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Research article

Fostering creativity through culturally grounded STEAM out-of-school time activities: A case study of Lanna lantern making in northern Thailand

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Abstract: Culturally grounded out-of-school time (OST) activities offer promising opportunities for science, technology, engineering, art, and mathematics (STEAM) learning, yet few studies have examined how local cultural practices can be systematically designed as interdisciplinary contexts for fostering children's creativity. This qualitative design and development research study explored how a STEAM OST activity based on Lanna lantern making elicited creativity among upper elementary students in Northern Thailand. The activity was developed through field exploration, expert validation, and a seven-stage STEM inquiry process integrating science, technology, engineering, arts, and mathematics. Five students (N = 5) participated in a single six-hour implementation at Chiang Mai. Data were collected through video-supported structured observation using the A-to-E creativity framework, three-level field notes, artifact analysis, and informal member checking. Agency and connecting were the most frequently observed dimensions, particularly in students' self-directed design choices and the application of evidence from hands-on investigations to lantern construction. Experimenting and daring also appeared across participants. Being curious was less visible through behavioral observation alone, suggesting methodological limits in capturing internal states, such as wonder. Given the small purposive sample and single-session design, findings are intended as analytic rather than statistical generalizations. This study offers a contextually grounded design example of integrating cultural heritage into STEAM OST learning and illustrates how craft-based activities may support the expression of multiple dimensions of children's creativity.

Keywords: STEAM education, creativity, out-of-school time, Lanna cultural heritage, design and development research

1. Introduction

Creativity has been identified as a foundational competency for twenty-first-century learners, integral to problem-solving, scientific discovery, and social innovation [1,2]. Science, technology, engineering, art, and mathematics (STEAM) education is widely recognized as a vehicle for nurturing creativity, particularly when the art component encompasses authentic cultural practices [3,4]. However, formal classroom STEAM implementation is constrained by teacher shortages, rigid curricula, and standardized assessment pressures [5]. Out-of-school time (OST) programs have consequently attracted growing research interest as environments where open-ended, culturally situated inquiry can flourish [6–9].

The A-to-E creativity framework [10] is the most comprehensive behavioral observational framework currently available for identifying children's creative thinking in STEAM contexts. The framework comprises five dimensions and 30 behavioral indicators. Agency (A) captures six behaviors reflecting self-direction: self-determination, personal relevance, having purpose, autonomy, personal choice and care, and agility. Being curious (B) encompasses six indicators of inquiry orientation: questioning, wondering, observing and comparing, exploring, evaluating candidly, and expressing wonder. Connecting (C) addresses six knowledge-linking behaviors: making connections between the social problem and design decisions, applying investigation knowledge, comparing with evidence, cultural connection, peer feedback, and considering multiple perspectives. Daring (D) comprises six risk-taking behaviors: divergent design, unconventional material choices, new techniques, emergent problem-solving, accepting feedback, and confident public presentation. Experimenting (E) encompasses six iterative behaviors: trial and error, comparing approaches, modifying the artifact, reflective learning, sharing process, and proposing further development. Several characteristics make this framework particularly well-suited to evaluating creativity in STEAM education. First, it was explicitly designed for naturalistic observation in making and designing contexts, producing behavioral evidence rather than self-reported or product-only data [10]. Second, its five dimensions align with the construct of "little-c" or everyday creativity [11] (i.e., the kind most relevant to primary education) rather than domain-specific expert performance. Third, the framework is culturally inclusive, positioning cultural connection (C4) as an indicator rather than a contextual variable, thereby integrating rather than othering cultural identity in creativity assessment. Fourth, it has demonstrated cross-contextual validity: Tippett and Gonzalez [11] reanalyzed data from 52 science, technology, engineering, and mathematics (STEM) creativity episodes and confirmed agency as the most frequently observed dimension, while also identifying a systematic underestimation of being curious through behavioral observation alone, a methodological insight directly relevant to field-based STEAM OST research. These properties collectively make the A-to-E framework a uniquely appropriate evaluative lens for creativity in culturally grounded STEAM out-of-school time settings.

Three gaps in the existing literature motivated this study. The A-to-E framework has not been applied to a non-digital, craft-based OST setting in Southeast Asia; its validation base remains concentrated in digital technology and early childhood contexts in Western countries. Northern

Thailand's Lanna cultural heritage, despite embedding authentic STEAM content across all five domains within living craft practices, has not been systematically developed as a STEAM learning context with expert-validated activity plans and empirical implementation data. Third, Sutaphan and Yuenyong's seven-stage STEM inquiry learning process [12] and the A-to-E framework [10] have not previously been co-aligned as a dual instructional-evaluative design system.

This study addresses all three gaps through a three-phase design and development research study. The primary research question was: How does a culturally grounded STEAM OST activity based on Lanna lantern making elicit creative inquiry in upper elementary students, as evidenced across the five A-to-E dimensions and assessed through a three-level rubric?

2. Conceptual framework

The conceptual framework of this study (Figure 1) integrates four mutually constitutive components into a unified system oriented toward enhancing students' creative inquiry. The first component, STEAM education, provides the interdisciplinary content foundation across science, technology, engineering, arts, and mathematics. It connects directly to the second component, the seven-stage STEM inquiry learning process [12], which provides the instructional architecture: students move from identifying an authentic social issue (Stage 1) through solution ideation (Stage 2), knowledge investigation (Stage 3), decision-making (Stage 4), prototype construction (Stage 5), testing and evaluation (Stage 6), and public socialization (Stage 7). The third component, Lanna cultural OST setting, provides the context: the living craft traditions of Northern Thailand supply the culturally authentic social problem, the making materials, the aesthetic vocabulary, and the community mentors. This context-component is not merely background but an active learning resource that connects new knowledge to existing funds of knowledge [13]. The fourth component, the A-to-E creativity framework [10], provides the evaluative lens through which creative thinking is observed, coded, and interpreted. In this study, a three-level rubric (emerging, developing, proficient) was developed and applied over the binary presence/absence coding of the original framework, allowing for differentiated assessment of creative inquiry depth rather than mere occurrence. The four components interact in specific ways: STEAM content determines which investigation activities are designed in Stages 3–4; the cultural context determines which social issue anchors Stage 1 and which aesthetic traditions are available in Stage 5; the inquiry process structures when each A-to-E dimension is most likely to emerge; and the creativity framework provides the post-hoc evaluative instrument. The central outcome (i.e., enhancing students' creative inquiry) is produced by the interaction of all four components, not by any single element in isolation.

2.1. STEAM education, cultural heritage, and creativity

STEAM education extends STEM by incorporating art as a dimension that connects technical knowledge with cultural meaning and aesthetic expression [3]. Aguilera and Ortiz-Revilla's [3] systematic review confirmed a positive relationship between STEAM education and student creativity. Culturally embedded STEAM activities consistently produce deeper engagement and more authentic creative expression than decontextualized approaches [8]. In Thailand, naturalistic observations of Grade 4 science classrooms confirmed that constructivist practice is severely limited in larger schools [14], confirming that formal classroom settings provide minimal conditions for the creative, open-ended learning that STEAM OST programs can offer.

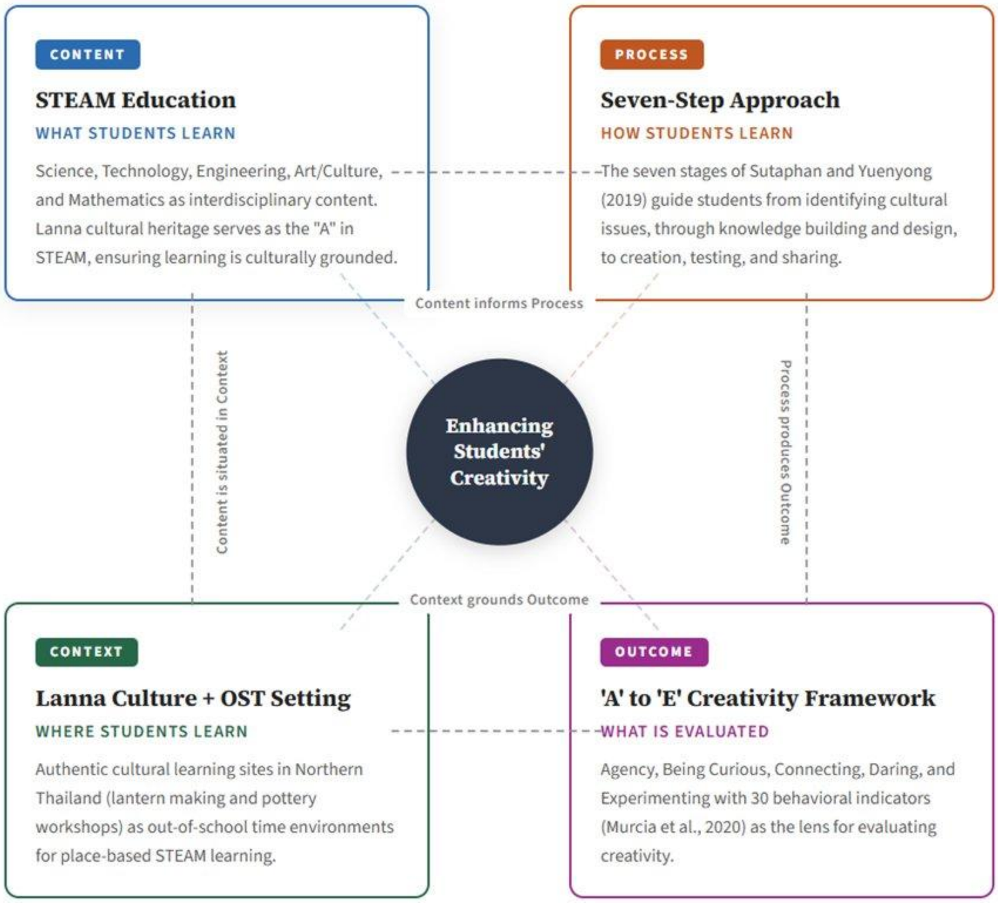

Figure 1. Conceptual framework of the study.

2.2. Creativity: Theoretical foundations and the role of culture

Creativity is widely understood as a complex, multifaceted construct. Most scholars agree that it involves two core criteria: originality, producing something new or novel, and fitness-for-purpose, the outcome must be appropriate and useful for the task at hand [15]. Kaufman and Beghetto [16] proposed a four-level model distinguishing big-c (extraordinary eminent contributions), pro-c (professional expertise-level creativity), little-c (everyday creativity), and mini-c (personal, subjective insights new and meaningful to the individual). For elementary students in informal learning settings, mini-c and little-c are most relevant: insights and actions that are new to the child, even if not new to the world. This study's use of the A-to-E framework aligns directly with this understanding: its behavioral indicators target the observable expressions of mini-c and little-c creativity in action during a craft-based design task.

Craft [17] introduced the concept of "possibility thinking" to describe children's creative exploration of the transition from "what is" to "what might be", creative thinking driven by curiosity, questioning, and open-ended exploration. This construct maps closely onto the being curious (B) and daring (D) dimensions of the A-to-E framework, providing a theoretical bridge between the framework's behavioral indicators and the broader creativity literature. Research consistently shows that elementary-aged children are naturally inclined toward this form of creative exploration, but that creative tendencies decline as schooling increasingly emphasizes conformity and standardized assessment [18]. STEAM OST activities offer a counter-environment: one in which the absence of evaluative pressure creates conditions for mini-c and little-c creativity to emerge [6,7].

The question of whether creativity is culturally situated has received growing attention in recent decades. Glavəanu [19] argues that creativity is fundamentally dialogic and distributed: it does not reside in an individual alone but emerges at the intersection between a person, their cultural tools and resources, and a community audience. This "cultural psychology of creativity" perspective implies that what counts as creative, and what enables creative expression, is shaped by the cultural context in which a learner operates. In the present study, this has a direct methodological implication: the A-to-E framework, developed by an Australian research team [10], uses behavioral indicators that are broadly cross-contextual (e.g., modifying an artifact, asking questions beyond the minimum required). The framework's explicit inclusion of a cultural connection indicator (C4, connecting one's artifact to craft traditions observed during the activity) is evidence of its cultural inclusiveness. In the Lanna context, this indicator was operationalized through zodiac motifs, tung-tail decorative elements, and connections to the Yi Peng festival tradition, cultural referents immediately meaningful to the Shan children at Ban Muang Phinong. No indicators required modification for the Northern Thai context; however, the behavioral anchors for several being curious indicators were supplemented by member checking data to capture culturally quieter forms of curiosity, consistent with the more reserved interactional norms of the Shan community. This finding extends Tippett and Gonzalez's [11] argument about the systematic underestimation of being curious to a specifically cultural dimension: behavioral silence does not mean cognitive stillness.

The cultural grounding of the activity supported creativity through three specific mechanisms. First, it provided an authentic problem (the lantern portability challenge experienced by night bazaar craftsmen) that connected the design task to a real community, giving children a genuine reason to care about the solution [9,13]. Second, the Lanna aesthetic vocabulary, the zodiac motifs, the tung-tail element, the recognizable visual language of khom lanna, provided a shared creative resource that children could draw on without instruction, activating cultural identity as a generative content rather than a mere backdrop. Third, the craft community setting itself validated a form of knowing tactile, spatial, and traditional, that formal schooling rarely legitimizes, creating conditions in which, children who might perform modestly in a classroom context could excel as creative designers.

2.3. The seven-stage STEM inquiry learning process

Sutaphan and Yuenyong [12] proposed the seven-stage STEM inquiry learning process as a context-based instructional framework beginning with an authentic real-world problem and culminating in the sharing of solutions, explicitly situating STEAM learning within students' cultural and community context [20].

2.4. The A-to-E creativity framework and the creative inquiry rubric

As described in the Introduction, Murcia et al. [10] developed the A-to-E creativity framework as a qualitative observational tool comprising five dimensions and 30 behavioral indicators. While the original framework uses binary presence/absence coding, this study extends its application by developing a three-level rubric for assessing creative inquiry depth.

The rubric maps the number of observed indicators per dimension onto three levels: emerging (1–2 indicators observed); developing (3–4 indicators observed); and proficient (5–6 indicators observed). The threshold values of 1–2, 3–4, and 5–6 were selected on pragmatic and descriptive grounds rather than empirically calibrated cut-points: given six indicators per dimension, these three bands represent the lower, middle, and upper thirds of the possible range. The rubric was pilot-tested informally during the expert validation phase (Phase 2), where panel members reviewed indicator coding against sample video segments and confirmed that the three-level differentiation was meaningfully interpretable. Importantly, the rubric should be understood as a descriptive heuristic, a tool for organizing and communicating qualitative variation, rather than a validated psychometric instrument. It does not claim to measure “amount of creativity”; it organizes the breadth of observed creative behaviors within each dimension to support qualitative comparison across participants. The rubric also does not assume equal weighting across indicators: some indicators (e.g., D3, experimenting with a new technique) may represent a qualitatively more demanding form of creative expression than others (e.g., D6, presenting work confidently). For this reason, the narrative accounts in Section 4.1–4.5 are essential companions to the rubric scores: they provide the qualitative depth that the indicator count cannot capture. The complete 30-indicator operationalization is presented in Appendix A.

Table 1. Three-level creative inquiry rubric applied to each A-to-E dimension.

Level	**Indicators observed / 6**	**Descriptor**	**Implication for creative inquiry**
0 – Not observed	0/6	No behavioral evidence of this dimension was recorded across any data source.	The activity context or participant disposition did not activate this dimension within the session.
1 – Emerging	1–2/6	One or two indicators present; creative inquiry in this dimension is beginning to surface but is not yet consistent or self-sustaining.	Prompting or extended exposure may be needed to develop this dimension further.
2 – Developing	3–4/6	Three or four indicators present; creative inquiry is evident across multiple aspects of the dimension with some consistency.	The student engages creatively across several aspects of this dimension; further development is possible with more open-ended challenge.
3 – Proficient	5–6/6	Five or six indicators present; creative inquiry across this dimension is sustained, multi-faceted, and independently driven.	The student demonstrates comprehensive creative engagement characteristic of the full dimension; qualitative evidence typically reveals sophisticated reasoning.

Note: Rubric levels are applied per dimension per participant based on the number of A-to-E behavioral indicators observed. The rubric is intended as a descriptive and interpretive heuristic category system rather than a validated psychometric instrument. A higher rubric score indicates broader range of observed creative behaviors within a dimension, not necessarily greater creativity intensity.

3. Methodology

3.1. Research design

This study adopted a qualitative design and development research (DDR) methodology [21], appropriate for creating, validating, and refining instructional products through systematic empirical investigation and expert judgment. Three sequential phases were conducted: Phase 1 (field exploration and activity selection), Phase 2 (activity development and expert validation), and Phase 3 (implementation and data collection).

3.2. Participants

Five upper elementary students (N = 5; one female, four male; aged 9–11 years) participated voluntarily in the Lanna lantern making activity. They were recruited from the Ban Muang Phinong community through a research assistant who is a classroom teacher at the local primary school with 23 years of experience and prior knowledge of all participants. Inclusion criteria were: (a) age 9–11, (b) voluntary agreement, and (c) written parental consent. All participants were enrolled at the same primary school and knew one another prior to participation. Participants are referred to throughout this article by individual pseudonyms, Lin, Lah, Som, Ker, and Tawan, assigned with the consent of participants and their families, following established practice in qualitative educational research (see also ethical note below). To support transferability, all five participants were members of the Shan (Tai Yai) ethnic community; their cultural background is described below.

The Shan (Tai Yai) are a Theravada Buddhist, Tai-speaking ethnic group originating from present-day Myanmar, with a longstanding community presence in Chiang Mai Province [22]. Children in these communities typically grow up bilingual in Shan and Northern Thai, with Standard Thai acquired through schooling.

The researcher gained access to the Ban Muang Phinong community through an established professional relationship with the research assistant, a Shan community member who has served as a primary school teacher in the village for 23 years. This intermediary relationship provided both logistical access to the school premises and social legitimacy within the community, as the research assistant was known personally to all participant families. The researcher made introductory visits to the school before recruitment began, attended a community meeting at the monastery to explain the study's purpose, and obtained written parental consent through face-to-face meetings facilitated by the research assistant. No parent or guardian was present during the activity session at the request of the families, who preferred children to participate independently. Credibility of access was further supported by the researcher's own position as a Lanna cultural community native with prior knowledge of Shan cultural practices through long-term residence in Chiang Mai, enabling culturally sensitive facilitation and communication throughout the session.

3.3. Intervention: OST Lanna lantern STEM education

3.3.1. Phase 1: Field exploration and activity selection

The researcher conducted systematic field exploration over four weeks in Chiang Mai through participant observation [23], artisan interviews, and STEAM content documentation. At Ban Mueang

Saat, the primary field site, a third-generation artisan family was identified who produce Lanna lanterns (Khom Lanna) for the Yi Peng Festival, religious offerings, and commercial sale through the Chiang Mai Night Bazaar. Field documentation confirmed rich STEAM content across all five domains: science (light transmission and optical properties of sa-paper versus kite-making paper versus thick fabric); technology (bamboo cutting, bending, and joining tools; hot-glue gun for bamboo-to-bamboo adhesion); engineering (triangulated load distribution in bamboo frame geometries); arts (centuries of Lanna visual tradition through zodiac motifs and the tung-tail decorative element); and mathematics (geometric reasoning about symmetry and proportion; packability against a 40 cm × 30 cm carry-on template). A key field finding was that modernization had disaggregated the original integrated craft into two specialist roles (i.e., frame construction and covering/decoration) practiced separately. This disaggregation became a pedagogical design rationale: the student activity reintegrated both processes to restore the historically complete craft experience. The social issue entry point was identified from field interviews: tourists purchasing Lanna lanterns at the night bazaar frequently cannot fit them in standard airline carry-on luggage, resulting in lost sales for craftsmen.

A set of six criteria guided activity selection (Table 2), informed by theoretical frameworks on STEAM education, OST programming, and child development [12,24,25].

Table 2. Six criteria for selecting local cultural activities for STEAM adaptation.

#	Criterion	Description
1	STEAM content richness	Demonstrably contains at least three of the five STEAM domains in ways that are observable and teachable.
2	Developmental suitability	Scientific concepts fall within the cognitive range of concrete operational learners (ages 9–11).
3	Time practicality for OST	Completable within approximately five to six hours as a satisfying complete single-session experience.
4	Safety without facilities	Implementable safely in a community setting without laboratory equipment.
5	Cultural relevance	Originates from a Lanna tradition recognizable and meaningful to children in Chiang Mai.
6	Open-ended creative expression	Includes at least one stage at which children can make real, meaningful choices not constrained to a single correct outcome.

Following systematic evaluation, Lanna lantern making at Ban Mueang Saat satisfied all six criteria and was selected. Natural dye fabric dyeing was excluded because it violated Criteria 2 (mordant chemistry is beyond concrete operational level), 3 (multi-day processing), and 4 (boiling and metallic salt mordants require laboratory safety facilities). This article reports on the Lanna lantern making activity; Lanna pottery making is reported separately.

3.3.2. Phase 2: Activity development and expert validation

The Lanna lantern making activity was developed using the seven-stage framework as the organizational scaffold and the A-to-E framework as the creativity design reference. Expert validation was conducted through a structured focus group with five specialists meeting all four selection criteria: (a) doctoral degree in science education; (b) more than 15 years of professional experience; (c) established publication record in science and STEM education; and (d) substantive familiarity with the STEM 7-step learning process. The panel comprised: two university science education lecturers with expertise in primary science pedagogy; one practicing primary school STEAM teacher; one STEM competency specialist from the educational support sector; and one expert in science project development for primary-level learners. Consensus was defined as agreement among at least four of five panel members (80%). Eleven recommendation categories were produced. Five key revisions shaped the final design: (1) Stage 5 extended to 100 minutes, subdivided into three 30-minute sub-segments with mandatory 5-minute rest breaks; (2) Stage 1 open problem discovery replaced with structured role-play and guided questioning, confirmed by pilot data showing all three pilot students produced irrelevant responses to open-ended prompts; (3) Stage 6 physical stress-testing replaced with non-destructive fitting test and light evaluation; (4) worksheets redesigned to prioritize drawing over text at Grade 4–5 reading level; and (5) individual rather than group format adopted to enable reliable A-to-E coding per student. The activity was pilot-tested with two to three students outside the main study sample before final implementation. Dependability is supported by complete documentation of all eleven recommendation categories and the revisions applied.

3.3.3. Phase 3: Implementation of the Lanna lantern STEAM OST activity

The activity session was held at the school grounds of Ban Muang Phinong, Amphoe San Pa Tong, Chiang Mai Province, on Sunday, 8 March 2026. The session followed four instructional blocks of 90 minutes each (09:00–10:30, 10:45–12:15, 13:00–14:30, 14:45–16:15), providing 360 minutes of instructional time. Activity materials were delivered orally to accommodate limited written Thai literacy among participants. Table 4 presents the validated activity plan, which constitutes the intervention protocol.

Figure 2. Participants constructing individual bamboo lantern frames during Stage 5 (prototype development), Ban Muang Phinong, Chiang Mai, 8 March 2026.

Table 3. Final activity plan: Lanna lantern making (Total: 360 minutes / 6 hours).

#	STEM Stage	A–E	Min	Key Student Activities	Worksheets / Materials
1	Identification of social issues	A, B	40	Researcher performs tourist-suitcase role-play. Guided questions lead to design challenge: 'How can we redesign the lantern to fit carry-on luggage?' Students examine authentic lantern and frame; record via drawing.	WS1: Observation and challenge card
2	Identification of potential solutions	A, B, D	40	Students individually sketch two possible packable designs. Reference objects removed mid-stage. Final sketch selection with brief justification.	WS2: Two-panel solution sketch sheet
3	Need for knowledge	B, C, E	40	Three investigations: (i) light transmission through three materials; (ii) structural strength of three frame shapes under lateral pressure; (iii) packability against 40 × 30 cm carry-on template.	WS3: Investigation record; torch, test chamber, three paper types, three bamboo frames, carry-on template.
4	Decision-making	A, C, D	40	Students review Stage 2 sketches against Stage 3 findings using a four-criteria decision grid. Final design selected and annotated with Stage 3 evidence.	WS4: Decision grid + final annotated design sketch
5	Development of prototype	A, D, E	100	Three 30-minute sub-segments with 5-minute rest breaks: (a) frame assembly; (b) paper covering; (c) Lanna-inspired decoration of own choice.	Bamboo strips, sa-paper, kite paper, hot-glue gun, latex adhesive, scissors; Lanna zodiac motif reference sheet.
6	Testing and evaluation	B, C, D, E	40	Non-destructive evaluation: fitting test (lantern placed in travel suitcase); light test (torch placed inside lantern). Student self-assessment on 10-point scale from craftsman and tourist perspectives.	WS6: Self-evaluation sheet; travel suitcase, torch.
7	Socialization and completion	A,B,C,D,E	40	Individual exhibition with name card. Gallery walk with sticky-note peer comments. Individual verbal presentation to researcher. Lanna designer certificate awarded.	Name card template, sticky notes, certificate template.

3.4. Data collection

Three complementary data sources were used for triangulation [26], each targeting different dimensions of the A-to-E framework and collected at specific points in the activity sequence. The first source was video-supported structured observation using the validated 30-indicator A-to-E checklist, with three-level field notes (descriptive, reflective, and analytic-memo) following Emerson, Fretz, and Shaw [23]. Video recording provided continuous coverage of all seven activity stages and was the primary observational record reviewed during post-session coding. The checklist was completed through repeated review of the video record, with field notes serving as a cross-validation source. A conservative evidence-based coding principle was applied: an indicator was marked as observed only when sufficient, explicit behavioral evidence was available from at least one data source. Where video and field notes provided conflicting or ambiguous evidence, the indicator was coded as absent. Credibility was supported by multi-source triangulation and the use of a peer-reviewed observational instrument [26] that underwent independent academic publication before data collection.

The second source was student artifact analysis, conducted at the conclusion of Stage 7 and covering completed lanterns, design worksheets (WS1–WS4 and WS6), and annotated design sketches. Artifact analysis was targeted at indicators in the connecting (C2, C3) and daring (D1, D2) dimensions, where written and sketched evidence provided verifiable records of reasoning and design decisions not always audible in the video. The third source was informal member checking: individual conversations of 10–15 minutes per participant were conducted at the conclusion of Stage 7, after the gallery walk. Structured questions addressed all five A-to-E dimensions and included probes for internal states, such as surprise, curiosity, and intention, states that behavioral observation alone cannot reliably capture. Member checking was particularly important for the being curious dimension (B1, B2, B4, B6), where video observation frequently underrepresents internal cognitive and affective states. Confirmability was supported through reflexive memos written by the researcher after each video review session, documenting interpretive decisions and the three positionality factors (pedagogical background, parental frame of reference, and Lanna cultural embeddedness) with explicit management strategies.

3.5. Data analysis

Data analysis followed a five-stage qualitative content analysis approach [27]. Each tool was used to analyze specific dimensions and indicators. Following indicator-level coding, the three-level creative inquiry rubric (Table 1) was applied.

Although the analysis was primarily deductive, organized around the predefined A-to-E dimensions, and an inductive strand was maintained throughout. During data organization and pattern identification stages, the researcher actively looked for behaviors or episodes that fell outside the A-to-E coding categories. Field notes and analytic memos were searched for recurring patterns not captured by the 30 indicators. Two such patterns were identified: (1) sustained silent concentration during craft construction, not readily interpretable as any single A-to-E indicator, was noted as a possible expression of aesthetic absorption; and (2) unprompted comparison of one’s own artifact with the artisan’s original lanterns (a photograph of which was posted in the room) occurred in three participants and suggested a form of quality-referencing not explicitly covered by the framework’s indicators. These observations are noted in the cross-case discussion (Section 4.6) as inductive supplements to the framework-driven findings.

4. Results and discussion

Table 4 presents the full 30-indicator coding matrix for all five participants, and Table 6 presents dimension-level rubric scores. The following subsections provide individual narrative accounts (Sections 5.1–5.5) drawing on video observation, artifact analysis, and member checking. Each narrative is structured around the rubric profile, followed by the most analytically significant behavioral evidence per dimension. A cross-case discussion follows in Section 5.6.

Figure 3. Students testing light transmission during Stage 3 (need for knowledge), Ban Muang Phinong, Chiang Mai, 8 March 2026.

Table 4. Summary matrix of observed A-to-E behavioral indicators (N = 5, Lanna lantern making).

Dimension / Indicator	Code	Lin	Lah	Som	Ker	Tawan	n/5
Agency	A1 – Self-determination	✓	✓	✓	✓	–	4/5
	A2 – Personal relevance	✓	–	–	✓	–	2/5
	A3 – Having purpose	✓	✓	✓	✓	✓	5/5 ★
	A4 – Autonomy	✓	✓	✓	✓	–	4/5
	A5 – Personal choice and care	✓	✓	✓	✓	✓	5/5 ★
	A6 – Agility	✓	✓	✓	✓	–	4/5
Being curious	B1 – Questioning	✓	✓	–	–	–	2/5
	B2 – Wondering	✓	✓	–	–	–	2/5
	B3 – Observing and comparing	✓	✓	✓	✓	✓	5/5 ★
	B4 – Exploring	✓	–	–	–	–	1/5
	B5 – Evaluating candidly	✓	✓	✓	✓	✓	5/5 ★
	B6 – Expressing wonder	–	–	–	–	–	0/5
Connecting	C1 – Making connections	✓	✓	✓	✓	✓	5/5 ★
	C2 – Applying knowledge	✓	✓	✓	✓	✓	5/5 ★
	C3 – Comparing with evidence	✓	✓	✓	✓	–	4/5
	C4 – Cultural connection	–	✓	✓	✓	✓	4/5
	C5 – Peer feedback	–	–	✓	–	–	1/5

	C6 – Multiple perspectives	–	✓	–	✓	–	2/5
Daring	D1 – Divergent design	–	✓	–	✓	✓	3/5
	D2 – Unconventional choice	–	✓	✓	–	✓	3/5
	D3 – New technique	–	–	–	✓	–	1/5
	D4 – Emergent problem-solving	✓	–	✓	✓	–	3/5
	D5 – Accepting feedback	✓	–	–	–	–	1/5
	D6 – Confident presentation	✓	✓	✓	✓	✓	5/5 ★
Experimenting	E1 – Trial and error	✓	–	–	✓	–	2/5
	E2 – Comparing approaches	–	–	–	–	–	0/5
	E3 – Modifying artifact	✓	✓	✓	✓	✓	5/5 ★
	E4 – Reflective learning	✓	✓	✓	✓	–	4/5
	E5 – Sharing process	✓	–	–	–	–	1/5
	E6 – Further development	✓	–	–	✓	–	2/5

Note: ✓ = indicator observed; – = not observed; ★ = universally observed (5/5). Conservative evidence-based coding principle applied throughout.

Table 5. Creative inquiry rubric profiles per participant (N = 5, Lanna lantern making).

Dimension	**Lin**	**Lah**	**Som**	**Ker**	**Tawan**	**Max**
Agency (A)	6→Proficient	5→Proficient	5→Proficient	6→Proficient	2→Emerging	6
Being curious (B)	5→Proficient	4→Developing	2→Emerging	2→Emerging	2→Emerging	6
Connecting (C)	3→Developing	5→Proficient	5→Proficient	5→Proficient	3→Developing	6
Daring (D)	3→Developing	3→Developing	3→Developing	4→Developing	3→Developing	6
Experimenting (E)	5→Proficient	2→Emerging	2→Emerging	4→Developing	1→Emerging	6
Total observed / 30	**22**	**19**	**17**	**21**	**11**	**30**

Note: Rubric levels: Emerging = 1–2 indicators; Developing = 3–4 indicators; Proficient = 5–6 indicators observed per dimension. Indicator counts derived from Table 4.

4.1. Lin: Creative inquiry profile – Broad proficiency with evidence-led decision-making

Lin produced the widest range of observed indicators (22/30) and achieved the proficient level in agency (6/6), being curious (5/6), and experimenting (5/6), with a developing profile in connecting (3/6) and daring (3/6).

Agency (proficient, 6/6): All six agency indicators were observed. Lin stated at Stage 1, 'I want to make the lantern smaller,' immediately claiming ownership of a specific design goal (A3). Throughout Stages 4–5, Lin independently revised the frame proportions when the initial octagonal structure proved too rigid to fold, demonstrating sustained autonomy (A4). Lin was one of two participants who selected materials without prompting (A2), choosing kite-making paper over sa-paper after Stage 3 light transmission evidence.

Being curious (proficient, 5/6): B6 (expressing wonder) was absent from the behavioral record, consistent with the methodological limit identified across all participants. However, member checking revealed that Lin had been genuinely surprised by the strength of triangular frames.

Connecting (developing, 3/6): C1 and C2 were observed – Lin's Stage 4 decision grid explicitly referenced the Stage 3 frame strength results. Lin was the only participant who did not incorporate a Lanna decorative element (C4 absent), consistent with a strong focus on the structural-functional portability problem.

Daring (Developing, 3/6): Lin demonstrated D4 (emergent problem-solving) by independently devising a fold-flat joint. D5 (accepting critical feedback) was observed only in Lin across all five participants.

Experimenting (proficient, 5/6): E1 (trial and error) was observed multiple times during Stage 5 frame assembly. Lin proposed testing whether a magnetic snap closure could replace the bamboo tie (E6).

4.2. Lah: Creative inquiry profile – Strong connecting with culturally divergent design

Lah observed 19 of 30 indicators and achieved proficient in agency (5/6) and connecting (5/6), with a developing profile in being curious (4/6) and daring (3/6), and emerging in experimenting (2/6). Lah's creative inquiry was distinguished by a culturally divergent design rationale.

The most analytically notable connecting behavior was Lah's use of C4: Lah connected the flat fish form to the Pisces zodiac motif from the Lanna reference sheet, illustrating how cultural identity (the recognition of Lanna zodiac symbolism as personally meaningful) directly shaped a divergent design choice. This moment exemplifies the mechanism by which cultural grounding activates creativity: Lah was not instructed to use a zodiac motif. The cultural resource was available, and Lah claimed it independently.

4.3. Som: Creative inquiry profile – Proficient connecting with miniaturization strategy

Som observed 17 of 30 indicators, achieving proficient in agency (5/6) and connecting (5/6), developing in daring (3/6), and emerging in being curious (2/6) and experimenting (2/6). Som's creative inquiry was characterized by a miniaturization strategy applied consistently across design and construction stages, and by the only peer-support behavior (C5) observed in the group.

4.4. Ker: Creative inquiry profile – Innovation-oriented with strongest daring

Ker observed 21 of 30 indicators and achieved proficient in agency (6/6) and connecting (5/6), developing in daring (4/6) and experimenting (4/6), and emerging in being curious (2/6). Ker produced the most functionally innovative artifact in the group, a two-panel detachable lantern.

Ker is the only participant in this study to achieve a complete agency profile. The C4 indicator was observed through the tung-tail Lanna decorative element added independently during Stage 5 decoration, illustrating again how Lanna cultural identity provided a creative resource that children drew upon without prompting.

4.5. Tawan: Creative inquiry profile – Emerging profile with action-based curiosity

Tawan observed 11 of 30 indicators and reached the emerging level in agency (2/6), being curious

(2/6), and experimenting (1/6), and the developing level in both connecting (3/6) and daring (3/6). Tawan's creative inquiry profile was the most constrained in the group; however, two analytically significant behavioral episodes illustrate that creative engagement occurred through action rather than verbal expression.

The most distinctive creative behavior in Tawan's session occurred during Stage 3: after the light-transmission test concluded, Tawan independently directed the torch through a notebook, then through pages separated one by one, in an unsolicited quantitative exploration of light transmission. Member checking confirmed that this was intentional: Tawan stated 'I wanted to see if one page was enough to block the light.'

4.6. Cross-case discussion

Five cross-case patterns emerge from the individual profiles. First, agency as a baseline creative disposition: four of five students reached the proficient level in agency, and A3 and A5 were observed universally (5/5). This is consistent with Tippett and Gonzalez's [11] finding that Agency is the most frequently observed A-to-E dimension; it suggests that the open-ended design brief and the inherent material challenges of bamboo construction reliably activate self-directed creative engagement as a behavioral baseline, even in participants whose overall profile is otherwise constrained.

Second, connecting at the Stage 3–4 knowledge bridge: C1 and C2 were both universal (5/5), indicating that the deliberate activity design (requiring students to reference Stage 3 evidence in the Stage 4 decision grid) produced consistent within-session knowledge transfer. This aligns with Sutaphan and Yuenyong's [12] argument that context-based inquiry structured around a real social problem supports genuine knowledge application rather than reproductive recall.

Third, being curious as systematically underestimated by behavioral observation: B6 was absent from the behavioral record across all five participants, despite member checking revealing internal surprise in at least three cases. This replicates Tippett and Gonzalez's [11] finding and extends it to an older age group and a craft context, providing direct empirical support for the argument that A-to-E research designs should treat member checking as a required rather than supplementary data source, particularly for being curious indicators.

Fourth, daring as evenly distributed but instrumentally constrained: all five participants reached the developing level in daring, yet no participant reached proficient. D6 (confident public presentation) was the only universally observed daring indicator, suggesting that the gallery walk structure reliably created a low-risk display environment. The absence of D3 in four of five participants and D5 in four of five suggests that single-session craft activities with time pressure tend to push students toward efficient solutions rather than exploratory technique deviations. This finding has implications for OST program design: extended multi-session formats may be required to activate the full daring dimension.

Fifth, the relationship between instructional scaffolding and creative expression warrants explicit discussion. The activity incorporated multiple layers of pedagogical support: structured worksheets, guided role-play, predefined investigations, a staged decision grid, explicit design criteria, and facilitator prompts at each stage. These scaffolds were essential for making the activity accessible to 9–11 year-olds within a single session. However, they also raise an important interpretive question: to what extent did the scaffolding elicit creative behaviors that would not have emerged in a more open-ended format? Several of the most clearly observed agency and connecting behaviors (e.g., the near-universal observation of A3 [having a clear design purpose] and C2 [applying Stage 3 knowledge to Stage 4 decisions]) were directly supported by the worksheet structure. It is therefore more accurate to describe these behaviors as scaffold-supported creative performance rather than fully spontaneous, self-initiated creativity. This does not diminish their significance: the ability to apply scientific evidence to a design decision within a structured sequence is a genuine creative act, and the scaffolding created the conditions for that act to occur. However, future research using more open-ended formats, or multi-session designs in which scaffolding is progressively reduced, would be needed to assess the extent to which these creative behaviors are self-sustaining without structured support.

Sixth, Lanna cultural identity as a creative resource: across multiple participants, cultural knowledge functioned as a generative substrate for creative decision-making rather than merely as a contextual backdrop. Lah's fish-shaped lantern connected to the Pisces zodiac motif; Ker added a tung-tail element independently; Som's miniaturization strategy drew on a Lanna aesthetic preference for proportional elegance. In each case, the cultural resource was activated without instruction: children recognized the cultural vocabulary and incorporated it into their designs. This suggests that the culturally grounded nature of the activity did not merely motivate engagement but actively structured the creative output. This finding aligns with Glavǝanu's [19] argument that creativity is distributed across persons and their cultural tools: the Lanna tradition provided a shared symbolic repertoire from which each child drew in individually distinctive ways.

The rubric extends beyond binary coding by revealing qualitative differences in creative inquiry at the same indicator count. The rubric provides a useful first-level differentiation, but qualitative narrative analysis, as provided in Sections 4.1–4.5, is necessary to characterize the nature rather than merely the breadth of creative inquiry.

5. Conclusions

This study provides an empirically grounded and methodologically differentiated account of how a culturally grounded STEAM OST activity based on Lanna lantern making elicits creative inquiry in upper elementary students. The application of a three-level rubric over the A-to-E creativity framework enables characterization of creative inquiry as a graded, multi-dimensional outcome rather than a binary checklist.

Agency and Connecting were the most robustly activated dimensions, with the activity's deliberate Stage 3–4 knowledge bridge producing universal within-session knowledge transfer. Daring emerged consistently but did not reach the proficient level for any participant, suggesting a structural constraint of single-session craft formats that future designs should address through extended engagement. Being curious was systematically underestimated by behavioral observation alone, with member checking revealing internal states not visible in the video record: this study recommends that A-to-E research designs treat member checking as a methodologically required rather than supplementary data source.

This study makes three contributions to the theoretical understanding of creativity in STEAM OST contexts. First, it empirically extends the A-to-E framework, originally developed in early childhood digital technology contexts in Australia [10], to an older elementary age group, a non-digital craft setting, and a Southeast Asian cultural context, finding that the framework's behavioral indicators are largely applicable across these dimensions with the methodological adjustment of treating member checking as essential rather than supplementary. Second, it provides evidence for Glavǝanu's [19] distributed creativity thesis in a specific empirical context: Lanna cultural knowledge functioned as a shared symbolic resource that children drew upon independently and distinctively, producing creative outcomes that STEM content alone could not have generated. Third, it establishes that the little-c and mini-c creativity framework of Kaufman and Beghetto [16], focused on personally meaningful insights and actions new to the individual, is an appropriate conceptual foundation for interpreting the A-to-E framework's behavioral evidence in craft-based OST settings: the children's creative acts were not globally novel, but they were genuinely new to each child and shaped by their individual cultural identity and prior knowledge.

Regarding the relationship between culture and creativity, this study contributes a specific empirical illustration of how cultural grounding operates as a mechanism rather than merely a motivation for creative expression. The three mechanisms identified, authentic problem ownership, cultural aesthetic vocabulary as a creative resource, and legitimization of tacit cultural knowledge, offer a transferable model for designers of culturally grounded STEAM programs. The finding that cultural identity activated creativity without explicit instruction (C4 observed in 4/5 participants independently) suggests that when learners' cultural knowledge is genuinely embedded in the activity design rather than used decoratively, it becomes an internal creative resource rather than an external prompt.

For educators and program designers, the validated six-criterion activity selection framework, expert validation protocol, and seven-stage activity plan provide a complete, transferable model for developing culturally grounded STEAM OST activities. Future research should examine the framework in multi-session formats, with larger and more diverse samples, and with formal inter-rater reliability procedures to address the single-coder limitation of this study. The single-coder limitation warrants particular attention: all indicator coding in this study was conducted by the researcher alone, without inter-rater reliability procedures or negotiated coding. Given the highly interpretive nature of several A-to-E indicators, particularly in the being curious and daring dimensions, the absence of independent coding is a significant constraint on confirmability. The conservative two-source evidence requirement applied throughout partially mitigates this concern, but does not replace the analytical consistency that independent coding would provide. Future studies applying the A-to-E framework in similar contexts are strongly encouraged to establish inter-rater reliability protocols before main data collection.

Author contributions

Pathompong Chummongkol: Conceptualization, methodology, data collection, writing original draft. Jiraporn Tupsai: Visualization, investigation, supervision. Chokchai Yuenyong: Reviewing and editing

Use of Generative AI tools declaration

During the preparation of this work, the author(s) used Claude AI to assist with language accuracy checking. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the published article.

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Conflict of interest

The authors declare no conflict of interest in this manuscript.

Ethics declaration

This study was reviewed and approved by the Center for Ethics in Human Research, Khon Kaen University, under the project title "Enhancing Students' Creativity Through STEM Out-of-school Time" (Reference No. HE673163). All research procedures were conducted in accordance with the approved ethical guidelines.

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Appendix

Appendix A. The 30 behavioral indicators of the A-to-E creativity framework

Table A. The 30 Behavioral Indicators of the A-to-E creativity framework (Murcia et al., 2020).

Code	Indicator	Observable Behavior (Ages 9–11)
A1	Self-determination	Initiates action or proposes alternatives independently without waiting for teacher direction
A2	Personal relevance	Connects the activity to own life, family, cultural identity, or prior experience
A3	Having purpose	States a clear self-defined design goal and consistently pursues it across stages
A4	Autonomy	Revises plan or material choices upon encountering obstacles without teacher guidance
A5	Personal choice & care	Tends to artifact with precision and care; demonstrates personal investment in quality
A6	Agility	Presents work or explains design process with confidence; chooses to adjust and remain flexible
B1	Questioning	Poses additional questions about materials, phenomena, or design possibilities beyond those prompted by the teacher
B2	Wondering	Explores materials or ideas before beginning construction; tests or handles objects speculatively
B3	Observing & comparing	Attentively observes and compares experimental outcomes; records distinctions between test results
B4	Exploring	Seeks additional information or explanation about an observed phenomenon beyond the minimum required
B5	Evaluating candidly	Evaluates own work candidly, going beyond a simple positive assessment; identifies specific gaps
B6	Expressing wonder	Expresses visible surprise, excitement, or wonder at unexpected experimental results
C1	Making connections	Links the social design problem to own design decisions independently, without teacher prompting
C2	Applying knowledge	Applies knowledge gained in Stage 3 experiments explicitly to Stage 4 design decisions
C3	Comparing with evidence	Compares design options with explicit reference to experimental evidence before committing
C4	Cultural connection	Connects own artifact to Lanna craft traditions observed during the activity
C5	Peer feedback	Provides peer feedback grounded in the design brief criteria rather than personal preference
C6	Multiple perspectives	Explicitly names and considers at least two contrasting viewpoints or design approaches before deciding
D1	Divergent design	Produces a sketch that differs meaningfully from the teacher's demonstration model
D2	Unconventional choice	Selects materials or forms outside the conventional range shown in the demonstration
D3	New technique	Experiments with a technique not seen in the demonstration during prototype construction
D4	Emergent	Solves an emergent construction problem using a method not modelled by the

	problem-solving	teacher
D5	Accepting feedback	Accepts critical peer or teacher feedback and uses it for improvement rather than rejecting it
D6	Confident presentation	Shares work publicly with confidence during the gallery walk, even when the outcome is imperfect
E1	Trial and error	Engages in trial and error more than once within a single construction stage
E2	Comparing approaches	Systematically compares outcomes of two or more approaches before committing to a final design
E3	Modifying artifact	Modifies the artifact during construction without being prompted by the teacher
E4	Reflective learning	Reflects on learning and identifies specific, actionable changes for a future attempt
E5	Sharing process	Voluntarily shares experimental process or technique discoveries with peers during the gallery walk
E6	Further development	Proposes concrete directions for further development or refinement after the activity ends

Note: Dimensions are Agency (A), Being Curious (B), Connecting (C), Daring (D), and Experimenting (E), each comprising six behavioral indicators. Adapted from Murcia et al. [10].

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