Developing the Astronomy and Architecture Unit for Providing Students’ Perception of the Relationship between Science, Technology, Engineering, and Mathematics

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Abstract. STEM education suggested that students should be enhanced to learn astronomy with integration between Science, Technology, Engineering and Mathematics. To help Thai students make sense of STEM education in astronomy learning, this paper presents learning activities of the Socio-cultural astronomy and architecture Unit. The developing of the Socio-cultural astronomy and architecture Unit is a part of research that aimed to enhance students’ perception of the relationship between Science, Technology, Engineering, and Mathematics. This paper will discuss how to develop the astronomy and architecture Unit through Socio-cultural approach that regarding sociocultural perspective into 5 stages. These included (1) Engagement, (2) Investigation, (3) Discussion and conclusion, (3) Create production understanding, and (5) Learning community reflection. The learning activities could be highlighted as following. First stage, students focus on various religious buildings in the ancient time that built like a solar calendar structure. Then, they give opinions in this issue; (1) How to build a solar calendar for identify true season in your district? (2) Why do not build a house perpendicular the Sun’s pathway? Second stage, students used Stellarium astronomical program to find the position of sunrise or sunset in each month. Then, study about the details of buildings in various global civilizations which aims to astronomical observations and create activities in relation to true seasons. Third stage, each student group conclude these ideas; the principles for building place like a solar calendar, building house and set the room activity that concern with the Sun’s pathway and saving energy in their house. Fourth stage, students was assigned to create a model of the solar calendar in their district. The model should relationship with the sunrise or sunset position in important astronomy dates, support astronomical observations, and become landmark for tourism. Finally, each group presented their model to the committee and then, wrote committee’s reflection, and their opinions. The paper may have implications for developing astronomy teaching with STEM education.

1. Introduction
In the 21st century, scientific and technological innovations have become increasingly important as we face the benefits and challenges of both globalization and a knowledge-based economy. To succeed in this new information-based and highly technological society, students need to develop their capabilities in STEM to levels much beyond what was considered acceptable in the past [15].

The goal and vision of the Thai science education suggests that science teaching and learning should lay emphasis on the relationship between science, technology and society; and lifelong learning [8]. And, the goal also aims to provide students with the intriguing study in Science, Technology,
Engineering and Mathematics. Thus, students should be use the knowledge in many subjects to solve real problems, research and improve many things in their real lives. All those issues need all knowledge they have, not individual one [1][17]. Therefore, integrated concept of science, technology, engineering and mathematics or STEM Education was recognized. Science is the subject that study from natural phenomena by scientific inquiry. Technology is the subject that applied all subjects to help solve the problems and also improving and developing to human need. Engineering is the subject that creative innovation and build many things to accommodate human by use the knowledge of Science, Mathematics and Technology to inventive. Mathematics is the subject that about calculation at this subject is very important foundation of education. It can be further in engineering [4][3].

Astronomy is one of area and now become the most effective catalysts that inspires young children to look upon the skies and marvel at the bounty of this celestial sphere has on offer. At the very young age, especially during their primary and secondary schools, children are more easily exposed to science and technology than other later stages in life and that is when their innovative mindsets and scientific capacities should be incubated. In addition, astronomy is an impetus to pave the way for the children to pursue their careers not only in the field of astronomy but also in other related sciences from engineering to biology or even space technology, adding more manpower into STEM workforce in the future [21]. Astronomy has been aptly called a “gateway drug” for STEM (Science, Technology, Engineering and Math) learning [6].

Astronomy is a natural science that deals with the study of celestial objects (such as the Sun, the Moon, stars, planets, comets, and galaxies) and phenomena that originate outside the Earth's atmosphere. Astronomy is one of the oldest sciences in the world [16][10][23]. Historical astronomers attempted to explain the actual motions of celestial objects from their observations [20]. So, many structural symbolic patterns were built to perceive and understand the sky. Archaeoastronomy is multidisciplinary science of architecture, archaeology, and astronomy [13]. It studies about pre-technological humankind’s awareness of celestial phenomena and its influence on their societies such as how ancient architecture were built, early forms of calendars, and the development of mathematical concepts [19]. It was the earliest concept in astronomical knowledge and a decisive factor in the emergence of agriculture and navigation in early civilizations [7]. It is not only deeply rooted in almost every culture [18], but it is still the basis of our modern system of time measurement such as the seasons and the calendar and of navigation and surveying [12].

Astronomy provides tremendous opportunity for interdisciplinary learning so astronomy activities should be emphasis on the relationship between multidisciplinary such as science, technology, engineering, mathematics, and also archaeoastronomy. Some educators suggested the 7 STEM guidelines activities for enhance students to learn science content on the relationship between science, technology, engineering, and mathematics (STEM). These include; Integrate Science, Technology, Engineering and Mathematics Content; Link all the Science, Mathematics and Technology to real world; Engage in inquiry; Project base; Apply Technology Strategically; Focus on the skills of the Twenty first Century; Building an awareness and participation in the community [23]. It indicates that Sociocultural approach could support all these 7 STEM guidelines activities to provide astronomy learning activities on the relation between STEM and also archaeoastronomy.

2. Socio-cultural Approach of Astronomy Learning
In this study, the author developed astronomy and architecture unit through Sociocultural approach that consisted of five stages including engagement, investigation, discussion and conclusion, create production understanding, and learning community reflection stage. The detail in each stage will show in the following:

(1) Engagement stage. The Sociocultural astronomy and architecture Units has to begin in scientific fact. Teachers lead the discussion that the axis of the Earth is tilted by 23.5 degrees to the plane in which it travels around the Sun. Different parts of the Earth point toward or away from the Sun at different times of the year, the cause of seasons. The observer on the Earth saw the position of sunrise and sunset change in cycle during a year. Then, set them to realm of societal and cultural context. The teacher designed the situation which concern cultural context or mentioning everyday events. Students look at the image of religious places in various historical territories. Particularly, Prasat Phanomrung,
Hindu temple in Buriram province that built like a solar calendar structure. Students were encouraged to share their prior knowledge and understanding which shown the knowledge gaps. Finally, they give opinions in these issue; (1) How to build a solar calendar for identify true season in Nonnarai district? (2) Why do not build a house perpendicular the Sun’s pathway?

(2) Investigation stage. The teacher assigned cooperative tasks. The students designed procedures to answer the question, solve the problem or complete the assignment with their group members. During learning activities, students were required for knowledge to research, share, and discuss with fellow group members. The teacher gives guidance and supports in manner to help students to finish tasks. Many strategies were helped students to understand some scientific content. For examples, cooperative learning, using the archaeoastronomy instrument unit, outdoor learning, and lecture. In this unit, students used Stellarium astronomical program in their computer notebook study the position of sunrise or sunset in each month. Then, study details of buildings in various global civilizations and in Thailand such as Prasat Phanomrung, Prasat Phu Phek which aims to astronomical observations and activities in relation to true seasons. In addition, know the reason why Thais believe that do not build a house perpendicular the Sun’s pathway?

(3) Discussion and conclusion stage. The students in each group were discuss about results from previous stage, develop a group’s conclusion, and shared its findings with the class. They use mind map to conclude these ideas; the principles for building place like a solar calendar, building house and set the room activity that concern with the Sun’s pathway and saving energy in their house. During learning, teacher aided students to communicate their thinking by prodding with questions that attempted to get students to clarify their thinking and further evaluate the value of their thoughts. Also, the teacher might assist students by means of modeling, giving reinforcement, instructing, explaining, or guiding. In addition, to demonstrate their conclusions, students were encouraged to use drawing, acting, writing, and any other method or tool that would aid them.

(4) Create production understanding stage. Teacher gives the situation for student to solve, or created final product, or do mini project that for demonstrated their understanding. This was the time for students to demonstrate their full grasp of the meanings (concepts) by using signs and tools. Not everyone's understanding was identical, but they shared similar and important key ideas. In this stage, students can create production understanding both in and out of the classroom. It probably illustrated students’ reasoning ability, and technological process. In the class, teachers give the Horizon table and assign students to create a model of the solar calendar in Nonnarai district. The model should relationship with the sunrise or sunset position in important astronomy dates such as Solstice or Equinox. Also, support astronomical observations and landmark for tourism. Student can use materials that can found in their community.

(5) Learning community reflection stage. Students need to act as people who are a part of society by presenting their production understanding with their learning communities. They might exhibit their product in public and receive feedback from expertise in that community. This process will help students rethinking on their ideas that it is effective for stakeholders or need to improve something on their products. Therefore, students probably exchanged their ideas or improved the product to the best. In the unit, student presented their model in front of the committee that includes; school director, astronomy teacher, social and culture teacher, art teacher. Then, write committee’s reflection, and their opinions (run on the leisure time around 1 hour for all group).

Summary: an important learning activities based on sociocultural perspective is help to improve students learning behavior through interaction and cooperation with one another [5][11][24] in social contexts [25]. Students constructed knowledge as a form of “situated cognition” [2]. The concept of astronomy and architecture are related to students’ contexts. In addition, the astronomy learning about astronomy and architecture would allow students to learn astronomy on the relation between concepts of science, technology, engineering, and mathematics. Because students will learning about the apparent motion of the Sun (science; the season concept), using the stellarium astronomical program to find the location of sunrise and sunset (technology), measurement the angle of the position of Equinox and Solstice on the horizon plate (Mathematics), inventing model of the solar calendar related to their location (Engineering).
3. Participants
The astronomy and architecture unit was trialed by the author in Naraikhumphongwittaya School. The school is located in the small Nonnarai district, Surin province, Thailand. This district is far from Surin province approximately 70 kilometres. The total number of Grade 7-12 students is approximately 700. Their parents work as laborers in Bangkok and as farmers. The Grade 9 participants in the second semester of 2014 academic year that include 32 students, 21 girls and 11 boys, who live in the district and other villages nearby.

4. Finding and Discussion

4.1 Student Understanding about astronomy and architecture concepts
The students have learned that ancient human looking the position of sunrise or sunset that changed every day and it is rising on the eastern horizon and setting on the western horizon. In the summer season, the Sun appear moving from true east to the north, and in the winter, it was veering to the south. Thus, human creating buildings or something such as places of worship that relating with the position of sunrise or sunset in someday to identify times of the season that is called Solar Calendar. Nowadays, the concept of housing in relation to the movement of the Sun during the year, it contributes to reduce the budget, and saving the energy which used in the house. Because of the rising and setting of the Sun in each season, it is affect the direction and the amount of light entering the building, and it also relationship with the temperature in the house living space. These knowledge could be encourage students interested in two ways; (1) build the house to save using energy, and (2) build each construction look like as solar calendar that to tell the time and sued for astronomical observations, furthermore make the house is sacred and more magical, as mentioned in the student's writing journal in the following:

- “If the modern house was built based on the rising and setting of the Sun, the house will become special place like ancient castle in the Khmer Empire.” (Chanat)
- “The main structure of the house that is not match the movement of the Sun during the year, the house will high temperature, the owner house will pay much money for the electricity.” (Pornpimai)

Teachers design activities to support students to collect the angle of the rising from true east and setting of the Sun from true west during the year (12 months) that using Stellarium astronomical program to stimulate. This activity allows students to know by themselves that the rising and setting of the Sun appears change the position every day in one year cycle. In addition, each area on the Earth receive difference angle of sunlight that cause the seasons on Earth. The astronomer identify that one astronomy year have four season, the point of four special day that include: Vernal Equinox (Vasantravisuwat; 21 March), Summer Solstice (Krisamayan; 21 June), Autumnal Equinox (Sashavisuwat; 23 September), Winter Solstice (Hemayan; 22 December) as shown in student's writing journal in the following:

- “I never know before about name of four seasons in Thai language and English, I always know that Thailand has three seasons: summer; winter and rainy season.” (Rungsiri)
- “I have seen with my own eyes that each month, sunrise and sunset does not in the same point location and it always not the same time. In summer, the Sun will appear close to the north celestial pole that from the true east. In this time, the Sun will quickly rise and slowly set, so long time this area have sunlight and so hot.” (Adchariya)
- “I just know that, the Sun appears to move close the north celestial pole about 23.5 degrees from the true east and also moving on to close the south celestial pole about 23.5 degrees, I use Stellarium software to simulation that.” (Tida)
- “Previous time, I only know that the Sun does not rise at the same location every day, but this is pattern of a different season that could be told the season, months or zodiac.” (Chanat)
After students was clear understanding that changing the position of the sunrise and sunset in a year could be identify the season, special holy days, and also help designing residential buildings to save energy. Teachers assign students to create a model of the solar calendar in Nonnarai district. The model should relationship with the sunrise or sunset position in important dates such as Solstice or Equinox. The model structure must support astronomical observations and landmark for tourism. Then, each group presented their model in front of the committee that includes; school director, astronomy teacher, social and culture teacher, art teacher. The researcher found that five models present about temples and ancient castles which some point relative with sunrise and sunset position on the day of Equinox, Summer Solstice, and Winter Solstice. However, only one male students group has designed a house structure that the main structure laying related to the Sun pathway (from east to west). The main objective is reducing much sunlight because if the main structure laying from north to south, the house will receive much directly sunlight on both the morning and evening. This activity helps students understand the concept of designing the ancient monastery as solar calendar that for tell the seasons, and including some ideas such as build housing related to the rising and setting of the Sun for saving the energy, as mentioned in the student's writing journal in the following:

- “I understand that why the Angkor temple is facing to the east that because the sunlight in the Equinox day will shine to the centre of the castle. If it happens, that mean that day was the beginning of the year, or a day to do some special activities.” (Peerakorn)
- “The positioning of the pagodas and temples in the ancient city that maybe they mark the positioning day of Summer Solstice, or Winter Solstice from the observation point as the centre of the main place.” (Phuwanat)
- “When I become working man, I will design and build a custom home as the special and attractive places both in beliefs about the sunlight, and for saving the energy.” (Sarawut)

Considering in the learning objectives of astronomy and architecture unit, after learning, the students were able to (1) explain the meaning of the celestial sphere, equator, the north celestial pole, the south celestial pole, and Earth’s axis. (2) Search and explain the cause that the rising and setting of the Sun is not exactly the same position, and the cause of seasons. The students could surely mention that the Earth’s rotation axis makes an angle of about 66.5 degrees with the plane of its orbit around the Sun, or about 23.5 degrees from the perpendicular to the ecliptic plane. Therefore, the position of sunrise and sunset were changes every day in one year cycle. It effect to the people’s lifestyle on the Earth that depend on their location on the Earth. Many people build the accommodations or landmarks related to the Sun’s pathway for different reasons. In addition, students can use the astronomical program to simulate the motion of the Sun throughout the years in around 30 minutes. It could be helps students quickly understand the concept of season.

4.2 Students’ reasoning and value clarification for astronomy and architecture
Teacher used pictures of religious places in several countries such as Prasat Phnomrmung, Burirum province, city wall castle, sanctuary, pagoda, and religious place to motivate students to interest about the solar calendar. Then, suggested them to understand that ancient human observed the position of sunrise and sunset which change every day. In summer, sunrise appearance shift from true east to the north and in the shift to the south in winter. They took the construction such as the stones, or temple are aligned to the Sun's position for used as astronomical observatory and also used it is a solar calendar as a seasonal clock. These concepts also inherited from generation to generation and have the influence to the present building. Because of the position of sunrise and sunset in each season affects the direction and amount of sunlight entering the building, it can make high or low temperature in the house. Therefore, housing construction which correlated with the Sun’s pathway during the year it could help the owner for saving the energy, do not use more air conditioner and save the electricity charge. After students understand the concept about season and solar calendar, teachers give the Horizon table and assign them to create a model of the solar calendar in Nonnarai district. The model should relationship with the sunrise or sunset position in important dates such as Solstice or Equinox. The model structure must support astronomical observations and landmark for tourism.
According to learning activities, it could be mention that students have scientific reasoning with other aspects, it combine season concept and others condition for buildings the landmark or the living place. For example, some students give the reason base on their belief such as if the house is consistent with the Sun’s pathway, it will make the house auspicious. Another reason is for saving energy and electricity costs as mentioned in the student's writing journal in the following:

- “I understand that many Angkor temples turned the main structure to the east because the sunlight in the Equinox day will shine inside to the center of the temple. It shows that the important day as the new year or a day to do some special activities.” (Group 1)
- “The location of pagodas in temples and ancient palace really are position marker which related to the position of sunrise or sunset in summer solstice, or winter solstice which can observe from one location as the center in that place” (Group 2)
- “When I grow up and build my own house, I will design it to be charming in both auspicious depend on ancient beliefs and also saving energy.” (Group 3)
- “If we build a religious place we will concern with the position of sunrise and sunset in important dates such as Equinox’s day. It should be an important tourist attraction to visit” (Group 6)

These assume that many groups of students held multidimensional value clarification for created the production understanding. Their reasoning depended on scientific knowledge, economy aspects, and the societal aspects such as believe and attractions.

4.3 Development of students’ technological process and learning in STEM Education

According to the Sociocultural approach for teaching and learning astronomy and architecture that consists of five stages: (1) Engagement stage, (2) Investigation stage, (3) Discussion and conclusion stage, (4) Create production understanding stage, and (5) Learning community reflection stage. In the fourth stage of the unit, teacher determined the situation and assigned students in each group work together to planning and designing the projects about the solar calendar in their district location.

In the create production understanding stage, and learning community reflection stage, each student’s group used the process involved in problem solving, creativity, designs that lead to the invention or creation of certain product and then presented their production understanding in their learning community for get some suggestions for further development. These process are classified as Technological process which in students’ reflection and writing in worksheets could summarized their technological process into 6 steps as follows: (1) Identify and analyze the situations, (2) Gather more relevant information, (3) Data analysis And choose an alternative, (4) Plan and created, (5) Test, evaluate, improve and develop (6) Present a product in their learning community. Here was the student's interview in the following:

- “First of all we read the situations and set the objective of the solar calendar architecture which we will make (1). Some ideas is not complete so we search more relevant information (2), when we have enough knowledge the member presented the ideas on the group and sometime debate (3). After that we choose the best ideas (3), planning together and created it (4). Before we send the product to teacher we check the model work (5) and presented perfect solar calendar architecture in front of 5 committees (6), and finally check and compare the result with others groups.” (Group 4, interview)

The six technological processes above is consistent with the STEM Education standards [9], and look like the Engineering process [14] and the stage of learning in the STEM Education that IPST promote for teaching and learning in Thailand. It consists of 6 stages as follows:

1) Problem Identification stage; understanding the problem or challenges, analyze conditions or limitations of problem situations, to determine the extent of the problem. It will lead to create the product or method to solve the problem.
2) Related Information Search stage; is a collection of information and concepts of science, mathematics, and technology which related to problem solving and evaluation the feasibility, the advantages and limitations.

3) Solution Design stage; is the application of information and ideas that related to the design of the product or solution designing which concern with the resource, limitations, and conditions situations.

4) Planning and Development stage; is determines the step for create the product and then create the product, work piece, or develop a solution to solve the problem.

5) Test, Evaluation and Design Improvement stage; is testing and evaluate the use of the product or the approach, and use the result to improve and develop it to the most effective product or solutions.

6) Presentation stage; is to present the production or effective step for solve the problems in the community, and get some suggestions for further development.

The author found that Sociocultural approach for teaching astronomy and architecture also supported students to learn through the STEM Education approach. In addition, in the create production understanding stage students also integrate conceptual approaches on STEM Education to create the product. In this study, the author called the integration of STEM education in celestial motion unit is A-STEM, because it include the archaeoastronomy concept in the units that include:

- A (Archaeo astronomy): Solar calendar
- S (Science): the apparent motion of the Sun (seasons concept)
- T (Technology): stellarium astronomical program, search information, integration of other knowledge for designing
- E (Engineering): inventing model of the solar calendar
- M (Mathematics): measurement the position of Equinox and Solstice on the horizon.

These assumed that the Sociocultural Astronomy and Architecture Unit could be enhanced students’ technological process. They have the step for create the product and each product design base on their societal and cultural context. In addition, the process is consistent with the STEM Education standards [24] and the engineering design process [14] which IPST still promote for teaching and learning in Thailand. It aims this technological process will enable student to create innovation for Thailand.

5. Conclusion
Development for learning of Astronomy and Architecture through Sociocultural approach can promote not only student understanding, students’ reasoning, but also the concept on STEM Education that students will integrate a knowledge between Science (apparent motion of the Sun and seasons concept), Technology (using the stellarium astronomical program), Engineering (Engineering design on the model of the solar calendar) and Mathematics (calculation and measurement) through societal and cultural context (archaeoastronomy). Finally, found that stage 4 (Create production understanding stage), and stage 5 (Learning community reflection stage) of the author Sociocultural approach could be enhanced students’ technological process and the engineering design process.

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