Preserving Krabi Krabong through Blended Self-Directed Learning Software and Dance Notation: A Digital Heritage Approach

Termpetch Sookhanaphibarn[1,*], Suthana Tingsabhat[2] and Kingkarn Sookhanaphibarn[3]

[1]*Faculty of Applied Arts, King Mongkut's University of Technology North Bangkok, Bangkok 10800, Thailand*
[2]*Faculty of Education, Chulalongkorn University, Bangkok 10330, Thailand*
[3]*Center of Specialty Innovation (CoSI), Bangkok University, Bangkok 12120, Thailand*

(*Corresponding author's e-mail: termpetch.s@arts.kmutnb.ac.th)

Abstract

This study explores a digital heritage approach for preserving *Krabi Krabong*, a traditional Thai martial art, through the development and implementation of blended self-directed learning software based on Labanotation. Using a quasi-experimental design, 45 teacher trainees without prior experience in Krabi Krabong participated in a four-week training program. The research followed three phases: (1) content analysis of Krabi Krabong curriculum and alignment with notation-based instruction, (2) development and expert validation of instructional tools, including a teaching guide, notation reading test, and performance assessment, and (3) classroom implementation to evaluate learning outcomes. All instruments demonstrated strong content validity (IOC = 1.00). Results revealed significant gains in notation comprehension, with average scores rising from 3.83 to 9.49, and in Krabi Krabong performance, from 1.30 to 2.90 (p < .001). Proficiency analysis showed that 72% of learners achieved "Good" to "Very Good" levels in notation comprehension, while 67% demonstrated basic proficiency in practical performance. The findings confirm that validated instructional design and technology-enhanced blended self-directed learning grounded in constructionist principles can bridge gaps between symbolic literacy and embodied practice. By combining notation-based documentation with interactive digital tools, this approach offers a replicable framework for integrating intangible cultural heritage into formal education. Policy implications include the potential integration of Krabi Krabong into physical education curricula, supported by digital resources that reduce reliance on limited expert instructors. Furthermore, the study suggests future pathways such as developing a "digital museum" of Krabi Krabong and extending the model to other martial traditions, including Muay Thai, Japanese Kenjutsu, and Chinese Wushu. Overall, the research contributes to digital heritage by demonstrating how blended self-directed learning platforms can democratize access, sustain cultural continuity, and modernize pedagogy for traditional performing arts in the digital era.

Keywords: Blended self-directed learning software, Constructionism, Cultural preservation, Dance notation, Digital heritage, Motion learning

Introduction

The preservation of intangible cultural heritage in the digital era requires innovative approaches that integrate traditional practices with technological solutions. *Krabi Krabong*, a Thai martial art that combines ritual, choreographed dance, and weapon-based performance, represents a vital cultural asset with deep historical and social significance. More than a martial practice, *Krabi Krabong* embodies ritualistic knowledge, symbolic expression, and community identity. Traditionally, its pedagogy was transmitted through oral instruction and direct demonstration by master practitioners, emphasizing lived experience and bodily discipline. However, the gradual decline in the number of expert instructors and limited formal incorporation into contemporary educational systems have placed this heritage at risk (Kerdkaew, 1984;

Wandee et al., 2025). Recent regional reports further indicate a measurable decline in Krabi Krabong practice. While official national statistics remain limited, ASEAN Secretariat (2024) identified Krabi Krabong as one of the martial arts requiring active safeguarding due to reduced practitioner visibility in community and school settings. Similarly, Thailand Foundation (2022) described Krabi Krabong as "making its way back," implying a preceding decline in public engagement. These indicators collectively highlight the urgency for educational and digital interventions to sustain this living tradition.

International policy frameworks emphasize the need to safeguard intangible cultural heritage through sustainable transmission rather than mere preservation of static traditions. UNESCO (2003) highlights that cultural practices must be passed on through adaptable systems that align with modern educational contexts and digital environments. In this light, Krabi Krabong should be regarded not only as a traditional performance but as a dynamic living practice that evolves with social and technological change— requiring preservation methods that support continued learning and intergenerational transfer.

Although Krabi Krabong holds strong cultural value, its transmission faces critical challenges in the digital era. The declining number of masters limits access to authentic mentorship, resulting in disrupted intergenerational knowledge transfer. Its complex codification— spanning ritual practices, symbolic gestures, and twelve weapon sequences—requires high precision in rhythm, direction, and bodily coordination, which can overwhelm novice learners without structured guidance. In addition, today's learners are shaped by fast-paced, media-driven environments that favor digital interaction over traditional learning. Consequently, sustaining engagement in Krabi Krabong has become increasingly difficult (Ronkainen et al., 2021; Al Rasyid & Nurharini, 2025). These challenges highlight the need for educational innovations that preserve cultural authenticity while aligning with contemporary learning needs.

In this context, dance notation systems provide a viable solution to the challenges of transmitting Krabi Krabong. As symbolic frameworks, they convert ephemeral movements into structured documentation that can be studied and passed on without constant reliance on expert instructors. Benesh notation introduced a visual language for recording movement (Benesh & Benesh, 1983), while Labanotation offered a more comprehensive system encompassing bodily dynamics, spatial direction, and rhythm (Fox, 2000; Wang et al., 2020). These systems laid the foundation for analyzing and teaching choreographic practices in both artistic and educational settings.

Technological advances have significantly broadened their application. Early tools such as Brown and Smoliar's (1976) graphics editor initiated digital movement documentation, followed by software like LabanWriter and LabanEditor that improved accessibility for scholars and learners (Kojima et al., 2002; Choensawat et al., 2010). Recent innovations include gesture-based 3D editors (Anderson et al., 2022), AI-assisted choreography notation (Lee, 2025), and motion capture systems that convert physical movement into symbolic form (Hachimura & Nakamura, 2001; Wang et al., 2020). Together, these developments position dance notation as a digital heritage tool capable of preserving and revitalizing complex movement traditions across cultures.

The educational dimension of this research is equally significant. Constructionist learning theory asserts that learners develop knowledge most effectively through active engagement, experimentation, and reflection (Na Songkhla, 2007; Iamsupasit, 2019; Morado et al., 2021). This aligns with current digital pedagogy innovations, including e-learning packages in physical education (Kaeduang et al., 2024), intelligent feedback systems that adapt to learner performance (Liu et al., 2024), and interactive digital media that enhance traditional dance instruction (Al Rasyid & Nurharini, 2025; Husnawati & Nurharini, 2024). Collectively, these studies show that integrating digital platforms with embodied practice enhances accessibility, motivation, and skill development while bridging generational gaps in cultural learning.

To address the decline in Krabi Krabong transmission, this study introduces a digital heritage model that uses dance notation as both a pedagogical and preservation tool. By integrating notation-based documentation with interactive blended self-directed learning software, learners can interpret symbolic movement systems while developing embodied skills. This approach responds to the shortage of expert

instructors and aligns cultural transmission with contemporary digital learning environments.

The model is grounded in three theoretical pillars. First, blended self-directed learning frames technology as a dialogic medium that sequences instruction, feedback, and reflection across guided and autonomous learning (Laurillard, 2012). Second, Merrill's First Principles of Instruction structure learning through task-centered progression, operationalized via notation-based activities and formative feedback (Merrill, 2002). Third, embodied cognition explains how symbolic understanding and physical execution co-develop, with digital practice supporting cognitive schemata before full motor performance (Johnson-Glenberg, 2018).

The objective of this study is to develop and evaluate blended self-directed learning software for teaching the fundamentals of dance notation within the context of *Krabi Krabong*. Specifically, the study seeks to:

1. Validate the instructional tools (teaching guide, notation reading test, and performance test) through expert review.

2. Examine the effectiveness of the blended self-directed learning model by comparing students' pre- and post-training scores in dance notation comprehension.

3. Assess improvements in students' *Krabi Krabong* performance after participation in the training program.

By addressing these objectives, the study contributes both to the preservation of *Krabi Krabong* as intangible cultural heritage and to the advancement of digital heritage methodologies in education.

Literature review

International dance notation software

Digital dance notation systems play a crucial role in preserving and transmitting movement-based cultural heritage. Labanotation, in particular, has become a widely adopted symbolic language capable of documenting human motion through structured representations of direction, rhythm, and timing, enabling performances to be studied and replicated across generations (Fox, 2000; Wang et al., 2020).
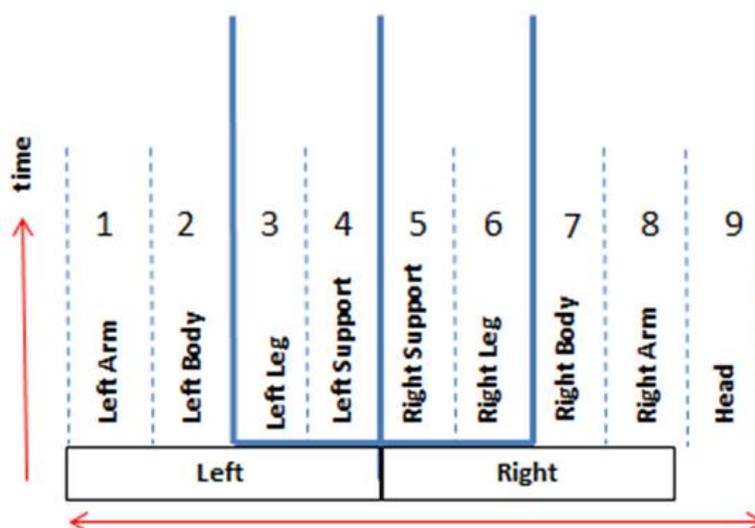
Figure 1 Basic structure of the Labanotation staff with nine columns representing body parts.

Early technological developments illustrated the potential of combining notation with digital tools. Brown and Smoliar (1976) created the first graphics editor for Labanotation, leading to applications such as LabanWriter at The Ohio State University, which visualized movement using nine vertical body columns (Fig. 1). These tools demonstrated the pedagogical value of symbolic visualization despite technical limitations (Fox, 2000). Progress continued with platforms like LabanDancer and LabanEditor, which translated static notation into animated 3D sequences and extended documentation to non-Western traditions such as Japanese Noh theatre (Kojima et al., 2002; Choensawat et al., 2010).

Recent innovations emphasize interaction, automation, and AI. Gesture-based 3D editors enhance

usability (Anderson et al., 2022), motion capture enables automatic notation generation for folk dances (Wang et al., 2020), and AI-driven systems support copyright protection for K-pop choreography (Lee, 2025). These

advancements show how dance notation has evolved from archival documentation into a dynamic tool for education, cultural preservation, and innovation.
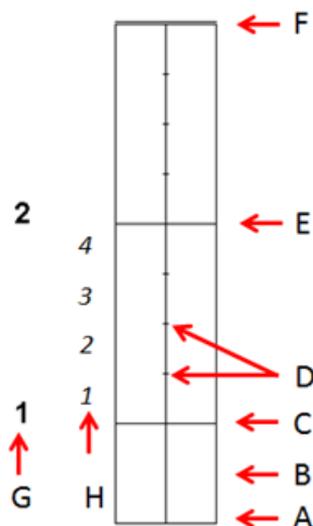
Figure 2 Notational elements in the Labanotation staff, including start lines, beats, and timing.

Collectively, these digital platforms underscore the dual benefits of notation software: they preserve movement traditions while improving accessibility for learners. By visualizing notational elements such as timing lines, spatial divisions, and directional vectors (Fig. 2), learners can interpret complex choreographies with greater clarity (Fig. 3).

This visualization also supports embodied learning by bridging the gap between symbolic systems and practical performance. In Thailand, where Krabi Krabong faces risks of declining transmission (Kerdkaew, 1984; Wandee et al., 2025), notation could provide a structured, sustainable model for preserving and teaching codified sequences.

Comparative use of labanotation across contexts

Labanotation has been applied in diverse cultural contexts, offering insights for Krabi Krabong education in Thailand. In Europe, it supports ballet training by preserving canonical repertoires and ensuring interpretative consistency (Benesh & Benesh, 1983). In Japan, it has been used to document Noh theater, capturing symbolic gestures and stylized body motions that oral instruction alone cannot sustain (Choensawat

et al., 2011). In Korea, AI-assisted notation addresses intellectual property protection in popular dance forms such as K-pop (Lee, 2025). These examples show how notation functions not only as an archival tool but also as a pedagogical and legal framework.

In Thailand, Krabi Krabong still relies primarily on face-to-face instruction, with minimal integration of notation systems. Although initial attempts at digital documentation exist (Sookhanaphibarn et al., 2023), full adoption remains limited. Comparing international practices reveals an opportunity for Thailand to utilize Labanotation as a structured method for preserving martial traditions while aligning with global digital heritage initiatives.

Constructionism and self-learning approaches

Pedagogical theory provides a strong foundation for integrating notation with digital learning. Constructionism, developed by Papert, posits that learners construct knowledge most effectively through active creation, experimentation, and reflection rather than passive reception (Morado et al., 2021). In Thailand, Na Songkhla (2007) highlighted web-based instruction as a means to foster learner autonomy, while Iamsupasit (2019) demonstrated how behavior

modification principles support self-regulation. These concepts align with notation-based learning, where students must iteratively interpret symbolic systems and translate them into embodied practice.

Digital platforms grounded in constructionism promote experimentation, peer collaboration, and reflective refinement—elements crucial for mastering complex movement traditions. Ronkainen et al. (2021) further linked embodied learning in sport to existential development and life skills. Applied to Krabi Krabong, notation-based software has the potential to cultivate both technical accuracy and broader competencies such as self-discipline and cultural identity.

Recent advances in digital dance and PE learning

Contemporary research demonstrates the increasing integration of digital platforms and AI into physical education and performing arts. Liu et al. (2024) showed that machine learning–based feedback systems maintain learner engagement through personalized performance data, while Kaeduang et al. (2024) developed PE e-learning packages that promote self-management, aligning with constructionist learning.

In dance education, flipbook-based e-modules improved learning outcomes in Central Javanese dance (Al Rasyid & Nurharini, 2025), and live worksheets supported exploratory movement learning among elementary students (Husnawati & Nurharini, 2024). Wandee et al. (2025) further linked Krabi Krabong training to measurable physiological benefits, bridging traditional martial arts and sport science.

Collectively, these studies demonstrate how notation, constructionist pedagogy, and digital technologies can reduce dependence on expert instructors, enhance access to cultural knowledge, and sustain intangible heritage. For Thailand, this provides a viable pathway to preserve Krabi Krabong while integrating it into contemporary education.
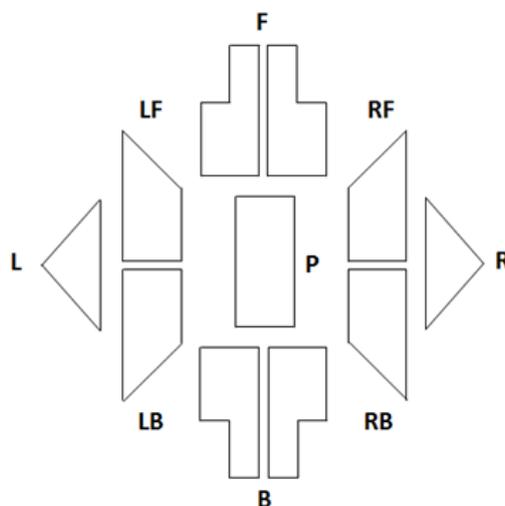
Figure 3 Nine horizontal direction symbols indicating movement orientation

Theoretical framework

1.) Blended self-directed learning

Blended self-directed learning views technology as a structured dialogue partner that complements teacher guidance while allowing self-paced exploration (Laurillard, 2012). In this study, the software assigns notation micro-tasks, provides immediate feedback, and logs learner attempts, whereas instructors focus on safety, technique, and performance intent. This aligns with movement education models where digital modules prepare conceptual understanding and face-to-face sessions refine kinesthetic execution.

2.) First principles of instruction

The instructional design follows Merrill's (2002) First Principles: (a) Problem-centered: learners decode and compose Labanotation for Krabi Krabong sequences. (b) Activation: prior movement schemas are triggered via video and warm-up drills. (c) Demonstration: canonical symbols and notation rules

are visualized in the software. (d) Application: learners complete graded tasks with formative feedback. (e) Integration: notation outputs guide peer rehearsal and reflection. These elements scaffold cognitive-to-physical transfer from screen to floor.

3.) Embodied cognition in digital learning

Embodied cognition posits that symbolic understanding and motor skill develop at different rates, with cognitive schemata stabilizing before full motor control (Johnson-Glenberg, 2018). In weapon-based choreography, mastering rhythm, posture, and timing require repeated practice with fatigue management. This framework explains why gains in notation literacy may appear earlier than improvements in physical performance.

4.) International cases in dance technology/digital heritage

Dance notation has supported documentation and pedagogy in ballet and theatre for decades (Benesh & Benesh, 1983; Brown & Smoliar, 1976; Fox, 2000). Its use has expanded to Noh theatre (Choensawat et al., 2011), digital editors enforcing symbol rules (Kojima et al., 2002; Anderson et al., 2022), and motion capture–notation automation (Wang et al., 2020). Situating Krabi Krabong within this lineage reinforces the validity of using Labanotation as a digital heritage and learning tool.

Methodology
Research design

This study adopted a quasi-experimental research design consisting of three sequential phases aimed at developing and evaluating blended self-directed learning software for Krabi Krabong instruction. The phases included: (1) content analysis of Krabi Krabong curriculum, (2) development of a digital instructional model with expert validation, and (3) implementation of the model in a training program with pre- and post-test evaluations. This design allowed systematic assessment of learners' progress while ensuring content fidelity and pedagogical validity (see Table 1).

Table 1 Quasi-experimental research process

Step Sequence	Details
1. Study and analyze the content	The researchers examined Krabi Krabong curriculum and aligned notation-based instructional content. Curriculum validity was verified by experts.
2. Create a model	A model was developed using video clips and notation guides. Experts reviewed materials for consistency using the Index of Congruence (IOC).
3. Implement tools	Instructional tools were applied in four weekly training sessions (2 hours/session). Pre- and post-tests assessed learners' notation reading and performance skills.

Participants and sampling
Target population and rationale

Participants were 45 third-year teacher trainees (approximately 70% female and 30% male), aged 20–23 years (M = 21.4, SD = 0.9), enrolled in the Faculty of Education. Pre-service teachers were targeted because (1) they represent likely future implementers of PE/arts modules, (2) they had no prior training in Krabi Krabong or dance-notation systems (Labanotation or Benesh), making them suitable novices for measuring instructional impact, and (3) access and scheduling feasibility allowed a coherent four-week intervention within the semester calendar. Most participants had completed basic movement or physical education courses, providing general motor familiarity but no symbolic-notation experience.

Sampling method

A convenience sampling with eligibility screening approach was used. Recruitment announcements were made via course channels and departmental boards. Interested students completed a brief eligibility form and provided informed consent prior to baseline testing.

Inclusion criteria

1. Enrolled in the Faculty of Education during the study term.

2. Age ≥18.

3. No prior formal training in Krabi Krabong and no prior exposure to Labanotation/Benesh notation.

4. Able to participate in four weekly 120-minute sessions.

5. Medically fit for light-to-moderate movement practice as self-declared.

Exclusion criteria

1. History of musculoskeletal or neurological conditions that could affect safe participation.

2. Prior certification or competitive experience in Thai traditional martial arts/dance.

3. Attendance below 75% of sessions.

4. Failure to complete either pre- or post-tests.

Allocation, blinding, and assessor training

Given institutional constraints and the exploratory focus, no control group was used. To mitigate bias, (1) assessors for performance scoring were blinded to time points (pre/post labels removed on scoring sheets), (2) a standardization meeting calibrated the scoring rubric (criteria for rhythm, precision, posture), and (3) inter-rater agreement was checked prior to main scoring; coefficients are reported in Results where applicable.

Ethical considerations and data protection

All procedures adhered to institutional ethical guidelines. Participants provided written informed consent and could withdraw at any time without penalty. Data was de-identified and stored on password-protected drives; only aggregated results are reported.

Limitations of sampling

The non-random, single-institution sample limits generalizability. Gender balance, prior PE experience, and digital familiarity were not controlled beyond screening, and the short intervention window may inflate practice effects. These limitations are acknowledged in the Discussion.

Research instruments

Three core instruments were constructed to support the instructional model (see Table 2):

1. Teaching manual for dance notation

- Content included notation principles, stick-dance notations, and integration with blended self-directed learning software.

- Structured according to Thailand's Basic Education Core Curriculum (B.E. 2551), emphasizing 12 foundational movements.

2. Notation reading skill test

- Comprised items on arm notation, leg notation, and stick-dance comprehension.

- Designed to measure recognition, interpretation, and application of notation symbols.

3. Performance test for Krabi Krabong

- Focused on execution of the *Tang Sok* (Elbow Position) and other standardized movements.

- Assessed rhythm, precision, and posture accuracy through expert observation.

Table 2 Components of research tools

Components	Details
Part 1: Teaching Guide	1. Basic notation principles
	2. Notation for stick dance
	3. Learning software integration
Part 2: Reading Skills Test	1. Arm notation reading
	2. Leg notation reading
	3. Stick-dance notation comprehension
Part 3: Performance Test	Execution of Tang Sok (Elbow Position) using notation

Tool construction and validation

The instruments were systematically constructed through the following steps:

1. Designing the learning framework based on curriculum indicators.

2. Drafting notation guides aligned with Krabi Krabong techniques.

3. Developing test items for notation comprehension and performance assessment.

4. Conducting expert validation with three specialists: one in military martial performance, one in dance notation, and one in traditional Thai dance.

Validation was conducted using a three-point scale (Agree, Uncertain, Disagree). The Index of Congruence (IOC) was calculated for each item, ensuring reliability and content validity of all tools prior to implementation.

Cronbach's Alpha could not be computed due to the small number of items in the test and rubric; future studies should include expanded item pools to enable full reliability analysis.

Software development pipeline (Expanded)
**Requirements and content modeling** (Figure 4.)

☐ Defined learning objectives from curriculum indicators: reading symbols (direction/level/tempo), mapping to arm–leg–weapon actions, and executing codified sequences.

☐ Built a content ontology linking notation symbols to Krabi Krabong primitives (e.g., stance, guard, strike, transition), enabling modular lesson design (Learn → Practice → Assess).
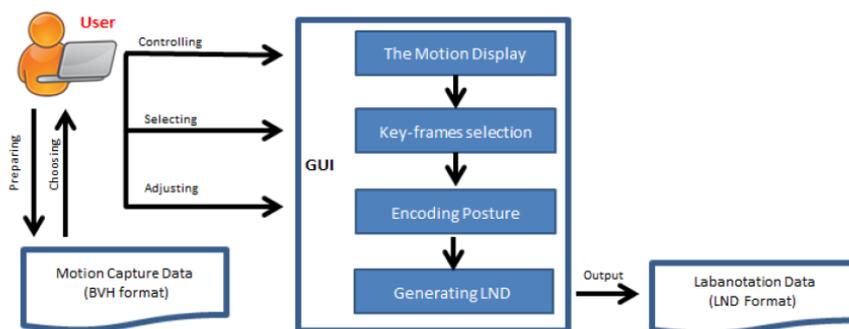
Figure 4 Overall framework for notation generation software
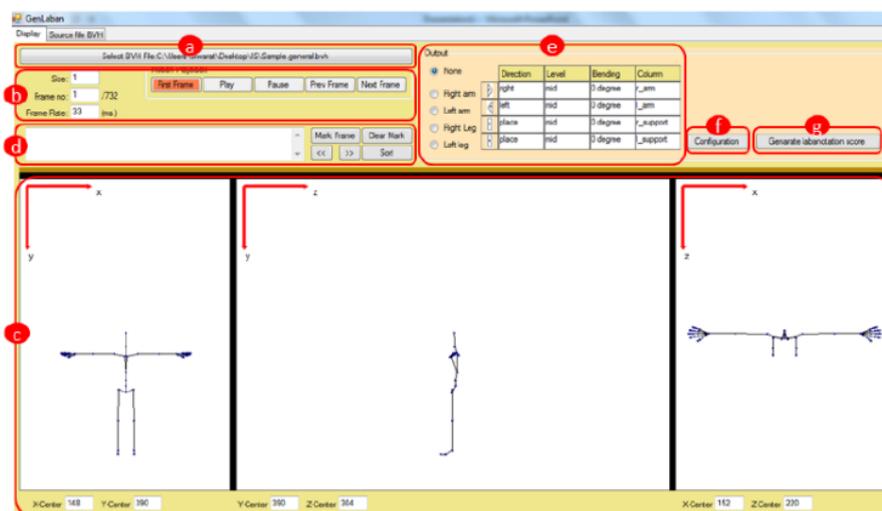
Figure 5 GUI layout with menu system
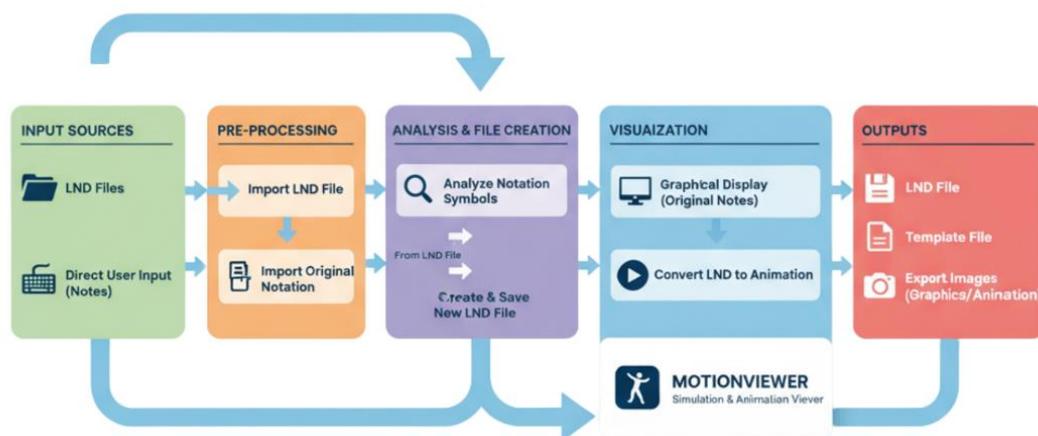
Figure 6 Overall framework for animation generation software

GUI/UX design (Figure 5.)

☐ Layout: (A) Notation Panel (vertical staff with nine columns; symbol palette; drag- and- drop and keystroke entry), (B) Timeline & Transport (play/pause, frame/ beat scrubbing, loop), (C) Video/ Avatar Pane (reference clip or 3D avatar preview), (D) Feedback Console (symbol correctness, timing mismatches, hints).

☐ Scaffolding: progressive disclosure of symbol complexity (from direction/ level to compound gestures); contextual tooltips; keyboard shortcuts.

☐ Assessment mode: locked staff with auto-check comparing learner input to ground- truth sequences; per- item and aggregate feedback; export of attempt logs.

☐ Localization & accessibility: Thai/ English labels; adjustable staff scale and font size; high-contrast option.

Motion capture ingestion and preprocessing

☐ Imported standardized motion sequences (e.g., BVH/FBX) for core Krabi actions.

Quality assurance and pilot usability

☐ Conducted expert walkthroughs to verify symbol correctness against movement clips; discrepancies flagged and resolved iteratively.

☐ Ran a think-aloud pilot with a small group to refine labels, button placement, and hint phrasing;

☐ Preprocessing: skeleton retargeting to a canonical rig; low- pass filtering; temporal alignment to reference beats; keyframe detection (velocity/acceleration thresholds) to segment gestures.

Symbol mapping engine (Figure 6.)

☐ Direction quantization: joint orientation vectors mapped to nine horizontal directions (forward/ backward/ lateral variants) consistent with Labanotation.

☐ Level classification: end- effector height relative to body landmarks → high/middle/low levels.

☐ Body-part assignment: rule-based mapping to staff columns (arms/legs/torso/weapon).

☐ Duration encoding: frame counts → beat units; ties and holds encoded across timing lines.

☐ Error tolerance: angular/ height thresholds allow small deviations without penalizing learners unnecessarily.

☐ Exports: notation render to SVG/ PNG/ PDF; sequence to JSON/ CSV for analytics; optional video sync for side-by-side playback.

collected qualitative feedback for UI polish prior to the four-week deployment.

Instructional Design and Data Collection

The instructional design was guided by Constructionism Theory, which emphasizes learning through doing, problem- solving, and experiential reflection (Iamsupasit, 2019; Na Songkhla, 2007;

Morado et al., 2021). This approach enabled learners to set personal goals, solve problems collaboratively, and engage in reflective iteration consistent with student-centered pedagogy.

The training was conducted with student teachers from the Faculty of Education. Sessions lasted two hours per week for four weeks, covering foundational to advanced notation skills for Krabi Krabong (see Table 3).

An orientation session was held prior to training. Each instructional unit began with a pre-test on notation reading and concluded with a skill assessment, followed by a comprehensive post-test after the final session.

Table 3 Basic notation teaching table for stick dance movements

Class Session	Topic	Objectives	In-Class Activities	Out-of-Class Activities
1 (120 min.)	Basic Knowledge of Notation: Origin, Meaning, and Significance	Understand the importance and components of notation	Lecture using PowerPoint	None
2 (120 min.)	Symbols of Basic Notation: Direction, Level, Tempo; Arm Movement Examples	Understand basic symbols and move arms accordingly	Lecture using animation; students practice movements	Students practice writing notations for arm movements
3 (120 min.)	Continuation of Basic Notation Symbols and Movement Examples	Reinforce symbol understanding through dance practice	Instructor-led physical practice with animation	Dance practice with notation support
4 (120 min.)	Krabi Dance Notation Symbols and Movement Terms	Understand posture-specific symbols for Krabi	Movement demonstration via animation and dance practice	Practice Krabi dance using notation guidance

Table 4 Expert evaluation of the Krabi dance notation teaching guide

Comments on the Teaching Guide	Percentage Agreement (%)	Index of Congruence (IOC)
1. Alignment with objectives	100	1.0
2. Alignment with content	100	1.0
3. Comprehensive coverage	100	1.0
4. Learning outcome relevance	100	1.0
Mean	**100**	**1.0**

Data analysis

Quantitative data from pre- and post-tests were analyzed using descriptive statistics (mean, standard deviation) and inferential statistics (paired sample t-test). These analyses assessed improvements in learners' notation comprehension and Krabi Krabong performance. Significance levels were set at $p < .05$ to determine the effectiveness of the intervention.

Results

The results of this study are presented according to the three stated research objectives: (1) validation of the instructional tools, (2) effectiveness of the self-learning software in enhancing notation comprehension, and (3) improvement of Krabi Krabong performance.

Objective 1: Validation of instructional tools

The teaching guide, notation reading test, and performance test were evaluated by three experts in martial performance, dance notation, and Thai traditional dance. The **Index of Congruence (IOC)** analysis demonstrated perfect agreement across all items, with each component achieving an IOC score of 1.00, indicating strong content validity.

The results for the dance notation teaching guide using Krabi dance skills are summarized in Table 4. The expert panel confirmed that the content was accurate, comprehensive, and appropriate for achieving the targeted learning outcomes. The IOC score for each item was 1.00, indicating perfect agreement among evaluators.

Table 5 Expert evaluation of the notation reading skills test

Comments on the Skills Test	Percentage Agreement (%)	Index of Congruence (IOC)
1. Alignment with objectives	100	1.0
2. Alignment with content	100	1.0
3. Comprehensive content coverage	100	1.0
4. Appropriate scoring methods	100	1.0
5. Suitable evaluation criteria	100	1.0
6. Alignment with learning outcomes	100	1.0
Mean	**100**	**1.0**

Table 6 Pre- and post-test scores for notation comprehension by gender

Gender	n	Pre-test M (SD)	Post-test M (SD)	Mean Gain	t(df)
Male	18	3.94 (1.28)	9.22 (1.01)	5.28	−12.54
Female	27	3.76 (1.22)	9.66 (1.05)	+5.90	−15.84
Total	45	3.83 (1.25)	9.49 (1.02)	+5.67	−21.36

$p < .001$

Table 7 Pre- and Post-test Krabi Krabong performance by physical background

Prior PE Experience	n	Pre-test M (SD)	Post-test M (SD)	Mean Gain	% Improvement
No prior PE training	22	1.25 (0.41)	2.82 (0.49)	+1.57	82%
Basic PE course only	15	1.33 (0.47)	2.93 (0.52)	+1.60	86%
Active in sports	8	1.38 (0.46)	3.00 (0.53)	+1.62	88%
Total	45	1.30 (0.45)	2.90 (0.51)	+1.60	85%

$p < .001$

Similarly, the test for reading dance notation skills was reviewed to ensure that it met its educational aims, covered all necessary content, and aligned with the expected outcomes. Table 5. summarizes the findings. The expert reviewers agreed unanimously, yielding a perfect average IOC of 1.0.

Both tools were confirmed to be accurate, comprehensive, and aligned with the intended learning outcomes.

Objective 2: Effectiveness of the blended self-directed learning software in notation comprehension

Following the four-week training program, students demonstrated significant improvement in their ability to read dance notation. The pre-test mean score was M = 3.83, while the post-test mean score increased to M = 9.49, reflecting a gain of 5.67 points ($p < .05$).

Proficiency levels were distributed as follows: Fair (8%), Good (30%), and Very Good (42%).

Proficiency distribution also shifted markedly: only 8% remained at a "Fair" level, while 72% achieved "Good" to "Very Good" comprehension. Figure 7 illustrates the distribution of learners' notation scores before and after training.
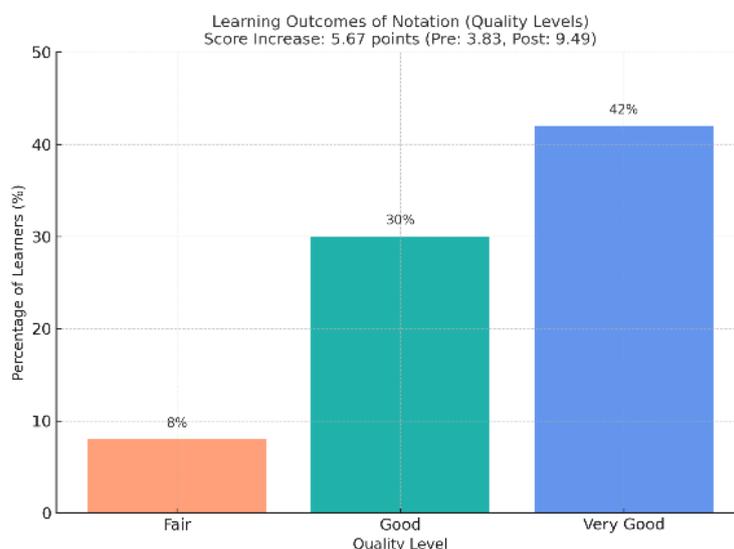

Figure 7 Shows the distribution of students' proficiency levels in notation writing.
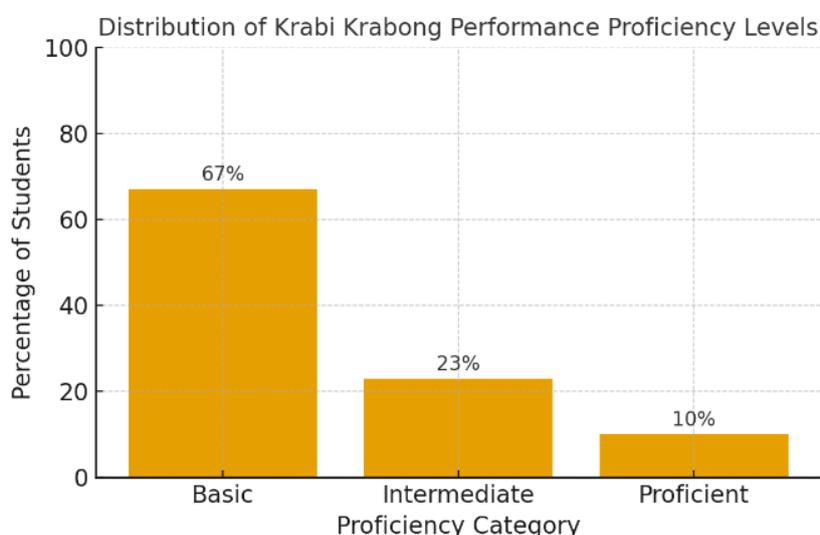

Figure 8 Shows the distribution of Krabi Krabong performance proficiency levels across three categories.

Objective 3: Improvement of Krabi Krabong Performance

Performance scores also improved significantly, though gains were smaller than for notation comprehension. The average pre-test score was **M = 1.30 (SD = 0.45)**, increasing to **M = 2.90 (SD = 0.51)** after training, yielding a mean gain of 1.60 points (t(44) = –14.82, p < .001).

As shown in Figure 8, 67% of students reached basic proficiency in Krabi Krabong movements, including the Tang Sok (elbow position).

All instructional tools achieved perfect content validity (IOC = 1.00 across items), confirming accuracy, completeness, and alignment with intended outcomes. Following four weeks of training, students' notation comprehension improved markedly from M = 3.83 (pre-test) to M = 9.49 (post-test), a gain of 5.67 points (*p* <

.05), with proficiency distributed as Fair 8%, Good 30%, and Very Good 42% (see Figure 7). Practical performance likewise increased from M = 1.30 to M = 2.90 ($p < .05$), with 85% of students showing improvement and 67% attaining basic proficiency in fundamental Krabi Krabong movements such as *Tang Sok* (see Table 6 and Figure 8). These results collectively indicate that the validated, notation-based blended self-directed learning approach effectively enhances both symbolic understanding and embodied execution of Krabi Krabong.

Discussions

The findings of this study can be discussed in relation to the three stated research objectives.

Objective 1: Validation of the instructional tools (automatic/notation-based software stack)

The perfect IOC values across the teaching guide, notation reading test, and performance rubric indicate strong content validity and alignment between intended outcomes and assessment (IOC = 1.00). This mirrors best practices in digital dance–documentation where accuracy and internal consistency of tools are prerequisites for effective transmission (Brown & Smoliar, 1976; Fox, 2000). The rigor echoes platform development such as LabanEditor and newer 3D editors in which interface constraints and symbol rules safeguard representational fidelity (Kojima et al., 2002; Anderson et al., 2022). For Krabi Krabong, this validation is consequential: a verified notation stack reduces ambiguity when converting movement primitives (stance/guard/strike/transition) into teachable units and provides a stable foundation for automation (Wang et al., 2020).

Objective 2: Effectiveness of the blended self-directed learning model in notation comprehension

Learners' substantial improvements from pretest to posttest in reading Labanotation indicate that visual, self-paced, and interactive learning reduces the cognitive load involved in symbol decoding (Choensawat et al., 2010; Wang et al., 2020). The results align with constructionist learning, which emphasizes learning through active practice, feedback, and reflection, where students construct mental models by creating and testing notation themselves (Na Songkhla,

2007; Iamsupasit, 2019; Morado et al., 2021). Similar findings in digital physical education show that intelligent feedback and modular e-learning systems maintain engagement and accelerate conceptual understanding (Liu et al., 2024; Kaeduang et al., 2024). These outcomes also explain why gains in notation literacy were greater than physical skill improvement: symbolic reasoning can progress quickly through repeated digital practice, while motor performance develops more slowly through neuromuscular adaptation. This pattern is consistent with blended self-directed learning sequences in which the system provides tasks and feedback (Laurillard, 2012) and follows Merrill's progression from demonstration to application using notation tasks (Merrill, 2002).

Objective 3: Improvement of Krabi Krabong performance (application to practice)

Performance scores improved, with most learners achieving basic proficiency in foundational sequences. This transfer from symbolic understanding to physical execution supports previous findings that blended or technology-enhanced practice improves self-efficacy and skill acquisition in movement education (Ronkainen et al., 2021; Kaeduang et al., 2024). The use of video-supported rehearsal and notation cues is consistent with research on multimodal feedback in motor learning (Sookhanaphibarn & Sookhanaphibarn, 2018; Sookhanaphibarn et al., 2023). The smaller effect size for performance compared to notation reading is expected because weapon-based choreography requires timing, strength, and postural control which typically develop over longer periods. Sport-science research on Krabi Krabong similarly shows that physiological adaptation increases with training volume and intensity (Wandee et al., 2025).

Three mechanisms likely contributed to these outcomes: first, practice density, as learners could try many notation exercises per session while physical attempts were fewer due to fatigue and safety concerns; second, feedback immediacy, because the software delivered symbol-level feedback instantly while kinesthetic feedback depended on teacher input; and third, the transfer gap, as converting symbols into full-body coordination requires perceptual and motor integration that cannot fully develop within four sessions. These mechanisms align with constructionist

and sport- learning theories which emphasize that cognitive understanding stabilizes earlier than motor execution (Morado et al., 2021; Ronkainen et al., 2021).

Effect size was not reported due to a lack of standard deviation data. Future research should include effect size and confidence intervals to improve statistical clarity. This study was also limited by a small sample size of 45 participants, a four-week intervention period, and convenience sampling. Since all participants were physical education trainees with prior movement experience, the findings may not generalize to beginners or non- specialist populations. Future work should test the system with novice learners to evaluate accessibility and inclusivity in digital heritage education.

The findings have practical applications in both education and community contexts. In teacher training, the blended self- directed learning model can be integrated into physical education or movement arts courses to enhance notation literacy and reflective practice. In community settings, cultural organizations can adopt the digital platform to support intergenerational transmission of Krabi Krabong by enabling practitioners to document, teach, and preserve movement knowledge using accessible technology. These implementations would support both educational innovation and cultural sustainability.

Limitations and future directions

This study has several limitations. The quasi-experimental design used a single-group sample from one institution through convenience sampling, which limits the generalizability of the results across age groups, regions, and training experiences. The four-week intervention provided only a short duration for motor learning and skill retention, suggesting that longer training and follow-up assessments are required for deeper insight. Although the instructional tools achieved perfect content validity (IOC = 1.00), further usability testing—such as System Usability Scale (SUS) scores, task success rates, and device-based performance would enhance external validity.

Future studies should include control or comparison groups (e.g., notation-only learning, blended self-directed learning, and traditional coaching) to examine differences in symbolic and physical performance. Incorporating adaptive feedback systems and intelligent hints (Liu et al., 2024) may further

support learner autonomy. Cross-cultural comparisons with movement notation in ballet (Benesh & Benesh, 1983), Noh theatre (Choensawat et al., 2011), or K-pop choreography (Lee, 2025) could refine the cultural adaptability of the framework. In addition, comparing motion-to-notation automation outputs with expert-crafted scores (Wang et al., 2020) would improve translation accuracy standards.

Finally, confidence intervals were not reported due to the absence of raw standard deviation data. Future research should include confidence intervals and effect sizes (e.g., Cohen's d) to strengthen the statistical transparency and interpretation of results.

Conclusions

This study demonstrated that integrating validated instructional tools with blended self- directed learning software effectively supports both the symbolic and practical dimensions of Krabi Krabong education. High IOC scores for the teaching guide, notation assessment, and performance evaluation confirmed the validity and reliability of the instruments, while experimental results showed significant improvement in learners' ability to interpret notation and apply it in physical performance. These outcomes highlight how digital heritage methodologies can address declining transmission, particularly as traditional master- apprentice teaching faces instructor shortages and reduced youth participation. By embedding notation-based instruction into a structured digital platform, the study preserved cultural authenticity while improving accessibility beyond conventional learning environments. At the policy level, this model can be integrated into secondary and higher education physical education curricula, aligning with national standards to enhance cultural literacy, physical competence, and identity formation. In addition, a digital museum that houses motion capture archives, notation libraries, and interactive learning modules could serve as both a cultural repository and an educational platform, positioning Krabi Krabong as a living heritage within Thailand's digital ecosystem. Furthermore, the methodology has cross- cultural applicability and can be extended to other martial and performance traditions such as Muay Thai, Japanese Kendo, Chinese Wushu, and Indonesian Pencak Silat. These findings confirm that technology is not an optional supplement but a necessary mechanism for

sustaining intangible cultural heritage through active, learner‑centered education. The approach aligns with Thailand's cultural and educational policies and offers a practical framework for teacher training, school implementation, and community‑ based transmission. Future research should extend training duration, include more diverse participant groups, and explore AI‑driven personalization to enhance learning outcomes and global relevance.

New knowledge gained

This study contributes to the intersection of digital technology and traditional arts education in three keyways.:

1. Instructional design for digital heritage was validated. The study developed and tested a notation-based learning system with strong content validity, demonstrating that cultural authenticity can be preserved while making heritage education scalable and systematic.

2. Blended self-directed learning software proved effective. Learners showed significant improvement in understanding and applying Labanotation. They were able to translate symbolic notation into physical performance, confirming the effectiveness of interactive, self-paced learning environments.

3. Constructionist learning was successfully integrated with heritage transmission. The system enabled learners to build knowledge through doing, reflecting, and iterating— supporting autonomy, goal-setting, and embodied understanding, in line with theories of embodied and sport education (Ronkainen et al., 2021; Morado et al., 2021).

Beyond these contributions, the model offers practical implications: it provides Thailand with a pathway to embed Krabi Krabong into physical education and digital repositories, while internationally, it offers a transferable framework for other martial and performance traditions. Ultimately, the research argues that intangible cultural heritage can be sustained not only through documentation, but through active, scalable, and learner‑centered education in the digital era.

Declaration of generative AI in scientific writing

Generative AI was used only for language refinement and reference formatting. It was not involved in idea generation, data analysis, interpretation, or content creation. All intellectual work and final interpretations were conducted by the authors, who assume full responsibility for the manuscript's accuracy and integrity.

CRediT author statement

Termpetch Sookhanaphibarn: Conceptualization, Project administration, Writing Original Draft, Writing Review & Editing.

Suthana Tingsabhat: Investigation, Data curation, Validation.

Kingkarn Sookhanaphibarn: Software, Formal analysis, Visualization.

References

Al Rasyid, B. A., & Nurharini, A. (2025). Flipbook-based e-module media to improve learning outcomes of Central Javanese traditional dance material. *Journal of Education Research and Evaluation, 9*(2), 437-444.

Anderson, K., Kordts, B., & Schrader, A. (2022). A novel 3D editor for gesture design based on Labanotation (pp. 577-584). In Proceedings of the 21ˢᵗ Congress of the International Ergonomics Association (IEA 2021). Cham, Switzerland: Springer.

ASEAN Secretariat. (2024). *Promoting and safeguarding traditional sports and games in ASEAN* [PDF report]. Association of Southeast Asian Nations. Retrieved from https://asean.org

Benesh, R., & Benesh, J. (1983). Reading dance: The birth of choreology. New York, NY: McGraw-Hill.

Brown, M. D., & Smoliar, S. W. (1976). A graphics editor for Labanotation. *Computer Graphics, 10*(2), 60-65.

Choensawat, W., Takahashi, S., Nakamura, M., & Hachimura, K. (2011). The use of Labanotation for choreographing a Noh-play. *Culture and Computing*, 167-168.

Choensawat, W., Takahashi, S., Nakamura, M., Choi, W., & Hachimura, K. (2010). Description and reproduction of stylized traditional dance body

motion by using Labanotation. *Transactions of the Virtual Reality Society of Japan, 15*(3), 379-388.

Fox, I. (2000). *Documentation technology for the 21st century* (pp. 136-142). In Proceedings of the World Dance. Tokyo, Japan: World Dance Alliance.

Hachimura, K., & Nakamura, M. (2001). *Method of generating coded description of human body motion from motion-captured data* (pp. 122-127). In Proceedings of the 10th IEEE International Workshop on Robot and Human Interactive Communication. Bordeaux, France: IEEE.

Husnawati, R. N., & Nurharini, A. (2024). Live worksheets media to improve exploration of dance movements of Grade II elementary school students. *Journal of Education Technology, 8*(1), 147-153.

Iamsupasit, S. (2019). *Theories and techniques in behavior modification*. Bangkok, Thailand: Chulalongkorn University Press.

Johnson-Glenberg, M. C. (2018). Immersive VR and education: Embodied design principles that include gesture and hand controls. *Frontiers in Robotics and AI, 5*, 81.

Kaeduang, M., Samawathdana, R., Tingsabhat, S., Sookhanaphibarn, T., & Autthamathitapakdee, K. (2024). *Enhancing self-management skills through PE e-learning packages* (pp. 1293-1294). In Proceedings of the 2024 IEEE 13th Global Conference on Consumer Electronics (GCCE). Fukuoka, Japan: IEEE.

Kerdkaew, F. (1984). *Krabi Krabong*. Bangkok, Thailand: Odeon Store.

Kojima, K., Hachimura, K., & Nakamura, M. (2002). *LabanEditor: Graphical editor for dance notation* (pp. 250-255). In Proceedings of the 11th IEEE International Workshop on Robot and Human Interactive Communication (RO-MAN 2002). Berlin, Germany: IEEE.

Laurillard, D. (2012). Teaching as a design science: Building pedagogical patterns for learning and technology (1st ed.). New York, NY: Routledge.

Lee, B. K. (2025). A study on AI-based automatic dance notation generation for K-POP choreography copyright protection. *Journal of*

The Korea Society of Computer and Information, 30(4), 19-24.

Liu, Y., Lu, D., Xu, D., Zheng, Y., Zhou, T., Li, N., & Feng, R. (2024). *Exploring intelligent feedback systems for student engagement in digitized physical education learning through machine learning* (pp. 114-118). In Proceedings of the 2024 International Conference on Artificial Intelligence and Future Education. Shanghai, China.

Merrill, M. D. (2002). First principles of instruction. *Educational Technology Research and Development, 50*(3), 43-59.

Morado, M. F., Melo, A. E., & Jarman, A. (2021). Learning by making: A framework to revisit practices in a constructionist learning environment. *British Journal of Educational Technology, 52*(3), 1093-1115.

Na Songkhla, J. (2007). Web-based instruction in e-learning system. Bangkok, Thailand: Chulalongkorn University Press.

Ronkainen, N. J., Aggerholm, K., Ryba, T. V., & Allen-Collinson, J. (2021). Learning in sport: From life skills to existential learning. *Sport, Education and Society, 26*(2), 214-227.

Sookhanaphibarn, T., & Sookhanaphibarn, K. (2018). *Enhancing table-tennis learning outcome using video-based self-recording during play and practice* (pp. 671-672). In Proceedings of the 2018 IEEE 7th Global Conference on Consumer Electronics (GCCE). Nara, Japan: IEEE.

Sookhanaphibarn, T., Tingsabhat, S., & Choensawat, W. (2023). *Utilizing self-learning software for the acquisition and exploration of standard dance notation fundamentals in Krabi Krabong arts education* (pp. 473-474). In Proceedings of the 2023 IEEE 12th Global Conference on Consumer Electronics (GCCE). Nara, Japan: IEEE.

Thailand Foundation. (2022). *Krabi-Krabong: An ancient Thai martial art making its way back*. Retrieved from https://www.thailandfoundation.or.th

UNESCO. (2003). Convention for the safeguarding of the intangible cultural heritage. Paris, France: United Nations Educational, Scientific and Cultural Organization. Retrieved from https://ich.unesco.org/en/convention

Wandee, A., Chabairam, B., & Homjan, S. (2025). Physiological responses on Krabi-Krabong skill learning in students of Buriram province. *Retos: Nuevas Tendencias en Educación Física, Deporte y Recreación, 68*, 159-169.

Wang, J., Miao, Z., Xie, N., Xu, W., & Li, A. (2020). Labanotation generation from motion capture data for protection of folk dance. *IEEE Access, 8*, 154186-154197.