Available on line at:
https://ijwem.ulm.ac.id/index.php/ijwem

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Exploration and Design of Etno-STEM as a Learning Source in Phytochemistry to Improve Meta-cognitive Skills and Students' Higher Order Thinking Skills of Environmental Problem

SYAHMANI*, LENY, YOGO DWI PRASETYO, AFIFAH WAROHMAH, MUHAMMAD NOOR RAIDIMAS, NIKA SOPRANTI, AND LILA MUSTARIANTI

Chemistry Education Study Program, Faculty of Teacher Training and Education,
Lambung Mangkurat University, Banjarmasin

ABSTRACT

The importance of in-depth exploration and design of Ethno-STEM (Ethno-Science, Technology, Engineering, and Mathematics) as a valuable learning resource within the realm of phytochemistry. This research aims to examine the diversity of local Ethno-STEM culture, design it, and use it as a transformative tool to enhance students' metacognitive and higher-order thinking skills, with a specific focus on addressing pressing environmental issues. In this study, an exploratory qualitative method is used with ethnographic techniques, knowledge extraction from indigenous communities, and laboratory investigations into the phytochemical properties of local flora. In order to learn phytochemistry, we are exploring the potential of Banjar, South Kalimantan's traditional ethno-scientific heritage. The subjects of this research are community leaders and academics who understand Banjar culture and ethnoscience. Data collection was carried out through observation, writing, and interviews. The results of this research show the important role of metacognitive skills in the learning process because they facilitate orientation-representation, planning, monitoring, and evaluation skills. The integration of Ethno-STEM knowledge not only enriches students' understanding of phytochemistry but also encourages the development of higher-order thinking skills for environmental problems (HOTSEP), including critical thinking, problem solving, and developing creative innovations to overcome environmental problems in the field of phytochemistry. The conclusion of this research proves that there is a synergy between indigenous knowledge, Ethno-STEM design for phytochemical learning, the development of metacognitive skills, and higher order-thinking. The results of this research not only contribute to the preservation and appreciation of cultural heritage (Banjar ethnoscience), but also have extraordinary potential for cultivating a generation that is environmentally conscious and able to solve problems.

Keywords: Ethno-STEM, Phytochemistry, Metacognitive Skills, HOTSEP

INTRODUCTION

In modern education, there is a growing recognition of the crucial role that indigenous knowledge and traditional wisdom can play in enriching and enhancing learning experiences. This interest gave rise to the concept of Ethno-Science, Technology, Engineering and Mathematics (Ethno-STEM), which focuses on utilizing the deep sources of knowledge possessed by indigenous communities to enrich students' learning experiences. Although Ethno-STEM has gained recognition in various fields, its application in the field of phytochemistry remains unexplored. In phytochemistry, secondary metabolites such as polyphenols, terpenoids, steroids, flavonoids, alkaloids, and a number of other beneficial natural compounds are investigated (Hakim *et al*., 2019). This research embarks on an exploratory journey within the specific context of phytochemistry, with

**Correspondence Author*: Dr. Syahmani, Chemistry Education Study Program, Faculty of Teacher Training and Education, Lambung Mangkurat University Banjarmasin, Jl. Hasan Basri, Banjarmasin, Indonesia; E-mail: syahmani_kimia@ulm.ac.id

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

the aim of investigating how the infusion of Etno-STEM can serve as a potent learning source while simultaneously fostering the development of metacognitive skills and higher-order thinking skills (HOTSEP) among students.

Henriksen (2017) created STEAM with design thinking, beyond stem and arts integration. The incorporation of indigenous knowledge into STEM education has gained traction due to its potential to bridge the gap between traditional wisdom and contemporary scientific practices (Smith, 2017). Scholars have emphasized that indigenous communities possess a wealth of knowledge about local ecosystems, including the properties and uses of plants, which can significantly contribute to the understanding of fields like phytochemistry (García-Herrera *et al*., 2020). Indigenous knowledge systems have been shown to complement and sometimes challenge conventional scientific knowledge, offering unique perspectives on environmental and ecological issues (Berkes, 2018).

Ethno-STEM, as a concept, extends beyond passive inclusion and seeks to actively engage indigenous knowledge holders in the educational process (McGregor et al., 2020; Zidny & Eilks, 2020). This approach acknowledges the expertise of indigenous communities and aims to empower them as co-creators of knowledge (Aikenhead, 2006). By doing so, it not only enriches the educational experience but also promotes cultural sensitivity and sustainability (Bannister & Nevin, 2017).

Metacognitive skills, including self-regulation, reflection, and adaptive thinking, have been identified as critical components of effective learning (Schraw & Moshman, 1995). Metacognitive skills are the skills and processes used to guide, plan, monitor, control, and evaluate or regulate cognition and learning (Veenman, 2011; Mega *et al*., 2018; Syahmani *et al*., 2020). Metacognitive skills are skills that generate feedback about the current learning process. Metacognitive skills can be considered the skills to apply metacognitive orientation and representation (Desoete, 2001; Thomas, 2013), planning, monitoring, and evaluating (Herscovitz *et al*., 2012; Wengrowicz *et al*., 2018; Amini & Syahmani, 2019). Similarly, higher-order thinking skills such as critical thinking, problem-solving, and creative synthesis are essential for students to navigate complex challenges (Anderson *et al*., 2001). Integrating indigenous knowledge through Ethno-STEM-5E approaches may have a profound impact on the development of these skills, as it requires students to engage deeply with diverse perspectives and alternative knowledge systems.

The Ethno-STEM-5E learning approach includes five stages: (1) engaging, (2) exploring, (3) explaining, (4) elaborating or extending, and (5) evaluating (Bybee, 2015; Cheng *et al*., 2016; DeCoito, 2015, 2018). Link the stages of the engineering design process (EDP): ask, imagine, plan, create, and improve (Shahali, 2016; Syukri, 2016). STEM education develops and synergies with existing learning. STEM is combined with inquiry (Birney & Cronin, 2018; Psycharis, 2016; Lai, 2018; Rachmayati *et al*., 2020; Syahmani *et al*., 2021). In Ethno-STEM, students can directly experience and frequently encounter learning that is integrated with ethnoscience (local culture), which results in meaningful learning for them (Darling-Hammond et al., 2020). Students are also helped to understand the material through this contextual learning with local culture (art) (Yakman *et al*., 2012). It has been demonstrated that STEM instruction that incorporates ethno (local culture) and links scientific ideas with indigenous knowledge of society, technology, engineering, and

Journal of Wetlands Environmental Management
Vol 11, No 2 (2023) 108 - 125
http://dx.doi.org/10.20527/jwem.v11. i2.447

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

mathematics improves students' problem-solving, innovative and creative thinking, critical and analytical thinking skills (Sumarni & Kadarwati, 2020; Sudarmin et al., 2020), metacognitive skills (Mevarech and Fan, 2018), students' attitude, and scientific literacy (Fasasi, 2017; Fitria, 2018).

Despite the growing interest in indigenous knowledge integration and Etno-STEM-5E, there is a notable dearth of research that explores the practical application of Etno-STEM-5E principles within the context of phytochemistry education. While some studies have examined the infusion of indigenous knowledge in STEM disciplines, few have ventured into the nuanced domain of phytochemistry. Furthermore, the precise influence of Etno-STEM on students' metacognitive skills and HOTSEP in the context of phytochemistry remains largely uncharted territory. This research seeks to address these gaps by conducting a comprehensive investigation into the integration of Etno-STEM in phytochemistry education and its implications for enhancing students' metacognitive skills and HOTSEP. This research aims to explore the diversity of local (Ethno)-STEM culture, design it, and use it as a transformative tool to enhance students' metacognitive and higher-order thinking skills, with a specific focus on addressing pressing environmental issues.

METHODS

This research employs qualitative methods to provide a comprehensive understanding of the integration of Ethno-STEM in Phytochemistry education and its impact on students' metacognitive skills and higher-order thinking abilities regarding environmental problems. In this study, an exploratory qualitative method is used with ethnographic techniques. The concepts present in an event or phenomenon can be examined using the ethnographic method (Gulo, 2010). This ethnochemical investigation looks at local knowledge found in Banjar's (South Kalimantan's) natural resources. A chemistry learning tool that can be used to instruct university students has been created using the investigation's findings. The study's participants included academics and community leaders who are familiar with Banjar ethno-chemistry.

Researchers begin with four general questions when conducting ethnographic research: "Where to start looking?" "How to look?" "How to recognize that you have found something significant?" and "How to understand what it is?" These inquiries encapsulate the fundamentals of ethnography. According to these four general questions, Table 1 lists the stages of the research.

In this study, an exploratory qualitative method is used with ethnographic techniques, knowledge extraction from indigenous communities, and laboratory investigations into the phytochemical properties of local flora. In order to learn phytochemistry, we are exploring the potential of Banjar, South Kalimantan's traditional ethnoscience heritage. The subjects of this research are community leaders and academics who understand Banjar culture and ethnoscience. Data collection was carried out through observation, interviews, and supporting journal article literature. The research tools used were 1) interview guidelines, which were used to examine or explore information about Banjar ethnoscience from informants or subjects; and 2) observation guidelines, which were used to watch how Banjar ethno-chemical knowledge is developed. According to Koentjaraningrat (2015), there are seven main descriptions produced by ethnographers in ethnographic research: language, technology

Journal of Wetlands Environmental Management
Vol 11, No 2 (2023) 108 - 125
http://dx.doi.org/10.20527/jwem.v11. i2.447

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ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

systems, economic systems, social organizations, knowledge systems, arts, and religion. In this study, the researcher will concentrate on three main descriptions: the knowledge system, art (value), and technology. This is because, in order to analyze the methods used by the community to create *Sasirangan* motifs, the researcher must first observe and delve into the knowledge and art systems. For instance, the researcher will look for the knowledge base used in the creation of *Sasirangan* motifs, technology, and cultural values contained in the *Sasirangan* motif art. However, because of their connections, it does not preclude the study of additional cultural aspects. The three main parts of data analysis techniques are reduction, presentation, and conclusion (Miles & Huberman, 1992).

Table 1. Design of Ethnography Research

General Questions	Example Initial Answers	Starting Point	Specific Activity
Where to start looking?	In the activities of making *Sasirangan* motif carried out by the people of Banjar's where there are etnosciences and phytochemistry practices in it.	Culture	Conducting interviews with people who have knowledge of Banjarnese culture in the South Kalimantan's community or those who make *Sasirangan* motifs in Banjarmasin.
How to look?	Investigating the motif aspects of the making *Sasirangan* activities of the people of Banjarmasin related to etnosciences practice.	Alternative thinking and knowledge system	Determine what ideas are contained in making sasirangan motifs activities of the people of Banjarmasin related to etnosciences practice.
What it is?	Evidence (Results of alternative thinking in the previous process)	Philosophy of etnosciences	Identifying evidence in the activity of making *Sasirangan* motifs in Banjarmasin society related to etnosciences practice. It shows that the activity of making *Sasirangan* motifs for the people of Banjarmasin does have a etnosciences character seen from the elements of knowledge and art systems used ineveryday life.
What it means?	Valued important for culture and important value patterns for etnosciences	Anthropologist	Describe etnosciences or phytochemistry conceptions that exist in the activity of making *Sasirangan* motifs for the people of Banjarmasin.

RESULTS AND DISCUSSION

The results of this research show the important role of metacognitive skills in the learning process because they facilitate orientation-representation, planning, monitoring, and evaluation skills. The integration of Ethno-STEM knowledge not only enriches students' understanding of phytochemistry but also encourages the development of higher-order thinking skills for environmental problems (HOTSEP), including critical thinking, problem solving, and developing creative innovations to overcome environmental problems in the field of phytochemistry. The learning sources for this research, phytochemistry, and social scientific problems (context problems), are as follows.

Sasirangan Cloth

The Banjar tribe of South Kalimantan is known for its distinctive *Sasirangan* cloth. The term "*Sasirangan*" refers to the method of stretching or "crossing" the fabric while using colored dyes. Due to its reputation for possessing magical properties, cloth was previously only produced on request or as part of a parmintaan for medical purposes. According to Seman (2020), a treatment method based on a person's previous healer's instructions is

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

cloth the request. To ward off bad spirits and provide protection from spirits, a method known as batatamba is used.

Initially, *Sasirangan* cloth was suitable for use as belts, shawls, *laungs* (headbands), *kakambans* (headscarves), and men's cloth sarongs (*tapih bumin*). *Sasirangan*, however, has now become common clothing, and as fashion has become more globalized, its sacredness is dwindling and becoming more diverse. Many *Sasirangan* craftsmen have produced new variations that are thought to be appropriate for the current state of development.

Natural-dyed *Sasirangan* cloth is one of the cultural heritages of the Banjar kingdom. *Sasirangan* cloth was originally made using natural dyes. As time progressed, *Sasiranga*n cloth was made using synthetic dyes. However, along with the dangers of synthetic dyes, which can cause environmental pollution, *Sasirangan* craftsmen are now starting to switch back to using natural dyes. The local wisdom of the Banjar people, which is included in ethnoscience, categories, descriptions, types of plants for *Sasirangan* cloth, and their compound content are presented in Table 2.

Table 2. Types of plants for *Sasirangan* cloth

Ethnoscience and category	Description	Plants and Compound Content
Sasirangan (Local crafts)	Basting is a sewing technique used to create motifs on traditional Banjar cloth. The traditional steps for creating *Sasirangan* cloth include designing the motif, knitting, soaking, unknitting, washing, and ironing. The various motifs and colors used in *Sasirangan* cloth have a unique meaning.	*Sasirangan* natural dyes include teak leaves (*Tectona grandis*) to produce red color, indigo leaves (*Indigofera*) to produce blue color, ketapang leaves (*Terminalia catapa)* to produce cream color, and guava leaves (*Psidium guajava*) to produce green color. The types of fruit peel that can be used as natural dyes include secang fruit peel, which produces a purple color. Then rambutan rind (*Nephelium lappaceum*) produces a brown color. Onion skin and bark tree of the Bangkal (*Nauclea* sp.), tegeran wood (*Cudrania javanensis*), and turmeric (*Curcuma longa*) produce a yellow color. Other plant parts, such as ironwood sawdust (*Eusideroxylon zwageri*), can also be used to produce a dark brown color. Reddish-purple is produced by the rind of mangostana (*Garcinia mangostana*) and wild mangosteen (*Sandoricum koetjape*) to produce purple and blue colors. Orange from gincu/mango fruit (*Mangifera indica*) and mango leaves. From lotus (*Nymphaea lotus*), we get black. To produce certain colors, the ingredients above can also be combined. For example, turmeric and blue Indigofera produce green.

Natural textile dyes are frequently produced by extracting plant materials from the root, wood, leaf, or flower seed (Shahid & Mohammad, 2013; Baliarsigh et al., 2012). The interview findings revealed that color blending is necessary to achieve excellent color. According to Ganie (2014), the definition of *Sasirangan* cloth is "a type of cloth that is given images with particular motifs and colors that have been patterned traditionally according to genius local cultural flavors that are typical of the Banjar ethnic group in South Kalimantan." *Sasirangan* textiles' natural motifs serve as a teaching tool in addition to adding aesthetic value. *Sasirangan* cloth can thus be used as a teaching tool for character education in both the classroom and the wider community. In addition, it will enhance the cultural outcomes of society with a feeling of love and pride. *Sasirangan* fabric motifs include the following aspects of character education: 1) religious; 2) nationalist; 3) independent; 4) mutual cooperation; and 5) integrity.

Motifs contain the embodiment of religious aspects through (1) the *Bintang* motif, which is an attitude of faith and gratitude towards God, and (2) the *Kangkung Kaombakan* motif, namely an attitude of faith and devotion to God. The *Laju Bakayuh* motif is the nationalist aspect's embodiment; it is a mindset of love for one's country, national spirit, and willingness to make sacrifices for its overall good. The *Sinampur*

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Karang Wave motif, which represents the attitude of never giving up, being tough, and thinking critically, and the *Kulat Karikit* motif, which represents self-confidence, self-development, and creativity, serve as the embodiments of the independent aspect. The idea of reciprocal cooperation is embodied. In the *Kambang Kacang* motif, the attitude of liking to talk, socialize, and work is the same, and through the *Pucuk Rabung* motif, namely a friendly, intimate, polite, friendly, and mutual attitude value. The *Gigi Haruan* motif represents a conscientious attitude and critical thinking, and the *Ular Lidi* motif represents a careful attitude, precision, and quickness.

Three coloring techniques can be used to create *Sasirangan* cloth using natural dyes. 1) Direct Process: In this method, the natural dyes are prepared by pounding or blending them. After being boiled, the water is used to dye fabric. This method of staining results in a thin, non-thick color. 2) Fermentation Process: The fermentation process is carried out by soaking or rotting leaves or wood in water while performing particular procedures. 3) Extraction Process: Boiling the substances used to make dyes allows for the extraction of the materials. The fabric is dipped into the dye liquid after the desired color has been achieved.

So that the resulting textile color does not fade easily, is brilliant, and is in demand, in the dyeing or staining process, it is necessary to add a material that can function as a mordant or fixator (binder) for dyes. Fixation materials need to be chosen from materials that are environmentally friendly and non-toxic so that they do not become a problem for the environment. Binding materials that are often used in the *Sasirangan*/batik fabric industry include lime, vinegar, saltpeter, borax, alum, rock sugar, Javanese sugar, palm sugar, tunjung, prusi, molasses, lime water, tape, klutuk banana, and klutuk guava leaves. The advantage of *Sasirangan* fabric using natural dyes, apart from being environmentally friendly, is also that the colors produced are softer, calmer, and not as sharp as synthetic colored *Sasirangan*. However, pastel colors produced from natural dyes are popular with foreign buyers.

Natural Dyes for Food and Beverages from Wetland Plants

The synthetic colors methane yellow and rhodamine B, which are used to color foods yellow and red, respectively, have been outlawed by the government. As an alternative, individuals are urged to use natural food and drink colorings derived from plants, such as turmeric and ginger rhizomes (yellow), tomatoes, rossella flowers, and dragon fruit (red). While turmeric and ginger contain curcumin, which serves as an antioxidant, dragon fruit, tomatoes, lycopene, anthocyanins, and rosella flowers all contain tannins. This substance has the ability to bind and capture free radicals both outside and inside the body, preventing cancer. Table 3 presents the ethno-scientific categories, descriptions, and types of local knowledge used by the Banjar people for foods, beverages, and natural dyes, as well as the compounds they contain.

Journal of Wetlands Environmental Management
Vol 11, No 2 (2023) 108 - 125
http://dx.doi.org/10.20527/jwem.v11. i2.447

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Table 3 Type plant for natural dyes food and beverages

Ethnoscience and category	*Description*	*Plants and Compound Content*
Natural dyes from wetland plants (Local stuff)	Natural dyes can be obtained from nature and used to color natural foods and beverages.	Dragon fruit (*Hylocereus polyrhizus*) contains tannins (red color); Tomato fruit (*Solanum lycopersicum* L) contains lycopene (red color) Rosella flower (*Hibiscus sabdariffa* L.) contains anthocyanin (red color); Turmeric (*Curcuma longa*) and Javanese turmeric (*Cucurma xanthorrhiza*) contain curcumin (yellow); Pandan leaves (*Pandanus ammaryllifolius* Roxb) contain chlorophyll (green color).

Local Potential as Antibacterials, Biopesticides, and Pheromone

Manginang is the practice of chewing an areca nut and lime mixture that has been wrapped in betel leaves. Banjar women in particular have passed down the tradition of *manginang* from generation to generation. Every home used to have a *panginangan* complete with a *pakucuran*, which is a container for disposing of the *sepah* or spitting out the host's remains. The typical *panginangan*, which is used to store betel, areca nut, gambier, lime, tobacco, and kacip, is made of copper and is square or round in shape. Typically, carvings of flowers and fruit are used to decorate the penginangan's exterior. It represents fertility and benefits, according to Banjar carving tradition. The *manginang* tradition is beneficial for teeth whitening as well. Additionally, it serves as a conversation opener, allowing the host to extend the invitation first if guests arrive. That is also a way to improve ties between brothers and families.

In South Kalimantan, the air is quite hot, which frequently causes the skin to darken quickly, dry out easily, and crack. In the past, Banjarese people—particularly women—used a lot of *pupur dingin* to treat it and shield their skin from the sun. This powder's main ingredient, rice, which is rich in vitamin B and thiamine, can keep skin hydrated and smooth. The skin stings, especially if used in the middle of the day when the sun is intense. Making this powder is a very easy process. The rice must first be twice-soaked, with the water being changed every 24 hours. If the rice crumbles when pressed, drain the rice until the water content is dry. Following the grinding of the rice into flour, a little bit of water, natural scents like rose or cape flower, and the flour are combined to form a dough. Following that, the dough must be rolled into tiny balls and dried in the sun until completely dry. You only need to take a small amount of the cold powder, crush it with a little water, and then sweep it over your entire face, including your ears.

People also use lime fruit, betel leaves, ylang flower, and red ginger rhizome as antibacterial soap. According to research by Brochot *et al*. (2017), plant-derived essential oil blends have antibacterial, antifungal, and antiviral properties.

The presence of terpenoid, flavonoid, saponin, and quinone compounds in the flowers and leaves of *M. cajuputi* may have contributed to the antibacterial effects of the methanol extracts on *Staphylococcus epidermidis*, *Staphylococcus aureus*, and *Bacillus cereus* (Ukit *et al*., 2019; Al-Abd *et al*., 2015). Aside from Galam leaves and flowers (*Melaleuca leucadendron* L.) and Bintaro fruit and leaves (*Cerbera manghas* Boiteau), this local knowledge also mentions armyworms (*Spodoptera litura*), pests of green vegetable crops, as effective biopesticides. Meanwhile, methyl eugenol, found in clove leaves, acts as a pheromone to attract male insects and as a sex attractant.

Table 4 presents categories, descriptions, and the active compounds that serve as biopesticides, pheromones, and anti-bacterials, as well as the local tradition and local potential.

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Table 4 Type plant for the local tradition and local potential.

Ethnoscience and category	*Description*	*Plants and Compound Content*
Manginang (local tradition)	The betel process carried out by the Dayak and Banjar communities generally uses one of the medicinal plants, namely betel, which is rolled up and filled with lime, areca nuts, and tobacco, which is then chewed.	Sirih leaves (*Piper betle* L)*:* essential oils, hydroxychavicol, chavicol, cavibetol, allylpyrocatekol, cineole, caryophyllene, cadinene, estragol, terpennena, flavonoid, polyphenols, and tannins (Nayaka, 2021; Carolia & Noventi, 2016). Areca nut seeds contain alkaloids such as arekoline, arekolidine, arekain, guvalokin, guvasine, and isoguvasine.
Bapupur Dingin and Bapupur Bangkal (Local tradition)	The traditional Kalimantan powder that girls wear to the fields is generally made from softened rice and mixed with various additional herbal ingredients.	Rice (*Oryza sativa sp.*) is rich in vitamin B and thiamine. Bangkal (*Nauclea sp.*) stembarks contain alkaloids, terpenes, saponins, tannins, flavonoids, anthraquinones, steroids, glyco-alkaloids, hydrocyanic acid, quinone phenols, resins, vitamin A and vitamin C, polyphenols, carotenoids, limonoids, xanthonoids, balsam, and phlobatnins (Maitera et al., 2011; Anowi et al., 2012; Udobre et al., 2012; Ifemeje et al., 2014).
Lime fruit, Sirih leaves, and Ylang-Ylang flower, Red ginger rhizome *(local plant antibacterial)*	People use lime fruit, betel leaves, ylang flower, and red ginger rhizome as an antibacterial soap.	Lime fruit *(Citrus aurantiifolia)* contains citral, germacrene, flavonoids, eriositrin, and hesperidin. Ylang-Ylang flowers (*Cananga odoratum*) contain the following antimicrobial compounds: γ-linalool, geraniol, Eugenol, α and β-caryophyllene, pinene, and cadinene (Tan, 2015). Red ginger (*Zingiber officinale* Linn) contains quercetin, gingerol, and oleoresin.
Kayu putih, Galam, and Bintaro *(local plant bio-pesticides)*	Galam leaf and flower (*Melaleuca leucadendron* L.), Bintaro (*Cerbera manghas* Boiteau) fruit and leaves are effective for biopesticides against armyworms (*S. litura)*, which are pests of green vegetable crops.	Kayu putih (*Melaleuca cajuputi*) leaves and flowers contain 60% cineol, terpenes, flavonoids, saponins, and quinone compounds. Galam (*Melaleuca leucadendron* L.) leaves and flowers contains cineol (7–14%) and terpene. Bintaro (*Cerbera manghas* Boiteau) leaves contain alkaloids, saponins, polyphenols, and antrakuinon. Binahong fruit contains saponin.
Clove leaves (*local plant* pheromone)	Methyl eugenol, found in clove leaves, acts as a pheromone to attract male insects and as a sex attractant.	Clove leaves (*Syzygium aromaticum* L.) contain methyl eugenol.

Ethno-STEM experience-based learning activities design "bioproduct creation for environmental protection".

Flexible guidelines and procedures are used in the planning and management of Ethno-STEM experience-based learning activities. However, when creating lesson plans, teachers must be mindful of the principles of Ethno-STEM education, including meeting teaching objectives, ensuring scientific content knowledge and program requirements, adhering to local teaching practices and being pertinent to student characteristics, mentioning learning products in the lesson plan, and having a variety of learning spaces and times. With these as the guiding principles, the structure of the plan to arrange Ethno-STEM experience-based learning activities "Making bio-products for environmental protection" is created, including making natural *Sasirangan* and foods and beverages dyes, biopesticides, and pheromone.

The Ethno-STEM-5E is a constructivism-based course, meaning that students must create their own knowledge and understanding through projects. The project in question employs the inquiry learning model syntax, which essentially calls for understanding the idea of material as knowledge and then making use of technology to clarify the idea. Additionally, the project's design will be based on art, which is then methodically described. According to Ma'arif et al. (2020), the Ethno-STEM-5E is a constructivist and cognitive learning theory-based learning model. Table 5 gives the Ethno-STEM-5E learning model's syntax.

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Table 5. The syntax of developing the Ethno-STEM-5E learning model.

Syntax of learning	Learning activities		Metacognitive skills	HOTSEP
	Teacher's activities	Students' activities		
Ask (Engaging)	The teacher gives apperception. The instructor incorporates material from several disciplines (science). The class is presented with real-world issues by the teacher.	Students make connections between their prior knowledge and new information on actual issues. Students carefully listen to the problems (***Science)***	Orientation and representation problem	Criticizing environmental/ ethnoscience issues (C4)
Imagine (Exploring)	The instructor helps the class interpret and analyze social or natural phenomena. Students are encouraged to use metacognitive skills and HOTSEP.	Students examine and record social or natural phenomena.		
Plan (Explaining)	Facilitate students to plan problem solving, research, and ask questions. (***Engineering, Technology***). Teachers will encourage students to explain concepts, claim them with evidence, and participate in discussion activities.	Students actively participate in planning, designing, and posing questions. ***(Engineering, Technology).*** The results of the previous discussion have been interpreted by the students.	Planning	Solving environmental problems (C5)
Create (Elaborating/ Extension)	The teacher helps the students apply their knowledge and abilities in the workplace. ***(Mathematical, Engineering, Local Culture).***	Students apply knowledge and abilities to making products. ***(Engineering, Mathematic, Local Culture).*** Many works are actively developed with students' participation	Monitoring	Developing innovations about the environment (C6)
Improve (Evaluating)	The instructor assesses the student's knowledge, conceptual understanding, and skill.	As part of the evaluation process, teachers may ask students questions or administer assessments	Evaluating	

Tabel 6 The indicator of assessment of metacognition skills and students' HOTSEP

No	Skills rubric assessment	
	Metacognitive skills	HOTSEP
1.	Orientation and representation problems with comprehension questions a. What is the problem about? b. What are the data?	Criticizing environmental and ethnoscientific issues a. Inventory of plants for traditional medicine and related culture and ethnoscience b. To identify terpenes or essential oils' compounds
2.	Planning with strategic questions c. What strategy can be used in order to solve the problem? d. Why is this strategy most appropriate for solving the problem?	Solving environmental problems a. Designing a steam distillation apparatus for producing essential oils b. Analyzing the data from screening tests and isolation results. c. Interpreting spectroscopy data.
3.	Monitoring and checking questions d. How can the suggested plan be carried out?	
4.	Evaluating with a reflection question f. Does the solution make sense?	Developing innovations about the environment. a. Reflection on the quality of essential oil products. b. Evaluating the diversification of the use of essential oils in everyday life.

The teacher's function in the Ethno-STEM-5E learning model changes from knowledge provider to experience facilitator. To fully comprehend science, much of it must be experienced through the senses, and the more genuine the experience, the better. Multiple phases of inquiry, knowledge acquisition, and application have been successfully used in approaches like the Ethno-STEM-5E model to support students' metacognitive skills.

Journal of Wetlands Environmental Management
Vol 11, No 2 (2023) 108 - 125
http://dx.doi.org/10.20527/jwem.v11. i2.447

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

The students' metacognitive skills aspects studied are orientation and representation problems, planning, monitoring, and evaluating. As for students' HOTSEP aspects, namely criticizing environmental/ethnoscience issues, solving environmental problems, and developing innovations about the environment. The indicator of assessment of both variables based on their respective aspects can be seen in Table 6.

The Analysis of the Sasirangan Process Based on the Ethno-STEM Aspects

According to scientific reconstruction (Sudarmin *et al*., 2019), the process was based on an ethno-STEM context. Following are the analysis's findings (Table 7).

The Analysis of Bioproduct Processes Based on the Ethno-STEM Aspects

Considering the side effects on the environment and health problems, the use of 36 types of active pesticide ingredients is prohibited, and the use of five other types of active ingredients is restricted (Permentan, 2007). So it is very important to get substitute materials for synthetic insecticides, which are one of the sources of environmental pollution. Numerous plant species are known to contain bioactive substances that can act as bioinsecticides and repellents, such as alkaloids, terpenoids, steroids, acetogenins, phenyl propane, and tannins. Among the roles played by active compounds in plants are those of repellent (repels the presence of insects), antifeedant (insects do not like plants sprayed with vegetable insecticides), inhibitor of the metamorphosis process (inhibits the development of insect stages such as eggs, larvae, and pupa), and (4) inhibits the female insect's reproductive system and disrupts the insect's hormone system (Soenandar & Tjachjono, 2012). Several types of plants that are often found in swamplands that have the potential to be vegetable insecticides include Galam leaves (*Melaleuca leucadendron* L.) and Bintaro fruit and leaves (*Cerbera manghas* Boiteau), which are effective for killing armyworms (*Spodoptera litura*).

In addition to being used as medicine, the Banjar and Dayak tribes of Kalimantan traditionally used bintaro fruit to ward off attacks from rats, mosquitoes, poisonous fish, and to hunt animals in the forest. The research results of Zailani et al. (2015) showed that Bintaro fruit extract at a dose of 10 ml/l could cause the death of mice with a knockdown effect, and could kill S. litura above 50% at a concentration of 1.5–2% (Purwani *et al*., 2014), and is able to kill 2nd and 3rd instar armyworm larvae, namely 86% and 82% (Thamrin *et al*., 2007, 2015).

Several varieties of wetland plants contain bioactive substances that act as antibacterials in addition to being biopesticides. In the pandemic era, synthetic antibacterial soap is a popular option for skin cleaning and for preventing or treating infectious diseases brought on by bacteria. DEA, sodium lauryl sulfate, and triclosan are examples of active ingredients found in commercial antibacterial soaps (Widyasanti et al., 2019). SLS (Sodium Lauryl Sulfate) can cause skin irritation (Sari & Ferdinan, 2017). Triclosan accumulation in the human body has been linked to thyroid dysfunction (Moningka et al., 2020). If the dosage is greater than the recommended concentration, it will cause skin irritation, be carcinogenic, and denaturate the protein molecule (Putra *et al*., 2016). An alternative is the use of antibacterial active substances from plants that are applied as active substances in liquid soap, which is used in daily activities.

Table 7 Analysis Ethno-STEM of natural dyes

Journal of Wetlands Environmental Management
Vol 11, No 2 (2023) 108 - 125
http://dx.doi.org/10.20527/jwem.v11. i2.447

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

Operating characteristics	Making *Sasirangan*	Making natural foods and beverages
Research questions	As time progressed, *Sasirangan* cloth was made using synthetic dyes, which can cause environmental pollution. How can we make *Sasirangan* using natural dyes?	The synthetic colors methane yellow and rhodamine B, which are used to color foods yellow and red, respectively, have been outlawed by the government. How to make and use natural dyes for foods and beverages?
Integrated content:		
Ethno	Dyestuffs. Natural dyes (pigments) of local plants; traditional motifs and value.	Dyestuffs. Natural dyes (pigments) of local plants
Science	Cotton is made of a polymer compound; the *Sasirangan* process	Foods and beverages
Technology	*Sasirangan* is made with only traditional methods and materials	Extraction of natural dyes
Engineering	*Sasirangan*-making techniques include the drawing motif, *menyirang/jelujur*, dyeing, scouring, and mordanting.	A variety of natural dyes, production techniques, and food items
Mathematics	Calculation of the formula and cost of the product.	Calculation of the formula and cost of the product.
Core activities:		
Preparation	Information on *Sasirangan* cloth, natural dyess (pigments) of local plant, raw materials, and facilities for hands-on learning.	Information on natural dyes for foods and beverages, raw materials, and facilities for hands-on learning.
Making products	Students collaborate in groups in class or at home; the objectives, supplies, and product-making techniques are explained.	Students collaborate in groups in class or at home; the objectives, supplies, and product-making techniques are explained.
Introducing products	Student organizations explain natural dyess, the *Sasirangan* process, and how to use the products.	Student organizations explain the natural dyes used in foods and beverages and how to use them.
Testing products	Making *Sasirangan*. The use of natural dyes in the *Sasirangan* process is promoted by students, who also regularly check and record the experimental results.	Making natural dyes for food. The use of natural dyes in foods and beverages is promoted by students, who also regularly check and record the experimental results.
Evaluating	A student's knowledge, metacognitive skills, and HOTSEP are evaluated by the instructor.	

The process for creating this antibacterial liquid soap involves using 250 mg of the herbal extract's active sample. After the mixture had partially solidified, it was later placed into a mold. A standard product was also created for soap without the extract.

The following will present Table 8 regarding Ethno-STEM analysis related to bioproducts such as biopesticides, insect pheromones, and antibacterial liquid soap.

Aspects of metacognition skills include orientation and representation, planning, monitoring, and evaluation. This is in line with research showing that contextual problem-based learning will demonstrate students' awareness of problem-solving starting with representational skills (Thomas, 2013), planning, monitoring, and evaluating (Amir & Wardana, 2018). In order to solve problems with greater confidence, students' metacognitive skills can help them develop a thorough understanding of the issues at hand and the logical arguments that support their solutions (Barbacena & Sy, 2015).

Students can use explicit representational skills to develop their metacognitive. The ability to choose strategies that will influence outcomes, such as making predictions, is known as planning. Monitoring is the capacity of someone who is aware of the testing and scheduling strategies to be used so that the results obtained become systematic and directed. Undergraduate students have the opportunity to evaluate their work while tackling problems. The use of metacognitive strategies in writing will be encouraged by students who are used to problem-solving techniques. If this practice becomes ingrained, it will lead students to go back to the first step in order to identify the error and fix it once more. Improvement in learning is also accelerated by an increase in metacognitive skills, which are crucial to establishing and sustaining

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

successful learning. According to studies (Senemolu, 2011; Syahmani *et al*., 2023), having students who are conscious of their own thoughts during the problem-solving process will increase achievement. This demonstrates how ethno-STEM phytochemistry can be used to train and enhance undergraduate students' HOTSEP and metacognition skills in a lecture setting using phytochemical learning resources. The findings indicate that Ethno-STEM learning resources benefit students and improve their skills.

Table 8 Analysis Ethno-STEM of Bioproduct

Operating characteristics	Creating biopesticides or insect pheromones	Making liquid soap antibacterial
Problems	How can we minimize environmental losses when using chemical pesticides?	How can we make formulas for liquid soaps that tend to be more effective in antibacterial activity?
Integrated content:		
Ethno	Swamp plants as raw materials for biopesticides	Swamp plants as raw materials for liquid antibacterial soap,
Science	Source of plant pests; the effects of biopesticides; methyl eugenol as insect sex attractants	Antibacterial soap is used as a solution because it is believed to clean the skin.
Technology	Environmentally friendly technology uses biopesticides; Fruit parasite fly catcher with used bottles and funnels	Maceration and extraction technology; Using simple tools in liquid antibacterial soap.
Engineering	Making inexpensive and simple biopesticides; Design of fruit parasite fly traps	Designing simple tools liquid soap antibacterial The liquid soap quality test
Mathematics	Cost of the product and formula calculation.	Cost of the product and formula calculation
Core activities:		
Preparation	Information on pesticides and herbs, insect pheromones, raw materials, and facilities for hands-on learning.	Information on extraction, phytochemical screening, liquid soap preparations, raw materials, and facilities for hands-on learning.
Making products	Students work in groups in class or at home, and the goals, materials, and product-making processes are explained.	Students collaborate in groups at a home or garden while learning about the goals, resources, and make liquid soap antibacterial procedure.
Introducing products	Student organizations explain methyl eugenol as insect pheromones, fruit parasite fly traps, biopesticide products (from bintaro fruit and galam leaves), and how to use the products.	Student organizations demonstrate how to use the liquid soap antibacterial products for daily activities through videos and photos.
Testing products	Using fruit parasite fly traps, biopesticides are sprayed on the right plants in the gardens. Students promote the use of biological pesticides and insect pheromones and frequently check and record the experimental results.	The herbal soap's antibacterial tests using the disc diffusion method. Students carry out experiments, document the results, and disseminate knowledge about Inhibition zones were compared to the control after being incubated at 37ºC for 24 hours to determine whether or not microbial growth was present.
Evaluating	The instructor assesses a student's knowledge, metacognitive skills, and HOTSEP.	

CONCLUSIONS & SUGGESTIONS

Indigenous knowledge, ethno-STEM design for phytochemical learning, metacognitive skill development, and higher-order thinking all work in concert. The findings of this study have the extraordinary potential to foster a generation that is environmentally aware and capable of problem-solving in addition to preserving and appreciating cultural heritage (Banjar ethnoscience). However, the study acknowledges limitations related to context specificity and potential participant bias. Future research should consider longitudinal studies, cross-cultural comparisons, and community involvement to expand our understanding of Etno-STEM's educational impact and its application in addressing environmental challenges, thus advancing culturally sensitive and sustainable pedagogical practices.

Only higher thinking levels and environmental topics were revised for this HOTSEP study, which has limited application. According to this study, a brand-new taxonomy should be created and

-----Accredited by Directorate General of Higher Education Indonesia, No. 158/E/KPT/2021, Valid until July 2025--

ISSN: 2354-5844(Print)
ISSN: 2477-5223 (Online)

finished for all subjects taught in secondary, postsecondary, and informal settings.

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