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STEM Learning Activity through Making Natural Paints from Plants Process

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Abstract. The paper will clarify STEM learning activities related to the natural paint-making process. The STEM education learning activity will be developed based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach. These learning activities aim to show the student teachers' learning through (1) how to make natural paint from flowers and plants and (2) producing natural paints are available for use, low-cost, and effective. The 7 stages of STEM education are used as the processes for making natural paints from flowers and plants (beetroot, red cabbage, butterfly pea, and turmeric) into useable paints. The results from the learning activity shown that beetroot, red cabbage, butterfly pea, and turmeric have the properties to synthesize color ink and use it for artist setting. The inks synthesized are eco-friendly, avoid biological waste, and avoid hazardous chemical. This paper will discuss how to provide students with a chance to apply STEM knowledge through these activities to encourage students and local people to conduct natural painting with natural ingredients for safety and health.

Keywords: STEM education, Natural Paints, Synthetic

Introduction

In the 21st century is the generation the Industrial Revolution 4.0 and it has created intense economic competition between countries. The development of science, technology, engineering, and mathematics has become a priority agenda for economic and social development through the declare of the Industrial Development Policy in Cambodia 2015-2025 (Moeys, 2016). STEM policy shown that Cambodia is a developing country, it is the most necessary to encouraged learning STEM activity in order to produce human resource in Cambodia. STEM education is a study model that provides opportunities to integrate the four key skills of science, technology, engineering, and mathematics to implement a combination of decision-making decisions or any problem.

Cambodia had just implemented STEM education in the education program one year after the policy. It aims to develop K–12 and higher education students in science, technology, engineering, and mathematics to meet the needs of the labor market and the ASEAN community. STEM education improves students' critical thinking skills and

positive STEM perceptions, and it indirectly influences their understanding of their careers (Haciolu and Gulhan, 2021). STEM education helps students to improve behavior activity creative and innovate. STEM education learning activities have an effect on students' creative thinking skills (Sirajudin & Suratno, 2021; Sutaphan and Yuenyong, 2023).

The literatures suggest that STEM education pedagogy would be provided in the following aspects: (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 necessitate the use of scientific and mathematical concepts through design justification; (d) the development of 21st century skills is emphasized; and (e) the integrator is the engineering practices and engineering design of technologies as the context (Moore et.al., 2015; Sutaphan and Yuenyong, 2019).

The conceptualization of STEM education pedagogy should engage students to identify the real-world problems such as disasters (e.g. flooding, earthquake, tsunami etc.), pollutions, environmental issues, biotechnology, food, health, cosmetics, ecosystem, green energy, climate change, entrepreneurs' issues, and so on (Suparee and Yuenyong, 2021; Sutaphan and Yuenyong, 2019; Sutaphan and Yuenyong, 2023; Wongsila and Yuenyong, 2019). In order to regulate teacher's ideas of developing STEM education learning activities for engaging students' developing solutions for real-world problem, Sutaphan and Yuenyong (2019) suggested 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. The framework of stages of teaching included seven stages of teaching. These included (1) identification of social issues, (2) identification of potential solutions, (3) need for knowledge, (4) decision-making, (5) development of prototype or product, (6) test and evaluation of the solution, and (7) socialization and completion decision stage.

And, literature revealed that some studies adopted framework of Sutaphan and Yuenyong (2019) STEM education pedagogy to develop the STEM education units in different contexts in Asia (Adita and Yuenyong, 2021; Ebal Jr et.al., 2019; Fachrunnisa et.al., 2021; Koes-H et.al., 2021; Guarin et.al., 2021; Masita et.al., 2021; Nugraheni and Yuenyong, 2022; Sutiawan et.al., 2021; Theerasan and Yuenyong, 2019;Villaruuz et.al., 2019). This study, therefore, focused on applying STEM in learning process by using 7 step model of STEM education, which provided students with the opportunity to make natural paints from a plant process that, in recent years, many students have used in art class. Students can apply scientific knowledge or others to design a solution for making something new in their daily lives.

Development of Making Natural Paints STEM Education Unit

The STEM education learning activity will be developed based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach. In Cambodia, students usually use paint for their learning activities, especially in art class. Based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach, seven stages are provided: (1) identification of social issues; (2) identification of potential solutions; (3) need for knowledge; (4) decision-making; (5) development of a prototype or product; (6) testing and evaluation of the solution; (7) socialization and completion of the decision stage. Through this learning activity, students apply knowledge to create natural paints. Students apply knowledge in Chemistry, Mathematics, Engineering, Biology, and Economics to produce natural paints. In chemistry, students think about ingredients. In math, students calculate the proportions of ingredients in a production. Engineering is the study of packaging techniques, and biology is the study of the expiration of natural paints. In the economy, students think about the cost of ingredients in the production of natural paints. This lesson plan is shown in the table below.

Table 1: Lesson plan on natural paint from plant process STEM education learning process

STAGE	ACTIVITY
Identification of Social issues	Inspire students to think about making inks to use in the classroom, especially art classes. Synthetic paints which sale in the market are more popular than natural paints, however, due to their volatile organic compounds, which are harmful to nature and pose a threat to individuals who use them and harm the environment (V.A.R.Barao et al., 2022). Paints are a mixture of many substances such as resin, alcohol, carbon, pigments, lubricant, Synthetic Dye, aniline, dextrin, glycerin, fluorescents, and other materials (Wild, 2016). Lubricant is an oil that can affect human health and the environment, such as affecting water and soil sources (Madanhire et al., 2016) Synthetic dyes are toxic, causing disease to human health and also affecting the environment (Ngulube et al., 2017) Aniline is widely used as an intermediate chemical in the pharmaceutical and dye industries. These chemicals are of concern because they have an impact on public health and aquatic species in the environment to solve this problem, we need to: produce natural paints from flowers or plants; Learn how to make pigments from flowers or plants. Check raw materials, chemicals, budgets, and packaging for natural ink production (Chaturvedi & Katoch, 2020)
Identification of Problem Solution	To Solve this problem, we need to: 1. Produce natural paints from flowers or plants 2. Learn how to make pigments from flowers or plants. 3. Check raw materials, chemicals, budgets and packaging for natural ink production 4. Produce natural paints that are usable, low-cost. Organic paints are considered environmentally friendly as they are sourced from natural resources such as leaves, plants, roots, flowers, fruits, and minerals (Singh & Sharma, 2017).
Need for Knowledge	Find information on the internet and in books on knowledge related to the production of pigments from plants. Knowledge from research articles: ➢ Turmeric Turmeric is a yellowish-brown tuber with a yellowish interior and small tubers growing in the ground. Turmeric is a plant used in spices is a mixture of bright yellow chemicals due to the presence of a specific substance, Curcumin, which can help fight oxidation and inflammation (Jiggi, 2012). ➢ Beetroot Beetroot is a tuber vegetable that contains red pigment. The color of beetroot is red and pink because beetroot contain 75–95% betalains. The red pigment in beetroot betalains helps with antioxidant and anti-inflammatory properties.(Chandran et al., 2014). ➢ Coffee's pulp Coffee is a popular beverage in Cambodia, it is brewed with hot water for consumption, but its pulp is left behind. However, the coffee left behind loses its flavor, but its color does not change, and its color should be used for color synthesis.   

Table 1: (Cont')

STAGE	ACTIVITY
	➢ Butterfly pea flower Butterfly pea flower contains anthocyanin, which gives it a dark blue or purple color (Mary et al., 2020).  ➢ The red cabbage The red cabbage is derived from a plant pigment known as anthocyanins, which is a compound that causes it to turn purple because of its pigment content. Also, for painting (Danilo & Alfaro, 2021).  ➢ Vinegar Vinegar is used as an additive in the production of pigments because it is acetic acid, and it is used with water as a solvent as an additive to make these dyes environmentally friendly and biologically damaging. Adding more vinegar to this natural ink helps preserve the ink and stabilizes the ink so it lasts longer on paper when it dries (V.A.R.Barao et al., 2022).  ➢ Cassava starch Cassava starch is used as a binder in the form of water-based paints (Udonne & Obiokwu, 2013). ➢ Water Water acts as a solvent to break the polysaccharide bonds of glucose (Qian et al., 2019).  ➢ Salt Salt is a substance that absorbs water or moisture. We add salt to make the mixture more viscous (Parvathy & Jyothi, 2012). The plants are heated in water, vinegar, salt to create a color extraction, then noodles are added as a binder in the production of natural paints. Plants + Water + Binder = Natural paints
Decision Making	Discuss and decide on an experimental process that produces ink from plants. The plants that we use in our process are turmeric, beetroot, butterfly pea flower, red cabbage, Coffee's pulp. These plants are very abundant and easy to find in Cambodia. So it is very easy for us to find raw materials for natural paints production.
Development and prototype or Products	Through STEM learning activities students development and prototype or Products started to think about: In chemistry, students think about ingredients. In math, students calculate the proportions of ingredients in a production. Engineering is the study of packaging techniques, and biology is the study of the expiration of natural paints. In the economy, students think about the cost of ingredients in the production of natural paints. Martial and Procedure

Table 1: (Cont')

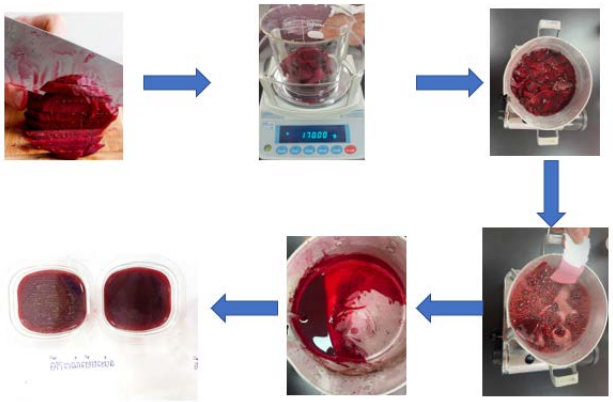
STAGE	ACTIVITY
Development and prototype or Products	Martial and Procedure Martial: Gas stove, spoon, pot, baker, knife Ingredients: Salt (NaCl), water, vinegar, Butterfly pea flower, Turmeric, Cassava starch, Red cabbage, Beetroot Procedure: The procedure of production is detailed for making color from beetroot, and other ingredients also have the same production pattern. The productions are following the steps below: The description of figure 1: Step 1: Split the beetroot into a small piece Step 2: Weighing 170 grams of beetroot Step 3: Measure 300mL of pure water Step 4: Mixed beetroot and water in the pot Step 5: Add a spoonful of vinegar Step6: Add a spoonful of vinegar and blend Step7: Heating for 30 minutes Step8: Test the color with white paper Step9: Filter the liquid pigments into a new pot Step10: Add two spoons of cassava starch and blend until it's mixed. Step11: Leave until it's cool and packaged.  Figure 1: the diagram of making color painting

Table 1: (Cont')

<table>
<tr><th>STAGE</th><th>ACTIVITY</th></tr>
<tr><td>Test & Evaluation of the solution</td><td>
After the process of packaging, the researchers tested the quality of the paint by observing nine criteria for each product, such as:
C1: Flow ability
C2: Color
C3: Brightness
C4: Drying time (paper)
C5: Expiration period

Table 1: Physical properties of natural paints from plants
<table>
<tr><th></th><th>Beetroot</th><th>Turmeric</th><th>Red cabbage</th><th>Butter fly flower</th><th>Coffee</th></tr>
<tr><td>C1</td><td>Free flowing</td><td>Free flowing</td><td>Free flowing</td><td>Free flowing</td><td>Free flowing</td></tr>
<tr><td>C2</td><td>Pink</td><td>Yellow</td><td>Pistachio</td><td>Green</td><td>Brown</td></tr>
<tr><td>C3</td><td>Good</td><td>Good</td><td>Good</td><td>Good</td><td>Good</td></tr>
<tr><td>C4</td><td>5-8 second</td><td>5-8 second</td><td>5-8 second</td><td>5-8 second</td><td>5-8 second</td></tr>
<tr><td>C5</td><td>1 month</td><td>1 month</td><td>1 month</td><td>1 month</td><td>1 month</td></tr>
</table>
The physical properties of the natural paints produced from the, local ingredients such as: Beetroot; Turmeric; Red cabbage; Butterfly flower; and Coffee are interpreted in Table1. The color paints are Free flowing, brightness, stable for Permeance, easy to dry and long period of expiration day. The paint colors are pink for Beetroot; yellow for Turmeric; pistachio for red cabbage; green for Butterfly flower and Brown for Coffee. The synthesized paints do not easily to erase due to the properties of color paints and it indicated that the color paints have good quality. However, some color paint displaying some change, when left in room conditions for 2 weeks:

Table 2: Physical properties 's variations of natural colors
<table>
<tr><th></th><th></th><th>Beetroot</th><th>Turmeric</th><th>Red cabbage</th><th>Butter fly flower</th><th>Coffee</th></tr>
<tr><td>Week1</td><td></td><td colspan="5">No Color Change</td></tr>
<tr><td>Week2</td><td>Day 1</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 2</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 3</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 4</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 5</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
<tr><td></td><td>Day 6</td><td>Slight Change</td><td>No Change</td><td>No Change</td><td>No Change</td><td>No Change</td></tr>
</table>
The Changes in natural color show in Table 2 that all colors do not change color within two weeks, except for the color of the Beetroot, which changes during the second week.
</td></tr>
</table>

Table 1: (Cont')

STAGE	ACTIVITY
	     
Socialization and completion decision stage	1. Share what you get with other students and teachers or on social media. 2. Other students and teachers comment on their promotion. 3. Evaluate based on comments in the project (number of likes and dislikes), creativity, Acceptable creativity and complexity of innovation.  Presented in class  Posted Video on Facebook and you tube Link: https://youtu.be/L9LbeBhPq7s

Table 1: (Cont')

STAGE	ACTIVITY
	 Science Fair at Phnom Penh Teacher Education College

Conclusions

The paper will clarify STEM learning activities related to the natural paint-making process. The STEM education learning activity will be developed based on Sutaphan and Yuenyong's (2019) context-based STEM education learning approach.

According to the problem of paints, the learning activities of the 7 stages encourage students to practice knowledge and create something related to the production of natural paints from plants. After finishing the project, students gain some more knowledge about the way to produce natural paints from plant processes, they can develop their product and make the decision to produce it.

The test and evaluation student shows the quality of their product and shows it to their teacher and their friends. This paper shows how to provide students with a chance to apply STEM knowledge through these activities to encourage students and local people to conduct natural painting with natural ingredients for safety and health.

References

Adita, A., Yuenyong, C. (2021). STEM Learning Activity through Tempeh Making Process. Journal of Physics: Conference Series 1835 (1), 012050

Barao, V.A.R. Coata, R.C. Shibli, J.A. Bertolini, M.& Souza, J.G.S. (2022). Natural Ink Synthesis from Flowers of Flame of Forest (Butea monosperma). Common Lantan (Lantana camara), and Berries of Malabar Spinach (Basella alba). Braz Dent J., 33(1), 1 – 12.

Chaturvedi, N. K., & Katoch, S. S. (2020). Remedial technologies for aniline and aniline derivatives elimination from wastewater. Journal of Health and Pollution, 10(25).

Ebal Jr, C.D., Luga, M.J.F., Flores, M.R.O., Zabala, D.J.P., Buan, A.T., and Yuenyong, C. (2019). Linear Equations in Two Variables STEM Education Learning Activities: Developing the Household Power Consumption Calculator App. *Journal of Physics: Conference Series*, 1340 (1), 012048

Fachrunnisa, R., Suwono, H. Yuenyong, S Sutaphan, N Praipayom. Eco-friendly fashion: A STEM sandpit project in Indonesian senior high school. Journal of Physics: Conference Series, 1835 (1), 012046 (2021).

Guarin, R.M., Buan, A.T., Malicoban, E., Barquilla, M.B., Yuenyong, C. (2019). Formulating Refreshment Drink Activity Utilizing STEM Education for Grade 8 Learners. *Journal of Physics: Conference Series*, 1340 (1), 012078

Hacioglu, Y., and Gulhan, F. (2021). The effects of STEM education on the students' critical thinking skills and STEM perceptions. Journal of Education in Science Environment and Health, 7(2), 139–155.

Koes-H, S, Nisa, I.K., Faiqatul, H.E., Wahyuni, T., Yuenyong, C., Sutaphan, S. (2021). The development of lesson plan of the water pressure booster pump STEM education. Journal of Physics: Conference Series 1835 (1), 012049

Madanhire, I., Mbohwa, C., Madanhire, I., & Mbohwa, C. (2016). Lubricant additive impacts on human health and the environment. Mitigating Environmental Impact of Petroleum Lubricants, 17–34.

Masita, R., Sutaphan, S. and Yuenyong, J. (2021). Developing Lesson Plan on the Healthier Local Snack STEM Education. *Asia Research Network Journal of Education*, 1(1), 43–49.

Moore T.J., Johnson C.C., Peters-Burton E.E., Guzey, S.S., (2015). The need for a STEM road map. In: Johnson CC, Peters-Burton EE, Moore TJ (eds) *STEM road map: a framework for integrated STEM education*. Routledge, p 1.

Ngulube, T., Gumbo, J. R., Masindi, V., & Maity, A. (2017). An update on synthetic dyes adsorption onto clay based minerals: A state-of-art review. Journal of Environmental Management, 191, 35–57.

Nugraheni, A R E and Yuenyong, C. (2022). Developing the Smog Problem in Indonesia STEM Education Learning Activity. *Asia Research Network Journal of Education*, 2 (3), 127-134

Setiawan, A.M., Yuenyong, C, Sutaphan, S., and Yuenyong, J. (2021). Developing lesson plan of the biogas from animal's dung STEM education. Journal of Physics: Conference Series 1835 (1), 012044, (2021).

Singh, N., & Sharma, V. (2017). Detail study of ink formulation from natural colourants. Int. J. Technol. Res. Enginering, 4(9), 1634–1636.

Sirajudin, N., & Suratno, J. (2021). Developing creativity through STEM education. Journal of Physics: Conference Series, 1806(1), 12211.

Suparee, M. and Yuenyong, C. (2021). Developing the STS electric and electric power unit for design based STEM activities. Journal of Physics: Conference Series 1835 (1), 012042

Sutaphan, S. and Yuenyong, C. (2019). STEM Education Teaching approach: Inquiry from the Context Based. *Journal of Physics: Conference Series*, 1340 (1), 012003

Sutaphan, S. and Yuenyong C. (2021). Examine pre-service science teachers' existing ideas about STEM education in school setting. Journal of Physics: Conference Series, 1835 (1), 012002

Sutaphan, S. and Yuenyong, C. (2023). Enhancing grade eight students' creative thinking in the water stem education learning unit. Cakrawala Pendidikan: Jurnal Ilmiah Pendidikan, 42(1), 120-135.

Theerasan C. and Yuenyong, C. (2019). Developing the Floating Restaurant STEM Education Learning Activities for Thai Secondary School Students. AIP Conference Proceedings. 2081, 030023-1– 030023-6.

Villaruz, E.J., Cardona, M.C.F., Buan, A.T., Barquilla, M.B., Yuenyong, C. (2019). Ice Cream STEM Education Learning Activity: Inquiry from the Context. *Journal of Physics: Conference Series*, 1340 (1), 012092

Wongsila, S. and Yuenyong, C. (2019). Enhancing Grade 12 Students' Critical Thinking and Problem-Solving Ability in Learning of the STS Genetics and DNA Technology Unit. Journal for the Education of Gifted Young Scientists, 7(2), 215-235. (2019)