning in STEM education was suggested by Williams (2019). He provided some practical ideas of STEM teaching and learning which focuses on processes and engagement of students in collaborative activity. He discussed that the principles of teaching and learning in STEM Education: (1) involves the integration of science, technology and mathematics, (2) is student centred, (3) engages students in collaborative activity, (4) focusses on processes, (5) occurs within the curriculum (is not extra-curricular), and is project and/or problem based.

STEM education teaching and learning should focus on the processes that could be provided as a way of structuring student activity. These processes included problem based, project based, inquiry, and design. The processes will engage students to generate ideas, research and investigate, evaluate, model their ideas, identify needs, solve problems, document what they do, and communicate. It is through engagement with these activities that students will learn not only crystalized knowledge but also get to practice the important fluid skills they need for their future [55]. Therefore, teachers may foster students not only strongly hold crystalized knowledge which mentioned already in curriculums, books, or facts; but also support them to develop the fluid skills which need to think flexibly. In order to be success on finding solutions or developing prototypes or products, students may develop also some fluid skills such as creative thinking, cooperation in group working, time management, communicate and convince to people, and so on.

Williams (2019) also reminded some implications when students move on the processes of doing STEM activities. STEM education should focus more on process rather than content. The STEM education important learning occurs through the activities of the process. However, content could be applied when the learning of content is necessary through an activity to a situation. A focus on the activities of a process will also enable students to learn from failure. Therefore, teachers should not expect too much too soon from students. It will take time for them to get used to this complexity, and
the progressive development from a simple approach to something more complex (and therefore more realistic) takes many years. There are skills involved in what we require of students as they progress through these stages and these skills need to be taught. Therefore, it is not only teaching about content based curriculum but also procedural knowledge. So each STEM project may have a focus on the development of a particular procedural skill, and over time students develop this repertoire of skills. STEM activities are diverse; even within one particular focus such as design processes, there is much diversity. The process can begin and end at different places. An inquiry approach may begin with an environmental problem, a design approach may begin with a product, a problem based approach may begin with a problem. The conclusion or goal of the process may also vary: a project based activity will usually conclude with a prototype, but an inquiry approach may end with a presentation.

In view of teaching, STEM education is teaching for learning. So, STEM education should not be some teaching is to get through the curriculum or to ensure students achieve well in an examination. Therefore, student center need to be considered in STEM learning activities. Students need more scaffolding as they progress through various activities of a process. This requires smart teaching, by ensuring the more naturally creative students have the flexibility to be creative in their pursuit of solutions, while other students, who are not sure what to do next, are provided with the support and directions they need [55].

To enhance students to learn in STEM education, the activities are engaged in a STEM process. The importance thing is the moving students back and forth between their thinking and doing. Students will begin by thinking about a problem or issue or need, and then in order to progress their thinking, they do something with that idea. As they test their idea by talking to others, sketching, modelling, etc., the idea is refined, enhanced, clarified or validated. This back and forth between thinking and doing is the way that procedural progress is made, and the extent to which it is facilitated, increases the potential of more sophisticated solutions and higher order thinking. The role of the teacher then becomes the facilitation of the transition between thinking and doing, allowing students time to think, and allowing them time (and structuring activities) to act on their thoughts [55].

3. Suggested Ideas of Context based inquiry as STS approach
Regarding on the conceptions of STEM education, the literatures indicated that STEM teaching and learning involved the integrator is the engineering practices and engineering design of technologies as the context; the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through design justification; and the context of instruction requires solving a real-world problem or task through teamwork [55]; [61]. And, it should focuses on the design processes that are much diversity. The STEM teaching and learning should provide an inquiry approach that may begin with an environmental problem, a design approach may begin with a product, a problem based approach may begin with a problem. Then, the related contents (e.g. science and mathematics) content could be applied when the learning of content is necessary through an activity to a situation [55].

Another view of Science technology and society (STS) is a teaching approach to enhancing students’ practicing knowledge in real world. The STS allows students to learn science through solving problem and scientific inquiry from related to societal issues or technological issues or products [62]; [59]. In UK, an example of introduce STS for STEM education, the ASE (2010) suggested the STS unit called SATIS (Science and Technology in Society) units in the UK STEM learning website to assist teachers in instructing from a STEM perspective. The SATIS revisited version was has updated and revitalized the groundbreaking SATIS units from the 1980's and 90's. The units provide a wide range of strategies to cover the program of study for How Science Works and the wide spectrum of science. Materials consist of bright stimulus visuals, student activities including research, discussion, role plays, quizzes and board games with background information sheets to suit a wide range of student interests and abilities. They also contain guidance for teachers and an overview of the science considered.
The STS unit always engages students through the social issues or technological issues. Then, students could generate some problems or questions based on those issues. The unit, then, move students to learn science and other related knowledge with aiming to find some knowledge for developing the possible solutions and select the appropriated solution for their society. It seems that STS teachers required holding strongly understanding of concept of technology in order to balance science teaching by its nature and science teaching related to society. Regarding to the philosophy of STS, the T-technology provided strongly linking up between science and society (Yuenyong, 2018). To establish well STS teaching, the philosophy of technology need to be discussed a little bit more.

Ankiewicz and de Swardt (2006) clarified that regarding on Mitcham (1994)’ tension between the two uses of technology provided a narrow and a wide meaning in technology present discourse, which roughly coincides with the manner in which two professional groups, namely engineers and social scientists, respectively. The concept “technology” has mainly been reserved by engineers to refer to a direct involvement with material construction and the manipulation of artefacts. In the social sciences the concept “technology” also includes making material artefacts, the completed objects, their usages and to a limited extent also the intellectual and social contexts. Sometimes technology is defined in such a way that it includes making non-material things like laws and language.

Mitcham’s framework is now accepted to be a ‘point of reference’ in the field of philosophy of technology, consists of the four modes of the manifestation of technology: technology as object, technology as knowledge, technology as activity, and technology as volition [17].

Technology as object could be seen through the nature of technological artefacts which attribute to a dual nature – physical and functional nature. Artifacts have a physical nature such as length, weight, colour, structure, geometry, and so on. And, at the same time, artifacts have a functional nature; for example, some objects allow us to use them for a specific purpose. In fact the purpose of design can be described as finding a right match between these two. In other words, designers seek for realising objects that have a physical nature that fits with the intended functional nature. But users in fact also deal with the relationship between the physical and the functional nature when they seek ways to use the artifact [17].

Technology as knowledge can be differentiated according to various types of knowledge, for example maxim, rules, theories etc. [32]. There are two types of knowledge in technology including conceptual knowledge (“knowing that”) and procedural knowledge (“knowing how”). However, these two types of knowledge cannot be separated. Conceptual or descriptive knowledge relates to the links between knowledge items, implying that when learners can identify these links, we can say that they have conceptual understanding. For example, in the area of ‘gearing’ we hope that students will see the relationship among the ‘direction of rotation’, ‘change of speed’, and ‘torque”’ [34]. Conceptual knowledge relevant to technology therefore includes justification from other subjects such as science [17]. Procedural knowledge referred to as tacit, personal or implicit knowledge. “Design, modelling, problem solving, systems approaches, project planning, quality assurance and optimisation are all candidates for technological procedural knowledge ...” [34]. Simon (1969, in [3]) who linked classic design methodology with problem solving theories from computer science and psychology, summarised the essential design knowledge base for the training of designers. These included evaluation of designs (e.g. statistics), computational methods (e.g. algorithms – linear programming, control theory), formal logic of design, search for alternatives, theory of structure and design organization, and representation of design problems. However, procedural knowledge cannot be taught. It can be gained by thorough practice only [17].

Technology as activity (methodology), in particular, provides insights in the procedural knowledge in technology [17]. The activity, for example, includes designing, making, and using or evaluating [29].

Volition is another view of technology. Technological aspects, therefore, are skills to support people with their decision making. The understanding of what, why, and how ideas, design, systems, volition of application scientific knowledge and other knowledge (e.g., philosophical, sociological, political, economic, humanistic aspects and so on) work becomes key aspects of surviving in society.
[17]. For example, citizens have to make decisions about energy issues (e.g., energy use, saving energy, and pollution) that require technological ideas and understanding. This aspect of public rhetoric about science and technology becomes dominated by dichotomies like ‘chances and problem’, ‘advantages and disadvantages’, or ‘uses and abuses’ [60]. This view generated the relationship between technology and our human will. These include (1) technology support extension of the human body and mind; (2) technological impact on culture or society; and (3) technology depends on values (e.g., ethical and aesthetic values) [17].

Thinking about technology according to its impact on entities stretching outside its essential nature is frequently found: as the impact of technology on the environment and society, but also the impact of human values and needs on technology [15]. Technology as knowledge, the second mode in which technology is manifested, has most frequently been the subject of analytical investigations in the epistemology or theory of knowledge, according to Mitcham (1994, p. 192). An epistemological aspect frequently coming to the fore is the nature of the relationship between the technological knowledge and knowledge of the natural sciences. By taking particular social implications of technology into account, the Science–Technology relationship can be extended to the field of Science, Technology and Society (STS) studies. STS studies are grounded in socio-technological understanding, that is, systematic knowledge of the mutual relationship between technical objects, the natural environment and social practice. Because technology is a key element of STS, it is expected that the philosophy of technology (in particular the ‘volition’ domain; see the previous paragraph) will have implications for STS studies. The dynamic nature of technology as such leaves its own philosophy in a tentative or flexible state. However, the implications of the philosophy of technology, which is in a development phase at the moment and certain changes in emphasis occur, for STS studies ought to be determined continuously. By taking particular social implications of technology into account, the Science–Technology relationship can be extended to the field of Science, Technology and Society (STS) studies. Based on the philosophy of technology, it could be mentioned that the STS teaching provided students to apply science and other knowledge to solve problems of human needs. This way of thinking is related to engineers [3].

Based on the second author research experiences on STS, he suggested school science teachers provided STS teaching approach in 2006 that consisted of 5 stages including (1) identification of social issues; (2) identification of potential solutions; (3) need for knowledge; (4) decision-making; and (5) socialization stage. Those science teachers, who followed Yuenyong (2006)’s STS approach, had showed some results of enhancing students’ practicing knowledge in real world. The using of Yuenyong (2006)’s STS approach for science teaching allowed students using applying scientific and other knowledge for designing the solutions, and provided the context of instruction requires solving a real-world problem or task through teamwork. It also found that those of practicing of Yuenyong (2006)’s STS approach in school enhanced students to design some products, systems, rules, models, or volitions as possible solutions. These studies indicated that students could design methodology in technology which usually used by engineers (Klahan and Yuenyong, 2012). The examples of those studies could be highlighted as following.

Chantaranima and Yuenyong (2014) revealed how they enhance students’ analytical thinking to develop some prototypes or products for social issues. On the way of developing product, it revealed that students required knowledge of sound and others for designing. They reported the results of enhancing Grade 11 students’ analytical thinking ability in learning about sound unit through STS approach. The sound unit was developed based the five stages of Yuenyong (2006)’s STS approach. The STS sound unit enhanced students’ analytical thinking through learning about nature of sound and property from the social context of applying scientific and other knowledge for space mission. Identification of social issues in this unit provided students to identify issues or problems from the situation of “Mission Cronossa”. This event was assumed that it is about “a spaceship had fallen down to a planet named ‘Leonpha’ during a mission to survey the ‘Kronessa’ planet. There were several astronauts injured and died because they could not contact principal spaceship.” Supposing that they were aerospace engineers assigned to design some equipment to help people in the space by NASA,
students were challenged. The invented equipment must be able to send some noise in space. This situation was used to stimulate students to identify the problem aspects. Those students must know what the problems in creating the equipment to voice in space are. It was found that most of students could identify the cause of problem. They suggested that sound cannot be transmitted naturally in space because it is a mechanical wave (the wave depends on medium for travelling). In identification of potential solutions, students were working in group to find possible equipment based on their thinking criteria. And, students’ planning showed that they will arrange equipment by using external attributes and functions as criteria regardless the principle of inventing and function new equipment. Their ideas of inventing could be categorized into three categories including decorations, sound receiver or transmitter, musical instrument, clothes, animal-imitated equipment. The ideas about decorations included rings, watches, belts, dental braces pendant, bangle, and necklace. The ideas about sound receiver or transmitter included walky-talky and Bluetooth. The musical instruments included guitar and space flute. The ideas related to clothes are space helmet and space clothes. The ideas related to animal-imitated equipment is Gumbie 1 (dragonfly). Based on these ideas, students had to find out the appropriate reasons to support their design and invention and to convince friends to accept their own ideas. In need for knowledge stage, students learned about scientific knowledge – sound and property in order to find good reason of choosing the best equipment to develop a model. In decision-making stage, students can designate what they think it is an importance, and among them in the group must make the decision together and concern the followings (1) How can we build the equipment to send some noise in space? (2) What should the equipment look like? And (3) What can the equipment do? And, in socialization stage, students organized an exhibition displaying their model of helping equipment equipped with sound transmitter in space. In exhibition, students from each group had to explain to and discuss with audients attending the exhibition to understand what those students designed and invented, how they did it, and what benefits it can provide?

Another example, Klahan and Yuenyong (2012) reported the implementation of Yuenyong (2006) STS approach. The study enhanced Grade 12 students’ technological capabilities in teaching and learning about electromagnetics through science technology and society (STS) approach. Findings revealed that teaching and learning about electromagnetic wave through Yuenyong (2006)’s STS approach supported students’ model forming on technological process including designing, acting, and applying. The process of model forming generated students’ performances that could be indicated how they listed possible solutions for issues related to electromagnetic wave. Regarding Jones (1997), this process could explain students’ capabilities under three ways including (1) student response to the requirements of the technological activity; (2) the total process of students carrying out the technological activity; and (3) influences on that process.

Student response, the student response to the requirements of the technological activity was analysed using significant features including (1) proposing model or task, (2) reasons for choice of model or task, and (3) selected model or task. Data analysis found that students proposed various kinds of model or tasks depending on their interest. These models could be classified into three categories. These include (1) safety such as thief warning signal, weapon scanner, electromagnetic wave absorber; (2) gaining knowledge such as short film, radio program, and village radio; and (3) luxury devices such as wave losing weight set, lightening zip, control car toy for pet. Total process, analysis of total process of 6 student models reflected what their process of developing those models. Total process of students carried out the technological activity that could be categorized into 4 pathways. Influence on that process could be interpreted from applying scientific and other knowledge and skills while students were constructing models. These influences included students’ concept of electromagnetic, special knowledge and skills, culture of learning, goal of students’ learning, learning resources, and scientific equipment. The influences on that process usually affected the students’ pathways and achieving of constructing models [29].

And, some implementations of Yuenyong (2006) STS approach gave students chance to apply their scientific and other knowledge for problem solving in context of entrepreneurship. It revealed that students not only apply science and mathematics knowledge for solving problem of social issues but
also values, culture, designing/procedure knowledge, marketing, financial thing, commence, economic, law, and so on. It could be mentioned that the STS unit enhance students to get ideas of linking between their innovative ideas to entrepreneurship that required applying the innovation to bring the ideas to life. Entrepreneurship refers to the process of developing new business ventures, or growing existing ones. Central to this activity are entrepreneurs: innovative and risk-taking individuals who seek to bring about change and new opportunities, both for themselves and for the business communities in which they operate [6].

Ahmad and Seymour (2008) analyzed key definitions of entrepreneurship activity. They categorized three key definitions of entrepreneurship activity. These are: (1) the creation of innovative products and markets through transformation of resources [19]; [49]; (2) the emergence and development of new firms [30]; and (3) the pursuit of opportunity through risk taking and alertness to asymmetric information [28]; [51]. An entrepreneur can work in their environment to try new things, recognize opportunities, and serve new markets. This type of innovative activity, within an established organization, is known as “intrapreneurship” [44]; [48]. Intrapreneurship may result in the formation of a new organization; however, it can also generate new administrative techniques or strategies, newly competitive attitudes, and new products, services or technologies [4].

de Jong and Wennekers (2008) provide a comprehensive listing of intrapreneurial activities and behavioral attributes. The activities include “opportunity perception, idea generation, designing a new product or another recombination of resources, internal coalition building, persuading the management, resource acquisition, planning and organizing” (p. 2).

Chachiyo et.al. (2019) reported their study about developing fermented bamboo shoots STEM education learning unit through Yuenyong (2006) STS approach. It revealed that students provided knowledge about chemical reaction in the process products of fermented bamboo shoots (FBSs). In the FBSs process product, students also took in to account local values and culture, marketing, financial thing, and commence. The identification stage, the unit provided the issues of the OTOP product in Khon Kaen and situation of market need for FBSs. This social issue allowed students to search and think more about how to make FBSs in your context, family or community. Identification of potential solution stage, students worked in team to design/solve the issue how to ferment bamboo shoots and how to design the FBSs packaging. On the way of developing potential solutions, students have analyzed 5 capitals (Natural, Physical, Social/Technology, Human and Financial) to develop lists of possible solutions. Need for knowledge stage, students learned about chemical reaction in mystery box, experiment about chemical reaction, doing simulation through PhET, and doing exercise about chemical formula. Based these activities, students may get some information if the change of the Fermented substances cause a chemical reaction. In decision making stage, it’s time to apply students’ knowledge to make FBSs by themself, based on knowledge of Chemical Reaction, rate of reaction, and factors of reaction. To design some products and packages, students require considering not only chemical reaction but also culture, market, bamboo supply and species. ISAN culture is another factor of designing because ISAN people accepted some taste of FBSs and some ways of cooking FBSs. Bamboo shoot species and supply should be concerned based on ISAN culture. The market and logistics also may influence the product process. Regarding on many ISAN people stay overseas, the product process may consider how much temperature of freezing for long time of traveling. Students, therefore, came up with various ideas of the FBSs process and products. Socialization stage, students share their ideas in school exhibition where students could redesign for the complete FBSs products.

4. Conceptual framework of context based STEM education teaching approach
It was suggested from the literatures to provide teaching and learning on STEM education. Moore et.al. (2015) clarified five characteristics distinguish integrated STEM instruction from other teacher pedagogy: (a) the content and practices of one or more anchor science and mathematics disciplines define some of the primary learning goals; (b) the integrator is the engineering practices and engineering design of technologies as the context; (c) the engineering design or engineering practices related to relevant technologies requires the use of scientific and mathematical concepts through
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capital, and natural capital) to support their list of possible solutions. Students need to think of 5W+1H questions (What, Where, When, Who, Why, and How-how to) that depends on each group created by their own designing prototypes and/or products (innovations).

3) Need for knowledge stage, learning activities should provide related to what kinds of knowledge were raised by students in the identification of potential solution stage. Particularly, students’ scientific and mathematical knowledge should be provided as need for decision making on how to do alternatives and the best solutions. Learning activities should be organized regarding on nature of science and mathematics. Scientific and mathematical concepts have been formulated in many ways to help students to understand technology and social issues. The majority of them perceived that STEM education need to be provided as integration knowledge among interdisciplinary STEM in context. It’s expected, STEM concepts was formulated through activities of demonstration, centripetal, experiments, and inside and out-side inquiry STEM classroom to search-study, research and prepare themselves to present their all possible solutions, and try to make decision which one is the appropriated solution.

4) Decision-making, the stage is designed students to apply scientific and mathematical knowledge and others for an appropriated solution. Students should have chance to argue about science and mathematics related to technological and societal issues. Students will list the possible solutions each group of students presented their solutions and then select an appropriated solution regarding their justification. This stage guideline will help students to use all the knowledge and make decision that they got to solve real-life problems. And also sharing their result of searching, studying, researching and decision-making-what and why they choose this one as an appropriated solution. Students involves in making a decision on how to use and/or apply the knowledge and technology. This aspect public rhetoric about their problems/issues related technological and social issue. Students’ argumentation becomes dominated by dichotomies like ‘chances and problem’, ‘advantages and disadvantages’, or uses and abuses’. Students have to select between alternatives of solution by systematically comparing as many relevant pro’s and con’s as possible. Then, students’ ideas, designing, proposing system, or volition will be drawn or constructed. STEM education, teaching strategies as inquiry in context may be used discussion among students’ group, and brainstorming to allow students designing the prototypes and/or products (innovations). On the process of students’ designing, they need to be enhanced to develop their possible solutions, select the best solution, and construct a prototypes and/or products together to learn-inquires what and how to be appropriated problem solver in this situation/context.

5) Development of prototype or product, students’ on tasks of designing, will provide models, simulations or others for solving this problem lead to making their innovation regarding on their planning and designing, and presenting their prototypes and/or products. Teachers need to provide activities regarding on engineering design as design-based learning. STEM activity requires students who could integrate and support creativity within activity. Teacher guided, supported, and suggested each group of students to provide learning activities regarding on engineering process design (EPD). The conceptual framework of the EPD allowed them to develop ideas to enhance students solving problem and applying STEM disciplines and relate to other knowledge through problem based learning, socio-scientific issues, and STS approach. The learning activities of enhancing students to develop prototypes or products need to support students to linking between two types of knowledge in technology including conceptual knowledge (“knowing that”) and procedural knowledge (“knowing how”). Conceptual knowledge relevant to technology therefore includes justification from other subjects such as science and mathematics. Procedural knowledge referred to as tacit, personal or implicit knowledge. Design, modelling, problem solving, systems approaches, project planning, quality assurance and optimisation are all candidates for technological procedural knowledge.

6) Test and evaluation of the solution, students have to provide the methods, materials/equipment appropriate for proofing their prototypes and/or products. And also students will be asked to develop their ideas what and how to test and evaluation of the solution. Concept of the test and evaluation should be provided concerning on science and mathematics knowledge, human needs, business and
industrial practices. The learning activities may remind students to provide the test and evaluation to make sure about “Is it working?” planning and designing, and prepare good presenting about what and how your prototypes and/or products its’ effective? Students may apply science and mathematics for doing experiments, providing mathematical models and simulations. The hands-on activities and/or experiment to convince teacher and their friends should not only provide inside but also out-side-classroom/school as inquiry in context. They may provide some story such as short films or storytelling to test or proof for human needs, business and industrial practices.

(7) Socialization and completion decision stage, as inquiry the end with a presentation, students presented their process of their planning, designing and making innovations, they have to share their prototypes and/or products (innovations). The stage is designed to allow students to validate their values and STEM knowledge for solutions during their sharing in society. Students reflected what aspects of STEM knowledge were applied on their designing and from your best, the possible ways to make it happen and can used in real-life. Teacher assessed students’ creative thinking on students’ planning, designing and making innovation. Present ideas to design and build, present how to test and evaluate of the solution. And, also present how the prototypes and/or products (innovations) could be explained as the real one. Students need to do something as people who are a part of society by reporting their proposal for solving problem. Students might exhibit their solution in public. Or, students may communicate their products, science projects, ideas, designing, proposing system, or volition to the head of community, or share to social media and newspaper. Then, students need to report what they learned from the validation or sharing their proposal or product through socialization process. Then, students share what they learn from the comment and/or feedback. Then, students need to be asked to write what they learn from those reflections which they may get some more ideas to re-design and completion decision.

5. Conclusion

According to literature review about STEM education, aspect of practicing knowledge in real world through STS approach and concept of technology and engineering, the paper have proposed STEM education pedagogy. The paper, then, proposed the theoretical framework of STEM education teaching approach as inquiry from the context based. The teaching approach consists of 7 stages. These include (1) Identification of social issues, (2) Identification of potential solution, (3) Need for knowledge, (4) Decision-making, (5) Development of prototype or product, (6) Test and evaluate the Solution, and (7) Socialization and completion decision stage.

Regarding on the 7 stages of context based STEM education teaching approach; it may provide a referent of STEM education teaching in school setting and STEM project teaching. Teachers may perceive concrete ways of getting start the STEM education learning activities when they are thinking about the identification of social issues. Then, the activities could be started from social issues and/or human needs such as disasters, pollutions, environmental issues, biotechnology, health, cosmetics, ecosystem, energy, market, commerce, and designing some technological products. The 7 stages will allow students using applying scientific and other knowledge for designing the solutions, and provided the context of instruction requires solving a real-world problem or task through teamwork. And, students will have also chance to apply their scientific and other knowledge for problem solving in context of entrepreneurship.

And, because the stages of teaching developed regarding on framework of STS and EPD, the learning activities could balance problem solving based on concept of technology and engineering. The stages of teaching also keep four modes of the manifestation of technology to design learning activities. Taking technology as object, therefore, reminds students to provide artifacts which attribute to a dual nature – physical and functional nature. Considering conceptual and procedural knowledge of technology give chance students to learn related knowledge and thinking and practicing about knowing how. As provided activities regarding on technological procedural knowledge (tacit, personal or implicit knowledge); students will perceive about design, modelling, problem solving, systems approaches, project planning, quality assurance and optimisation during developing prototypes or
products. Taking technology as activity supports students to learn about activity of designing, making, and using or evaluating. View of technology as volition will enhance students to generate the relationship between technology and our human will. These include (1) technology support extension of the human body and mind; (2) technological impact on culture or society; and (3) technology depends on values. As mentioned above, the 7 stages of context based STEM education teaching approach may suggest teachers to design STEM education learning activities in school setting.

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