Doctoral Dissertation

Cue-Guided Angklung Training System: Evaluating Usability, Learning Experience, and Perceptions from Players and Experts

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Abstract

Angklung is a traditional Indonesian musical instrument made from bamboo tubes and typically performed in an ensemble, where each player is responsible for a single note. Because of its ensemble nature, angklung performance heavily relies on a conductor who uses hand-sign cues to coordinate timing and note transitions. While ensemble playing fosters communal learning, it poses challenges for novices who wish to practice individually—especially when a human conductor or structured rehearsal setting is not available. This study addresses that gap by developing a **cue-guided angklung training system** that supports individual self-practice while maintaining pedagogical elements based on traditional hand-sign methods.

The main objective of this research is to develop and evaluate a **cue-guided training system** using two types of instructional approaches: **visual-cue** and **handsign-cue**, focusing on usability, user engagement, and learning impact for novice players. Three digital training methods were introduced: **Notebar (NB)**, which provides visual timing through color-coded bars; **Hand-Sign Bot (HB)**, which presents gestures in sync with note timing, allowing players to follow along during practice; and **Hand-Sign Bot with Preview (HBP),** which enhances HB by adding anticipatory gesture cues to support predictive timing. This study explores how such a system can be developed, how it affects player performance and experience, and how experts perceive the role of hand-sign-based instruction in angklung learning.

To achieve these aims, a four-phase methodology was used: research design, system development, experimental testing, and evaluation. The system was tested with 36 participants from diverse backgrounds—both Indonesian and international, with varying levels of music experience—divided into novice and experienced groups. The experimental procedure included pre- and post-test performance assessments, followed by usability and engagement surveys using the System Usability Scale (SUS) and the User Experience Questionnaire (UEQ-S). Additionally, expert interviews were conducted and analyzed using Framework Analysis to gather qualitative insights.

The findings show that all three training methods effectively support novice skill development, as the Friedman test indicated no statistically significant difference in performance improvements. However, there were notable differences in usability and engagement. **NB** was rated highest in usability, particularly by novice and non-musician participants, due to its simplicity and visual clarity. **HBP** was considered the most inventive and engaging, especially by users with prior musical experience. **HB**, while grounded in traditional pedagogy, received mixed responses because of its rigid format and steeper learning curve. Expert evaluations confirmed that HB and HBP successfully replicate essential aspects of human conducting gestures, making them pedagogically valid for instruction, though limited in expressive nuance and adaptability. Experts also recommended improvements such as customizable hand-sign libraries, alternate conductor avatars, and more unified visual cue designs across all training modes.

This research contributes a novel digital approach to angklung training by simulating conductor-led instruction in a self-directed learning environment. It bridges traditional music pedagogy with digital education while preserving cultural authenticity. The study concludes that cue-guided systems can effectively support individual angklung practice and recommends future developments in group-based and remote training, along with expanded visual personalization and expert-defined gesture customization.

Keyword:
Cue-guided system, Visual-Cue, Handsign-Cue, Novice Angklung Player, Digital Music Pedagogy, Usability Evaluation, User Engagement.

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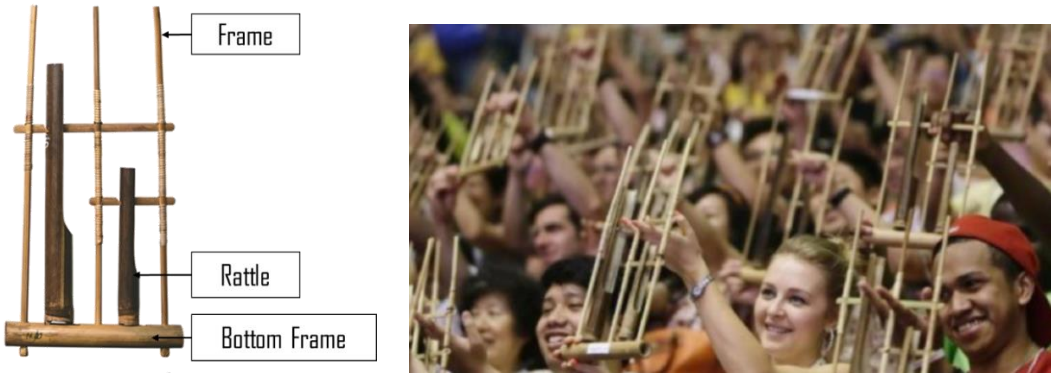
Chapter 1 Introduction

1.1. Background

Indonesia has several traditional musical instruments, one of which is the angklung. Currently, angklung is not only played for performing arts but is introduced in schools starting from elementary school to university [1]. Angklung is a bamboo traditional musical instrument originating from West Java, Indonesia [2], and was recognized by UNESCO as an Intangible Cultural Heritage in 2010 [3]. It comprises bamboo tubes with frames. Historically, angklung primarily utilized the Sundanese pentatonic scale (da-mi-na-ti-la-da') for traditional performances. Over time, the diatonic angklung (do-re-mi-fa-so-la-ti-do') was developed, making it accessible to a global audience and suitable for a broader range of musical genres, including national and international compositions [4].

The diatonic angklung has become a crucial part of Indonesia's cultural and educational system, particularly in West Java, where its inclusion in school curricula is mandatory [5]. Its unique structure—each instrument producing a single note—requires players to collaborate closely in groups to create harmonious melodies. This aspect emphasizes the instrument's role as a symbol of unity and cooperation, embodying the values of harmony and teamwork [6].

Angklung has different shapes and sizes, but there are two important parts to an angklung [7], which are: 1) frame: The primary function is to hold the rattle tubes; 2) rattle: the primary function is to produce a pitch frequency, but each rattle has each pitch frequency. In comparison, the function of the bottom frame is the foundation of the tubes and other frames. Figure 1.1 shows the shape of the angklung with a label for each part of the angklung.



(a) [8] (b) [9]

Figure 1.1: Picture of Angklung (a) and Angklung Performance from Foreigners (b)

The levels of angklung players are categorized into novice and experienced players (intermediate and advanced). Playing angklung is challenging for novices due to the instrument's distinctive structure. Each angklung produces only one note, which means each player is responsible for a specific note within the melody. This requires precise timing and coordination with the entire group, as a missed or delayed note can disrupt the overall performance. Novice-level angklung performances typically involve playing only a one-octave melody [10]. A leader who serves as a melody guide, known as the conductor, is also essential. At the novice level, the conductor employs hand-sign language. The basic idea is derived from Kodaly's hand-sign language [11]; however, in Indonesia, particularly in the West Java region, angklung experts have agreed to modify these hand-signs slightly. The modification was made because the original signs were considered culturally inappropriate in Indonesian society [12]. The modified hand signs are the "Saung Udjo hand signs" [13]. From this point forward, these hand signs are used by all angklung conductors in Indonesia. The movements of the Saung Udjo hand signs can be seen in Figure 1.2 below.

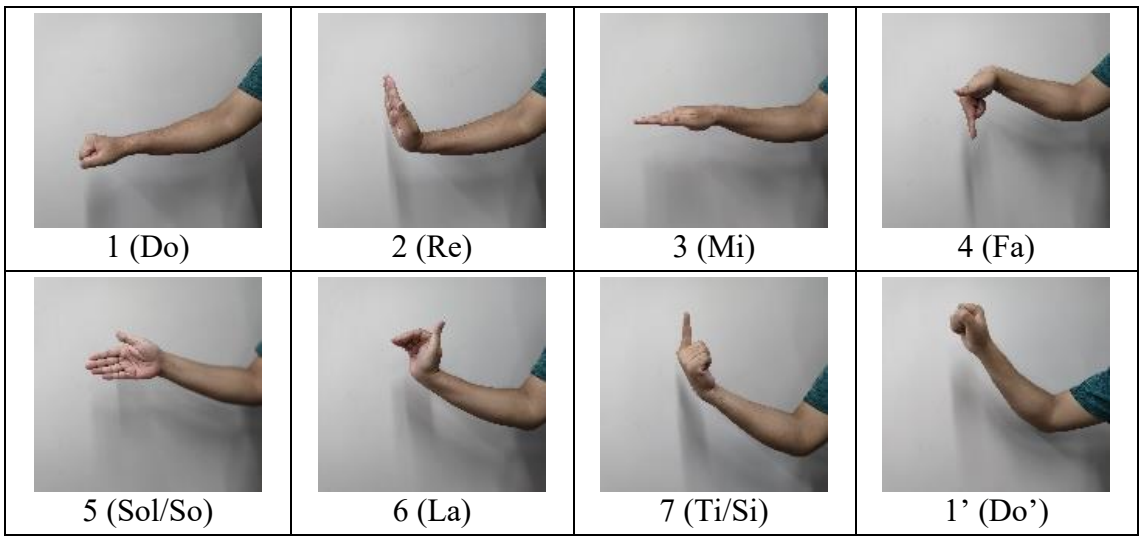


Figure 1.2: The conductor's hand signs for novice angklung players, popularized by Saung Angklung

In school-based angklung learning, novice players typically hold only one note and follow the conductor’s instructions closely to contribute to a complete musical piece. This dependency on a conductor and an entire ensemble poses significant limitations during practice sessions. Learners often cannot practice independently, especially when access to a human conductor or group members is limited. Such barriers are particularly apparent in early training, where learners need repetitive and guided practice to develop fundamental skills. These practical constraints have led to growing interest in training systems simulating conductor-led ensemble experiences in individual or small-group settings.

While recent technological efforts have introduced digital elements into angklung performance—for instance, using alternative controllers to trigger angklung sounds—these approaches often overlook the pedagogical needs of novice players and the traditional structure of ensemble coordination [14]. There remains a lack of systems

specifically designed to support learning progression, cue-following, and skill development in authentic angklung contexts.

To address this gap, the present research proposes a **Cue-Guided Angklung Training System** that enables novice angklung players to practice independently or in small groups without sacrificing the traditional learning model. By combining visual cues and hand-sign gestures, the system aims to replicate the role of a human conductor while fostering user engagement, enhancing skill acquisition, and maintaining cultural relevance. Through experimental evaluation and expert assessment, the study investigates how such a system can be developed and how it influences the angklung-playing experience, usability, and perceived effectiveness among learners and instructors.

1.2. Challenges for Novice Players

Angklung, by design, is an ensemble instrument that relies heavily on group coordination and conductor guidance. For novice players, this presents a unique set of challenges that can hinder their ability to develop individual playing skills. While the instrument is simple in construction, the learning context in which it is embedded—particularly its dependence on synchronization and real-time direction—poses difficulties for novices attempting to practice independently. Based on field observations and prior studies, several key issues have been identified:

1. **Difficulty Understanding Hand-Sign Conductors**
   Traditional angklung training relies on a human conductor using hand-signing gestures to signal note sequences. However, novice players often find it challenging to interpret these gestures accurately, especially when learning without step-by-step scaffolding or consistent exposure. This gap in understanding creates confusion during practice and performance.
2. **Struggle to Anticipate the Next Note**
   Novice players frequently experience hesitation when transitioning between notes. This is typically due to the lack of anticipatory visual or gestural cues that would otherwise help prepare for the next musical action. Without the ability to foresee what comes next, players often react late or miss cues entirely.
3. **Low Confidence in Playing**
   The combination of uncertainty, miscoordination, and missed cues contributes to low self-confidence in many novices. This lack of confidence reduces motivation to practice and may result in avoidance behaviors, limiting skill reinforcement opportunities.
4. **Difficulty Adapting to Tempo Changes and Dynamics**
   Even at the basic level, songs may involve changes in speed or intensity. Novice players—particularly those without a musical background—often struggle to follow these changes, leading to further disconnection between their playing and the intended rhythm or emotion of the piece.
5. **Limited Access to Human Conductors**
   In non-formal or resource-limited contexts, qualified angklung conductors may not always be available. This restricts the frequency and quality of practice sessions, especially for students practicing outside of school hours or in remote areas.

These challenges collectively reveal a critical limitation in the current angklung training environment: the absence of a reliable structure for **individual, self-paced learning**. The traditional model assumes the presence of a group and a conductor, leaving little room for independent development. As a result, many novice players cannot make meaningful progress unless embedded in a fully supported ensemble setting.

To address this gap, the present research proposes a **self-training system** that simulates essential aspects of angklung instruction—such as cue-following, timing, and anticipation—through a series of digital training methods. By reducing dependence on group members and enabling practice without a human conductor, the system aims to support novices in developing fundamental skills and confidence, preparing them for future group-based performance.

This study proposes a structured angklung training system that enables independent practice while simulating real-world angklung training conditions to address these challenges. The system introduces three core training methods:

1. **Notebar (NB):** A visual cue system that guides players by displaying color-coded bars to indicate note timing and duration.
2. **Hand-Sign Bot without Preview (HB):** A digital hand-sign guide that replicates traditional angklung conducting gestures, enabling players to practice without the presence of a human conductor.
3. **Hand-Sign Bot with Preview (HBP):** An enhanced version of HB that includes anticipatory gesture cues, allowing players to prepare for upcoming notes in advance.

1.3. Research Objectives

To address the challenges faced by novice angklung players during training and to explore effective alternatives that simulate real-world learning environments, this study sets out a series of research objectives as follows: **To develop and evaluate a cue-guided angklung training system for novice players, using visual-cue and handsign-cue approaches to support individual learning, focusing on player performance, user experience, and expert evaluation.**

1.4. Research Questions

This study seeks to answer the following questions:

1. **RQ1: How can a cue-guided training system be developed to support angklung learning for novice players?**
2. **RQ2: How do players and experts perceive the angklung-playing experience using a cue-guided system?**
    a. RQ2a: How does player performance change when using a cue-guided system?
    b. RQ2b: How do players experience usability and user engagement when using a cue-guided system?
    c. RQ2c: What are experts' perspectives on the challenges and advantages of handsign-cue approaches in angklung training?

1.5. Scope of the Study

This study focuses on developing and evaluating a structured angklung training system designed for **novice players**, with particular emphasis on individual self-training. The system introduces three cue-guided training methods: **Notebar (NB)**, **Hand-Sign Bot without Preview (HB)**, and **Hand-Sign Bot with Preview (HBP)**. These methods are designed to provide visual and gestural cues that simulate the presence of a human conductor, enabling independent practice without requiring group coordination or ensemble rehearsal.

To clearly define the boundaries of the research, the study scope is divided into two categories: aspects that are included (Table 1.1) and those that are deliberately excluded (Table 1.2). The following table presents the key elements covered in this study.

Table 1.1: Scope of the Study

Scope Area	Description
Training System Design	Development of a screen-based angklung training system using three methods: NB, HB, and HBP. The system simulates conductor cues through visual and gestural elements to support individual practice.
Training Methods Evaluated	Evaluation of training effectiveness through: (1) performance change (pre- and post-test), (2) usability and user engagement (SUS and UEQ-S), and (3) expert evaluation of the hand-sign-based cueing methods.
Participant Selection	Participants include novice players from both Indonesian and international contexts, as well as expert angklung instructors. All testing is conducted in a one-player-one-instrument setting.

The scope of this study also acknowledges certain aspects that fall outside the intended research boundaries. These exclusions are necessary to ensure focus, feasibility, and clarity in the implementation and analysis of the training system. The following table outlines the elements excluded from this research.

Table 1.2: Excluded from This Study

Excluded Element	Rationale
Group-Based Training	No ensemble or multiplayer interaction is involved. The study is limited to individual training scenarios.
Advanced Playing Techniques	The system targets novice-level learning only. Complex techniques for intermediate or advanced players are beyond the current study.
Gesture Recognition and Adaptive Feedback	The system does not interpret player gestures or adapt in response to input. All cues are presented using fixed, pre-programmed timing.

In conclusion, this study is strictly limited to evaluating a cue-guided training system for novice angklung players in an individual learning context. While the system draws inspiration from traditional ensemble instruction, this research does not encompass group-based experimentation or adaptive feedback mechanisms.

1.6. Research Positioning and Contribution

This section explains the position of the present study within the wider domain of digital music learning technologies and outlines its specific contributions to angklung education. It highlights how the proposed **cue-guided system** addresses limitations in current instrumental training methods, particularly for instruments that rely on visual cues and timing coordination. The discussion also clarifies the system's novelty in supporting individual practice for ensemble-type instruments, while preserving cultural integrity and pedagogical relevance.

1.6.1. Position within Music Education Technology

This study is positioned within the growing field of digital music education, specifically in the context of **self-guided training for instruments that require collaborative timing**, such as angklung. Unlike most digital learning systems—typically designed for melodic or solo instruments using notation-based guidance [15], rhythm-matching games [16], or AI-assisted feedback [17]—this research focuses on visual cue-following for **single-note instruments** in a **non-ensemble training context**.

Among these categories, visual-cue–based training systems have become particularly common in commercial rhythm games and educational tools. Applications such as Piano Tiles, Taiko no Tatsujin, and similar rhythm-matching platforms rely heavily on predictable visual timing cues to guide user responses. While such systems are effective in building hand-eye coordination and beat anticipation, they primarily support individualized, reactive training. These methods are not designed to replicate instructional roles, such as a human conductor's nuanced, expressive gestures.

While angklung is traditionally performed in coordinated groups, current digital platforms offer limited support for players to practice independently while still engaging with the underlying timing structure of ensemble-based music. Most existing systems do not replicate the cue-guided nature of angklung performance, nor do they reflect the culturally specific hand-sign methods commonly used in educational and performance settings.

By proposing a **cue-guided digital training framework**, this research expands the scope of music learning technologies to support individual practice for ensemble-type instruments. It emphasizes the development of cue-following skills and anticipatory timing, which are essential for later ensemble integration but are often overlooked in individual practice tools.

1.6.2. Novel Contribution of the Study

This research introduces two cue-guided digital tools—**Hand-Sign Bot without Preview (HB)** and **Hand-Sign Bot with Preview (HBP)**—designed to assist novice angklung players in practicing independently using structured visual cues. HB simulates culturally grounded hand-sign gestures to guide note execution, while HBP extends this by adding anticipatory cues that help players prepare for upcoming transitions.

To the best of our knowledge, this is the first study to digitize the handsign-based conducting method used in angklung education, and implement it in a screen-based self-

training system. Unlike prior virtual conductor tools, which focus on orchestral simulation [18], HB and HBP are developed for single-note execution, emphasizing gesture clarity and player timing without the need for group coordination.

Furthermore, HBP introduces a dual-conductor approach by displaying upcoming gestures one second in advance—an innovation not found in rhythm-based games or typical conducting systems. This supports proactive timing strategies for players who require more time to process visual input.

Importantly, while the angklung is a group-dependent instrument, this study strictly focuses on individual learning scenarios. All performance assessments, user evaluations, and expert reviews are conducted within self-training environments, without requiring multi-player synchronization or real-time interaction. By combining traditional conducting pedagogy with digital self-learning tools, this study contributes a novel instructional model for ensemble-type instruments that enables independent practice while preserving cultural authenticity.

From an Information Science and HCI perspective, this study contributes a structured interface design that enables timing coordination through pre-defined visual and gestural cues, without relying on score literacy or symbolic gesture interpretation. This approach offers a model for accessible, low-barrier music training systems that simulate ensemble behavior in individual learning environments.

1.7. Methodology Overview

This study employs a four-phase research methodology to design, implement, and evaluate a cue-guided angklung training system tailored for novice players. The research methodology is aligned with the overarching research objective (RO) and structured to answer the primary and sub-research questions (RQ1, RQ2, RQ2a, RQ2b, RQ2c).
The methodology is divided into the following phases:

1. **Research Design**: Establishing the research framework, instruments, and data collection strategies for evaluating learning performance and user experience.
2. **System Development (RQ1)**: Design and implement three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—based on traditional angklung instruction practices with digital enhancements that simulate the role of a human conductor.
3. **Experimental Testing (RQ2)**: Participants from varied backgrounds and skill levels engage in angklung training using all three methods. A structured pre-test and post-test experimental design measures performance improvement and training impact.
4. **Evaluation (RQ2a, RQ2b, RQ2c)**: This phase incorporates both quantitative and qualitative analyses to interpret performance scores, usability responses (SUS), user experience evaluations (UEQ-S), and expert feedback, ensuring a multi-perspective understanding of training effectiveness.

Each phase is elaborated in **Chapter 3**, with detailed procedures, instruments, and analysis strategies.

1.7.1. Research Design

The research is designed as a **within-subject experimental study** involving both quantitative and qualitative data collection. All participants experienced all three training methods—NB, HB, and HBP—in a counterbalanced sequence to avoid order effects. Quantitative data are used to assess three primary dimensions:

- **Usability feedback**, collected via the **System Usability Scale (SUS)**.
- **User experience scores**, using the **User Experience Questionnaire - Short version (UEQ-S)**.
- **Performance scores**, measured pre- and post-intervention using a human conductor as a baseline.

In parallel, qualitative data are collected from:

- **Participant comments** are used to capture subjective learning experiences.
- **Expert interviews**, focused on Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP) methods, were analyzed through Framework Analysis.

This design ensures a comprehensive evaluation of the angklung training system, aligning with the research objective to assess both system usability and its impact on musical performance.

1.7.2. System Development (RQ1)

The second phase focuses on system development to address RQ1; three training methods were developed:

1. **Baseline Method (Notebar/NB)**: A visual guide using color-coded bars that signal when and which note to play. It serves as a baseline method for comparison.
2. **Proposed Method (Hand-Sign Bot without Preview/HB)**: A digital agent performing hand-sign gestures based on the traditional Saung Udjo system. This method replicates the guiding function of a human conductor.
3. **Proposed Method (Hand-Sign Bot with Preview/HBP)**: This is an extended version of HB that adds a secondary conductor that displays the next note one second ahead. It is intended to enhance player anticipation and timing accuracy.

The system was designed to be visual and adaptable to novice skill levels. To reflect novice-level playing, the training content was limited to a single-octave range ('do to do'). The training interface was developed with clear visual cues and handsign-cue guidance. All methods were embedded into a consistent digital training environment, ensuring comparability across conditions.

1.7.3. Experimental Testing (RQ2)

The experimental phase evaluates the learning impact of the three training methods using a **Pre-Post Test Experimental Design**, guided by a human conductor as a reference point. This phase directly addresses RQ2 and its sub-questions (RQ2a, RQ2b, RQ2c).

Participant Selection included:

- Non-Indonesian Novices: International participants unfamiliar with angklung and Indonesian conducting conventions.

- Indonesian Participants: Both novice and experienced angklung players.

Experimental Procedure:
Each participant followed a structured training schedule involving training sessions:

- Pre-test with Human Conductor (HC)
- Training with the training method (NB, HB, and HBP)
- Post-test with HC

The order of method exposure was counterbalanced among participants to control learning effects.

Data Collection:

- Quantitative performance scores were recorded for each session.
- Usability and engagement were evaluated using SUS and UEQ-S questionnaires.
- Qualitative comments were collected through post-session reflections.

This structured procedure enabled comparative evaluation of each method's effectiveness in supporting timing accuracy and learning progression among novice angklung players.

1.7.4. Evaluation (RQ2a, RQ2b, RQ2c)

The final phase of the research involves quantitative and qualitative evaluation.

RQ2a & RQ2b – Quantitative Evaluation

To determine whether significant differences existed in performance and experience among the three training methods, a **non-parametric Friedman Test was used to compare three related training methods**. This test is suitable for small sample sizes and repeated measures.

For both novice and experienced groups:

- **RQ2a** (Player Performance Score): The Friedman Test was applied to pre-post score differences across NB, HB, and HBP.
- **RQ2b** (Player Experience): The same test was applied to SUS and UEQ-S scores to detect perceived usability and engagement variations.

Where appropriate, **Post-Hoc Wilcoxon Signed-Rank Tests** were conducted to explore pairwise differences between methods.

RQ2c – Expert Evaluation

Expert interviews were conducted with four angklung instructors. Their evaluation focused on HB and HBP as digital alternatives to human conductors. The data were analyzed using **Framework Analysis (FA)**, consisting of five structured steps:

1. **Familiarization**: Transcribing expert feedback and identifying preliminary patterns.
2. **Identifying a Thematic Framework**: Extracting four central themes:
    - *Gesture clarity and accuracy*
    - *Effectiveness for novice training*
    - *Realism and resemblance to a human conductor*
    - *Limitations and areas for future improvement*
3. **Indexing and Coding**: Organizing expert responses under these thematic categories.
4. **Charting**: Tabulating insights into a matrix for comparison across experts.

5. **Mapping and Interpretation**: Synthesizing key findings into actionable conclusions, aligning with RQ2c.

This combined evaluation approach ensures that findings reflect statistical outcomes and pedagogical and cultural relevance, supporting the broader goals of inclusive and accessible angklung education.

1.8. Dissertation Structure

This dissertation is structured into seven chapters, systematically presenting the research foundation, methodological design, system implementation, experimental results, and final reflections. The structure follows a logical flow aligned with the research objectives and questions, beginning with the motivation and ending with the implications of the proposed cue-guided angklung training system.

Chapter 1: Introduction
This chapter establishes the foundation of the study by introducing the background of angklung as a traditional ensemble instrument and the challenges it poses for novice learners. It outlines the research objectives and questions, which center on the development and evaluation of a cue-guided self-training system. The scope of the study is clearly defined, emphasizing the focus on individual (self-training) practice only. A high-level summary of the research methodology and experimental setup is also provided, followed by an overview of the dissertation structure.

Chapter 2: Literature Review
This chapter reviews related works in angklung education, digital music training, and hand-sign-based learning. It examines general instrumental training strategies, including notation-based, rhythm-based, and gesture-guided systems, positioning the current research within broader music education technology. The review also explores relevant pedagogical frameworks such as the Kodály method and multisensory learning, identifying a key research gap in digital cue-guided training for angklung. The chapter concludes by establishing the theoretical and technological foundations for developing HB and HBP as digital hand-sign cueing models.

Chapter 3: Research Methodology
This chapter outlines the research design in four phases: (1) Research Design, (2) System Development, (3) Experimental Testing, and (4) Evaluation. It describes how each phase aligns with the corresponding research questions. The development phase (RQ1) focuses on building Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The testing phase (RQ2) involves pre- and post-test experiments, while the evaluation phase (RQ2a, RQ2b, RQ2c) covers performance analysis, user experience (SUS and UEQ-S), and expert feedback. Data analysis applies non-parametric statistical techniques (Friedman Test, Wilcoxon Signed-Rank Test) and Framework Analysis for qualitative interpretation.

Chapter 4: System Design and Implementation
This chapter addresses RQ1, detailing how the cue-guided angklung training system was developed to support individual practice. It describes the system architecture and the three

training methods: NB (visual-cue-based), HB (handsign-cue), and HBP (enhanced handsign-cue with anticipatory gestures). The chapter explains how each method simulates the role of a human conductor and how full-body avatar design enhances gesture clarity. Technical implementation and preconditions for user interaction are also discussed. This chapter concludes with an evaluation of system readiness for experimentation.

Chapter 5: Experiment
This chapter describes the experimental design used to evaluate the training methods. It includes participant group definitions (novice vs experienced; Indonesian vs non-Indonesian; with vs without musical background), task procedures, note allocation, and performance measurement. The chapter also explains the counterbalanced training setup to ensure fairness and eliminate learning bias across NB, HB, and HBP.

Chapter 6: Results and Analysis
This chapter presents findings that directly address RQ2 and its sub-questions. For RQ2a, it analyzes player performance scores across training methods and participant groups. For RQ2b, it discusses usability and engagement using SUS and UEQ-S results. For RQ2c, it presents expert evaluations using Framework Analysis, highlighting challenges and advantages of hand-sign-based training. The chapter concludes with a comprehensive synthesis of how players and experts perceive the training methods in terms of usability, effectiveness, and pedagogical relevance.

Chapter 7: Discussion and Conclusion
This chapter discusses the implications of the findings and answers the research questions holistically. It reflects on the usability, engagement, and learning effectiveness of HB and HBP, validating their role in structured angklung training. Limitations are acknowledged, including the study's focus on the self-training phase only, small sample sizes, and the lack of adaptive feedback. The chapter outlines future research directions, including development of group-training and remote-training scenarios, customizable gestures, and visual cue integration. The dissertation concludes by reaffirming its contribution to music education technology and angklung pedagogy.

Chapter 2 Literature Review

2.1. Introduction to Angklung and Its Educational Role

Angklung is a traditional Indonesian musical instrument made of bamboo tubes that are shaken to produce sound. It is unique because each instrument plays only one note, meaning multiple players must work together to perform a full melody. This collaborative nature makes angklung an effective tool for music education, as it promotes coordination, teamwork, and rhythmic precision among players [19]. While traditionally designed for ensemble settings, this study focuses on enabling individual practice through digital cue-based guidance.

In recent years, angklung has gained recognition beyond Indonesia, used in formal and informal educational settings worldwide. Its simplicity in playing mechanics and cultural significance make it an ideal instrument for introducing students to music concepts, particularly in group-based learning environments [20]. This section explores the historical background of angklung and its role in music education, highlighting its integration into modern teaching methodologies.

2.1.1. History of Angklung

The angklung is a traditional Indonesian musical instrument made of bamboo, known for its unique shaking mechanism that produces harmonious tones. Its journey from being a ritualistic object in agrarian societies to a global cultural symbol demonstrates its adaptability and resilience. This section explores the history of the angklung, its transformations, and its contemporary significance, supported by visual aids and comparative analysis.

The origins of the angklung can be traced back to the Sundanese people of West Java, Indonesia. It was initially utilized as a part of ritualistic and agrarian practices, where its music was believed to invoke the favour of Dewi Sri, the goddess of rice and fertility. According to Rahayani and MacGill, the angklung served as a communal tool, strengthening social bonds and celebrating agricultural success [9]. It’s simple yet profound function underscores its roots in the local spiritual and agrarian lifestyle.

As time progressed, the angklung evolved from its ritualistic role into a medium of entertainment and education. During the colonial period, it became a symbol of resistance and resilience. For instance, performances of angklung music were used to maintain local identity in the face of cultural suppression by colonial powers. Lestari and Sarjono highlight that this era marked a transition where the angklung began to represent a broader cultural manifestation, moving beyond its traditional rural context [21].

The 20th century saw further transformations in the angklung's function and form. Daeng Soetigna, a key figure in modernizing the angklung, developed a diatonic version in the 1930s, making it compatible with Western music scales. This innovation was pivotal in integrating angklung into formal education and broader global audiences [22].

This modern angklung could now perform traditional Indonesian songs and contemporary and international music, significantly broadening its appeal and utility.

The angklung's global recognition began to take shape in the mid-20th century. In 2010, UNESCO officially recognized angklung as an Intangible Cultural Heritage of Humanity, cementing its status as an integral part of global cultural heritage. Guna and Sjoraida argue that this recognition has enabled Indonesia to use the angklung as a tool for cultural diplomacy, fostering cross-cultural communication and appreciation [23]. International performances, particularly by groups such as Saung Angklung Udjo, have introduced the angklung to audiences worldwide, from Thailand to Europe and beyond.

Interestingly, the angklung has also found a unique place in Thailand, where it has been adopted and adapted into the local cultural landscape. Amatyakul describes the journey of the angklung in Thailand, emphasizing how it has been incorporated into Thai schools and communities, demonstrating its cross-cultural adaptability and appeal [24].

The angklung has embraced technological advancements in recent years, blending tradition with modernity. Wibowo et al. note that in the era of Industry 4.0, angklung has found new relevance through digital applications and educational tools [22]. These innovations ensure the preservation of angklung's traditional essence while adapting to contemporary demands for accessibility and engagement. Moreover, public pedagogy has played a vital role in maintaining and promoting the angklung as a cultural asset. Rahayani and MacGill emphasize the importance of community-based education and public performances in sustaining the angklung's legacy [9]. These initiatives preserve its historical significance and inspire new generations to engage with this traditional art form.

2.1.2. The Role of Angklung in Music Education

Angklung's unique ensemble-based playing style makes it an effective instrument for music education, particularly for novice learners. Unlike solo instruments where students must learn multiple notes and chords, angklung simplifies the learning process by allowing each player to focus on a single pitch while contributing to a collective melody. In an educational setting, angklung provides several pedagogical benefits [9], [25]:

1. Developing Coordination and Teamwork: Since each player holds only one note, successful performance requires students to listen carefully, follow timing cues, and collaborate with others.
2. Enhancing Rhythm and Timing Skills: Angklung players must shake the instrument at precise moments, improving their sense of rhythm and timing in a structured way.
3. Accessibility for All Skill Levels: Due to its simple playing mechanics, angklung is suitable for both music novices and experienced musicians, making it ideal for classroom instruction.
4. Cultural Awareness and Appreciation: Learning angklung introduces students to Indonesian heritage, fostering cross-cultural understanding in international music education programs.

Given these advantages, angklung has been widely incorporated into school curriculums, university programs, and community workshops. Its ability to bridge traditional and modern teaching methods makes it a versatile and effective educational tool.

2.1.3. Characteristics of Angklung Instrument

Angklung is a traditional Indonesian musical instrument originating from West Java, known for its cultural significance and distinctive construction [25], [26]. Each angklung consists of bamboo tubes mounted on a frame and is designed to produce a single musical note, determined by the specific length and diameter of the tubes [25]. This single-note nature necessitates collaboration among multiple players to perform even the simplest of melodies, highlighting the importance of ensemble coordination and mutual awareness in angklung performances [14]. Unlike other melodic instruments that can be played solo, angklung inherently embodies a communal performance model, where teamwork is essential to achieving musical coherence [21].

The sound production mechanism of the angklung relies on a shaking motion, which causes the bamboo tubes to resonate. This shaking technique is integral not only to the instrument's sound quality but also to the cultural identity it represents. The acoustic properties of bamboo, combined with traditional craftsmanship, contribute to the unique tonal character of angklung music [25]. Moreover, the instrument serves as more than a musical device; it is regarded as a cultural symbol, representing harmony, cooperation, and shared identity within Indonesian society [21].

Due to its ensemble nature, playing angklung requires synchronization with a conductor, particularly in educational and performance settings. This is especially true for novice-level players, who typically hold only one note and must rely on clear cues to maintain rhythm and sequence [14].. Traditionally, a human conductor uses hand-sign language to guide players through melodies. However, this setup presents challenges for practice, especially when access to a full group or a skilled conductor is limited. These constraints underscore the need for alternative training approaches that preserve the essence of ensemble playing while enabling individual practice.

While some modern adaptations have introduced digital technologies into angklung performance, such as using non-traditional controllers, these developments often prioritize musical novelty over structured training and cultural authenticity [14]. Therefore, to support novice-level angklung training in a manner consistent with traditional playing styles, it is essential to explore systems that retain their collaborative nature while enabling accessible and effective **individual** practice, especially in the absence of a human conductor or group environment. This context forms the basis for developing a cue-guided angklung training system, as examined in this study.

2.2. Conducting and Movement-Based Learning in Angklung Education

Teaching angklung is deeply rooted in movement-based learning approaches, where teachers use hand signs and conducting techniques to guide students. Unlike static musical training methods, angklung learning incorporates kinesthetic, participatory, and multisensory approaches, effectively developing student coordination, rhythm, and teamwork. This section explores various pedagogical techniques used in angklung education, including kinesthetic learning, participatory methods, cultural contextualization, and the role of the human conductor.

2.2.1. Kinesthetic Learning Approach in Angklung Training

Angklung training integrates physical movement as a core learning element, where students respond to visual and kinesthetic cues rather than relying solely on written notation.

1. Hand-sign language is the primary instructional tool, allowing students to associate movements with musical notes.
2. Students listen to verbal instructions and physically respond by shaking the angklung according to the teacher's hand movements.
3. This approach enhances coordination between visual perception, auditory cues, and motor responses, improving musical timing and synchronization.

Studies in music education research have shown that movement-based learning significantly enhances musical comprehension, particularly in young learners who benefit from active engagement [27].

2.2.2. Participatory and Collaborative Learning in Angklung Practice

Unlike individual instrument training, angklung requires active participation from all players, creating an inherently collaborative learning environment.

1. Each student plays a single note, meaning they must synchronize their playing with their peers to produce a complete melody.
2. Students do not passively receive information; instead, they must actively engage by following real-time conductor cues and responding immediately.
3. This method fosters social interaction, teamwork, and musical awareness. Although commonly applied in group-based music education, these principles are adapted in this study to support individual cue-guided training through simulated conductor instructions.

Educational studies emphasize that participatory learning leads to better retention and engagement, particularly when students feel they are part of a collective experience [28].

2.2.3. Contextual Learning Inspired by Saung Udjo

Saung Udjo, one of Indonesia's most prominent angklung education centers, is known for integrating Sundanese cultural values into its music teaching methodology.

1. Teachers incorporate storytelling and traditional narratives to make angklung learning more immersive and culturally meaningful.
2. The lessons combine music with cultural identity, allowing students to develop a deeper appreciation for Indonesian heritage while mastering angklung techniques.
3. Contextual learning ensures that students do not see angklung as a musical tool but as a representation of Indonesian cultural history and communal values.

This approach aligns with modern ethnomusicology studies, highlighting cultural integration's importance in music education [29].

2.2.4. The Role of Human Conductors in Angklung Education

The teacher in angklung training plays the role of a human conductor, guiding students through coordinated hand gestures. This conducting-based approach is essential for maintaining rhythm, timing, and group harmony.

1. The conductor's movements dictate when and how students should shake their angklung, similar to a traditional orchestra setting.
2. Students develop discipline and concentration, as they must focus on the conductor's cues while being aware of the overall group sound.
3. This role-based learning structure improves musical responsiveness, making students more adaptable to live performance settings.

Formative Assessment Through Conductor-Led Instruction

Unlike standardized music tests, angklung training involves ongoing formative assessment, where teachers evaluate student progress based on real-time responses to hand signals.

1. Teachers assess students' reaction speed and synchronization accuracy to determine their understanding of musical timing.
2. Immediate feedback allows moment-to-moment correction, making learning more fluid and responsive.

Studies in music pedagogy emphasize that real-time instructor feedback enhances learning outcomes compared to passive instruction [30].

2.2.5. Pedagogical in Angklung Education

As described, the pedagogical approach in angklung education emphasizes **active, participatory, and multisensory learning**. The teacher uses **hand-sign language** as a primary tool, integrating **kinesthetic and visual methods** to teach students. This approach aligns with experiential learning and cultural-based education principles, essential in fostering deeper understanding and engagement among learners [31], [32]. Key elements of this approach include:

1. **Movement-Based Learning**: Students respond physically to hand signals, enhancing coordination and understanding through kinesthetic engagement. This method supports the theory of **embodied cognition**, which highlights the connection between physical movement and cognitive development [33].
2. **Participatory Learning**: Students actively participate by playing their angklung according to their assigned notes, fostering collaboration and environmental awareness. This reflects the principles of **social constructivism**, where learning is facilitated through interaction and shared experiences [34].
3. **Cultural Context**: Inspired by the Saung Udjo method, the approach incorporates local cultural values, making learning more meaningful and contextual. This aligns with the concept of **culturally responsive teaching**, which emphasizes the importance of integrating students' cultural backgrounds into the learning process [35].

4. **Formative Assessment**: The teacher evaluates students' abilities in real-time by observing their responses, allowing for immediate feedback and adjustments. This practice is supported by **formative assessment theory**, which highlights the role of continuous feedback in enhancing learning outcomes [36].
5. **Multisensory Engagement**: The method combines auditory, visual, and kinesthetic elements, improving comprehension and memory retention. This approach is rooted in **multisensory learning theory**, which suggests that engaging multiple senses enhances learning effectiveness [37].
6. **Dynamics Conductor**: The teacher acts as a conductor, guiding students to work together, maintain harmony, and develop discipline and focus. This reflects the principles of **collaborative learning**, where group dynamics and leadership play a crucial role in achieving collective goals [38].

This pedagogical framework teaches musical skills and cultivates teamwork, concentration, and cultural appreciation, making it a holistic approach to angklung education. Integrating cultural values, multisensory methods, and collaborative practices provides a comprehensive, practical, and meaningful learning model.

2.3. Kodály Hand Sign and Its Application

The Kodály hand sign system, developed initially to enhance music education, has found applications beyond its initial context, particularly in ensemble music like angklung. This section explores the history and evolution of Kodály hand signs, their integration into angklung performances, and the modifications introduced by Saung Angklung Udjo to adapt these gestures to the unique characteristics of the angklung ensemble.

2.3.1. The History of Kodály Hand Sign

The Kodály hand sign system was developed as part of Zoltán Kodály's educational philosophy in the early 20th century [39]. It was heavily influenced by John Curwen's Tonic Sol-Fa system, which used hand gestures to represent the solfège syllables (do, re, mi, fa, sol, la, ti, do') [40]. Kodály adapted these gestures to provide a kinesthetic connection to pitch, helping learners visualize and physically embody the tonal relationships [41]. The system assigns a specific hand gesture to each note in the diatonic scale, enabling learners to understand intervals and melodic structures more intuitively. Figure 2.1 below illustrates the hand gestures associated with the solfège syllables, and Table 2.1 shows the meaning/representation of notes.

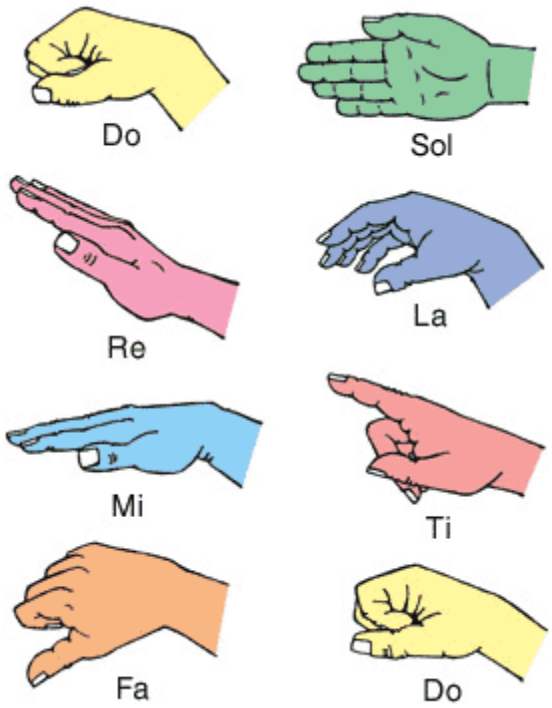


Figure 2.1: Kodály Hand Sign [42]

Table 2.1: Kodály Hand Sign System (Meaning) [43]

Hand Sign	Solfege Syllable	Meaning/Representation
Closed Fist	Do	Stable, home tone (tonic).
Vertical Palm	Re	Rising or leaning upward.
Horizontal Palm	Mi	Balanced, steady tone.
Thumb Downward	Fa	Pulling downward, signaling gravity.
Flat Hand	Sol	Open, expansive, resonant tone.
Cuped Hand	La	Gentle, lyrical, melancholic tone.
Index Pointing Upward	Ti	Striving upward, leading to the tonic.

2.3.2. The Use of Hand Sign in Angklung

Integrating hand signs in angklung performances is a relatively modern adaptation to facilitate group musical communication. Angklung is a *collective ensemble instrument*, where polyphony is achieved through player collaboration. Conductors typically use hand signs to indicate the notes to be played, their duration, and the desired dynamics. These signals are particularly beneficial in teaching novice players and students who may not have formal musical training. The application of hand signs in angklung resonates with the Kodály philosophy, as it provides a clear and universally understandable medium for conducting and learning. Figure 2.2 illustrates a conductor using hand signs during an angklung performance.

Figure 2.2: Using hand signs in playing angklung [44]

Hand signs in angklung are primarily used in the following contexts:

1. **During Rehearsals:** Hand signs are introduced in rehearsals to familiarize players with their cues. The conductor uses hand signs to indicate when each note should be played, its duration, and the dynamics (e.g., loud or soft). This helps players develop synchronization, particularly in large groups or novice ensembles where verbal instructions may be insufficient.
2. **In Live Performances:** Conductors employ hand signs to guide the ensemble during live execution. This ensures the seamless flow of the music and allows the conductor to make on-the-spot adjustments to note entry or exit.
3. **In Educational Settings:** Hand signs are a fundamental part of teaching angklung, particularly for students learning music theory or rhythm for the first time. By combining visual and auditory stimuli, hand signs help learners internalize the structure of melodies and harmonies. This is especially beneficial for novice learners, including those with limited access to auditory cues.
4. **In Large-Scale Collaborative Performances:** In situations where ensembles involve dozens or even hundreds of players, such as performances at Saung Angklung Udjo, hand signs become indispensable. They enable conductors to communicate effectively across a large group without the need for verbal instructions.

2.3.3. Modified Hand Sign Movements by Saung Udjo

Saung Angklung Udjo has adapted the original Kodály hand signs to better align with Indonesian cultural norms and the pedagogical needs of angklung performance. While most signs follow the Kodály system, certain gestures have been intentionally modified. For instance, the *fa* gesture—initially a thumb-down motion—were altered to avoid connotations deemed impolite in Indonesian culture [12] (see Figure 2.3).

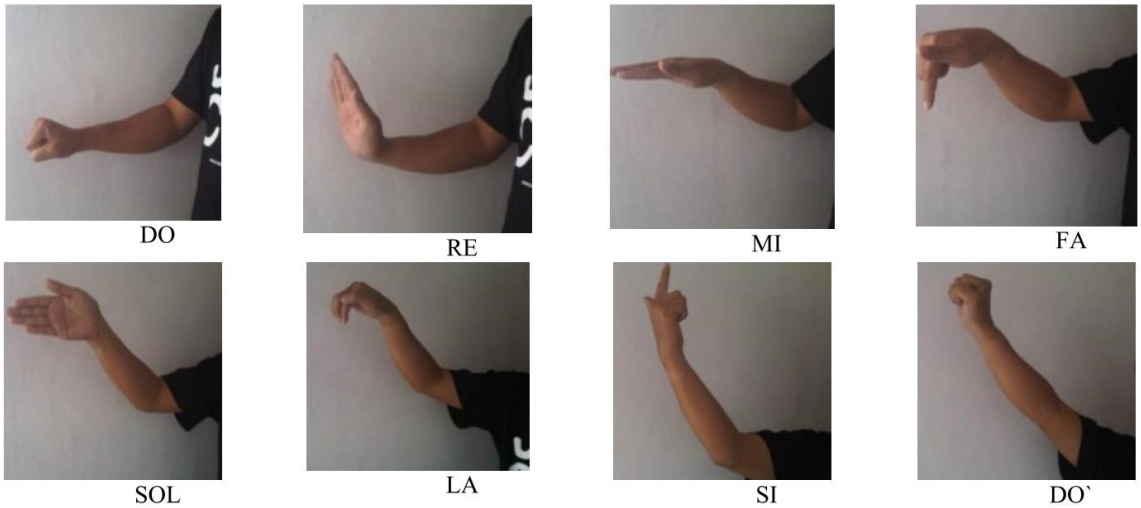


Figure 2.3: The hand signs after being modified by Saung Angklung Udjo [12]

These adaptations serve cultural sensitivity and pedagogical goals. The hand-sign system at Saung Udjo was designed to support **"instant performance"**: a model in which audiences or untrained participants can immediately participate in angklung playing without prior rehearsal. Each player holds only **one note**, and by associating that note with a single, apparent hand-sign gesture, they can follow the conductor's cue without needing to understand music theory or memorize sequences.

This system transforms the hand sign into a **universal visual language** for angklung, enabling accessible participation in musical performances. Rather than interpreting the semantic meaning of the gesture, players associate **a gesture with a single-note action**, aligning perfectly with the structure of cue-guided training explored in this study. Although the gestures are not formally standardized or patented, their widespread and consistent use at Saung Udjo has made them a recognizable part of angklung education and public pedagogy.

2.4. Music Education and Technology

Technology integration into music education has significantly expanded the scope of instructional methodologies, particularly for individual learners. Over the past decade, digital tools have increasingly supported flexible, self-paced practice environments through interactive interfaces, adaptive systems, and visual guidance mechanisms. These advancements have opened new possibilities for instruments traditionally associated with ensemble settings, such as angklung, by simulating conductor-player interactions in solo training contexts.

While conventional digital platforms in music education often focus on notation-based learning or ear training for Western instruments (e.g., piano or violin), recent developments have shown that culturally grounded instruments also benefit from tailored technological support. Specifically for angklung—which requires synchronization, cue-following, and ensemble-like coordination—technology allows players to experience structured musical flow individually, even without the presence of a human conductor or peers. In this study, ensemble-like coordination refers to the simulation of group-based

musical timing, conductor-following, and note cueing behaviors within an individual training setting, without the presence of other players.

In this study, technology is not positioned merely as a medium for delivering digital musical content but as an instructional agent that delivers visual cues to support physical timing, anticipation, and cue recognition. Through cue-guided methods such as Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP), the system replicates key aspects of traditional angklung rehearsal: gesture-based instruction, single-note assignment, and ensemble-like coordination [45].

The role of technology in this context is pedagogical rather than performative. It facilitates a form of solo training that retains ensemble characteristics, emphasizing gesture imitation and synchronization rather than symbolic interpretation or score memorization. As such, this cue-guided approach contributes to a growing body of research exploring how digital systems can support embodied, culturally responsive, and kinesthetic music learning for traditional instruments.

2.4.1. Technological Innovations in Music Instruction

Technological innovation has introduced a wide array of tools to support music education, ranging from individualized training applications to collaborative digital environments. These tools can be broadly categorized into two domains: (1) adaptive learning and feedback systems, and (2) digital platforms for collaborative learning. Both categories are highly relevant to ensemble-like coordination, particularly in the context of cue-guided angklung training.

2.4.1.1. Adaptive Cueing and Visual Guidance Tools

One of the most significant contributions of technology to music education is the development of adaptive learning tools capable of adjusting instruction based on individual progress. These systems often incorporate performance monitoring and corrective guidance, enabling students to identify and resolve timing or pitch-related errors during practice.

Zhang [17] highlights the role of personalized digital music environments that dynamically adapt to a learner's skill level, increasing engagement and learning efficiency. These platforms monitor user input and offer task difficulty adjustments based on synchronous cue delivery.

Haug et al. [46] further demonstrate that cue-driven music training tools enhance timing precision and rhythm stability by facilitating what they term as a "flow state"—a condition of sustained focus and optimal cognitive engagement. Such systems are especially applicable to instruments like angklung, which demand precise timing even when only a single note is played.

These platforms reduce the cognitive load of synchronizing with others by providing shared visual indicators and synchronous cue markers, allowing players to rehearse ensemble-like transitions in a self-training environment.

2.4.1.2. Individual Learning Systems with Simulated Ensemble Support

Music education also benefits from digital platforms designed to simulate ensemble dynamics through shared interfaces and synchronized cue delivery. These platforms enable learners to rehearse in collaborative settings, even when physically apart, by integrating synchronous cue delivery.

Johnson et al. [47] emphasize that online collaborative tools can strengthen coordination between players by delivering unified timing indicators, which is essential for instruments like angklung that rely on collective execution. These platforms reduce the cognitive load of synchronizing with others by providing visual metronomes and shared cue markers.

Smith et al. [48] explore the use of augmented reality (AR) and virtual reality (VR) environments for remote rehearsal, showing that simulated ensemble settings can replicate the attentional and timing demands of live performance. These technologies are particularly promising for angklung training, where visual and spatial awareness of conductor cues is fundamental.

2.4.2. Theoretical Foundations for Rhythm and Motor Synchronization

Rhythm is a fundamental aspect of music performance that requires precise timing and coordination. Understanding rhythm perception's cognitive and motor processes can help design more effective technology-based training methods.

2.4.2.1. Cognitive Load, Anticipatory Timing, and Motor Planning

Rhythm perception involves complex interactions between auditory processing and motor coordination. Ciuha et al. [49] discuss how the brain processes rhythmic patterns and how musicians develop motor skills to execute them accurately. Their research highlights the importance of auditory feedback and motor coordination in rhythm training. This aligns with the findings of Zhang [17] and Haug et al. [46], who emphasize that synchronous corrective feedback significantly enhances rhythm accuracy.

For angklung players, rhythm learning is not just about individual accuracy—it also involves responding to a conductor’s cues and maintaining synchronization with an ensemble. Technology can assist in this process through interactive rhythm exercises, animated guides, and conductor simulation systems.

2.4.2.2. Designing for Ensemble-Like Synchronization in Individual Training

Ensemble-like coordination relies heavily on precise timing and cue-following, even in individual practice. Digital tools can improve group synchronization by providing visual indicators, metronome-assisted cues, and AI-generated timing guidance.

Johnson et al. [47] demonstrate that synchronized digital platforms can improve ensemble cohesion by displaying real-time visual indicators of upcoming beats and note transitions. Similarly, Smith et al. [48] propose that VR and AR environments can replicate ensemble settings, allowing musicians to rehearse virtually as if performing live.

Although the term ensemble is used, this study applies the concept only to simulate conductor-player coordination in solo training contexts, without involving actual group performance.

2.4.3. Challenges and Opportunities for Traditional Instrument Digitization

Despite significant advancements in digital music education, research on the application of technology to traditional instruments like the angklung remains limited. This section explores the lack of representation of traditional instruments in digital platforms and the challenges in developing technology that accommodates traditional music education.

2.4.3.1. Technology Gaps in Supporting Non-Western Music Practices

Most existing music education technology is designed for Western instruments such as the piano, guitar, and violin. However, recent studies by Lee et al. [50] and Patel et al. [51] highlight the importance of culturally relevant technological solutions that support non-Western musical traditions.

Individual angklung training presents unique challenges—particularly in representing conductor-style hand-sign cues, supporting single-note performance roles, and simulating ensemble-like synchronization. Unlike Western notation-based instruments, angklung music is guided by visual hand signs and auditory memory, rather than standardized scores. Therefore, culturally responsive and cue-based training systems—such as those developed in this study—are necessary to bridge this gap in digital music education.

2.4.3.2. Interface Design and Cultural Fidelity in Instrument Training Tools

Designing digital learning tools for traditional instruments presents several key challenges:

1. **Notation Representation:** Traditional angklung music does not use standard sheet music. Instead, it relies on hand signals and auditory memory. This requires visual rhythm guides and interactive animations rather than conventional notation-based teaching methods.
2. **Group Coordination:** Each angklung player holds only one note, so performance requires synchronized execution. To support this, digital systems should provide tempo-aligned visual guidance and automated cue scheduling that enables ensemble-like transitions during individual training.

2.5. Angklung and Its Educational Significance

Angklung is widely recognized as a traditional musical instrument and an effective educational tool that promotes collaborative learning, cognitive development, and cultural appreciation. Rooted in its ensemble-based nature, angklung education typically involves synchronization, conductor-following, and note-based cooperation. However, in this study, these principles are adapted into a cue-guided training model for individual

practice. This section outlines the cognitive, social, and intercultural value of angklung learning, particularly in relation to its evolving global role and potential for technology-supported instruction.

2.5.1. Cognitive and Social Benefits of Angklung Learning

The angklung learning process integrates auditory, kinesthetic, and social domains, offering multiple benefits for novice learners. When adapted into individual training contexts—such as in this study's cue-guided system—these benefits can still be preserved through structured visual and gestural cues that simulate ensemble conditions.

One notable cognitive benefit of angklung learning is improved motor coordination. Even in single-note settings, players must react to timing cues with precision, developing fine motor skills and response timing. This task becomes more cognitively engaging when players follow visual cues from a conductor or bot, simulating group responsiveness [30].

From a perceptual standpoint, angklung also enhances rhythm sensitivity and pitch awareness. Because each player listens for their cue within a larger musical sequence, learners train their auditory attention and internal timing accuracy. Research has shown that rhythm-based music education enhances auditory processing and temporal coordination, even outside ensemble environments [52].

Socially, angklung promotes cooperative behavior, especially in group-based formats. While this study emphasizes solo training, the structure and design of cue-guided systems retain ensemble-like dynamics—encouraging attentional focus, turn-taking, and reactive playing. These skills foster a sense of collective awareness, even in solo rehearsal, and contribute to non-verbal communication development [53].

Furthermore, engaging with angklung has been shown to yield emotional benefits such as increased motivation, self-confidence, and stress reduction—effects commonly associated with community-based music activities. Even when practiced individually, the simulation of ensemble experiences may preserve some of these psychological advantages [9]. These effects contribute to higher engagement levels in music education, making angklung an accessible and inclusive instrument for learners of all ages.

Given these cognitive and social advantages, angklung is increasingly being recognized as a powerful educational tool beyond traditional music training. Many educators and researchers advocate for its integration into formal and informal learning environments, as it offers a holistic approach to skill development.

2.5.2. Angklung in Global Music Education

Angklung has gained international recognition in music education as a UNESCO-recognized cultural heritage. Many institutions worldwide have adopted angklung as a teaching tool, emphasizing cross-cultural exchange and global appreciation of Indonesian musical traditions.

One of the primary ways angklung has been incorporated into global music education is through formal education programs. Many schools in Indonesia have included angklung in their national curriculum, allowing students to develop an appreciation for traditional music while learning essential musical skills. Outside Indonesia, international institutions have adopted angklung through workshops and world music courses,

providing learners with exposure to collaborative musical forms grounded in cultural context [28]. These programs highlight angklung's potential to introduce foundational music concepts through a culturally rich medium.

International collaborations have further elevated angklung as a symbol of unity. Through festivals, educational exchanges, and cross-cultural performances, angklung contributes to a growing movement that values traditional instruments in global educational frameworks [54].

Nevertheless, the implementation of angklung education outside Indonesia faces practical limitations, particularly due to a lack of trained conductors and standardized teaching resources. In this context, cue-guided digital systems such as the Hand-Sign Bot are well-positioned to address this gap. By replicating essential features of human conductor guidance through animated gestures and visual cues, these systems offer a scalable solution for expanding angklung instruction in international settings [55].

2.6. Related on Kodály Method and Existing Angklung Training Systems

The exploration of educational systems for music training is a growing area of research, especially with the increasing integration of technology. This section reviews related works in two key areas: research on hand signs in the Kodály method and existing angklung training systems. The former provides insight using hand gestures for music pedagogy, while the latter examines the development and characteristics of angklung-focused technological systems.

2.6.1. Research on Hand Sign in Kodály Method

Hand signs are vital to the Kodály method, enabling students to visualize and kinesthetically engage with musical notes. The Kodály approach, rooted in Zoltán Kodály's philosophy, emphasizes the integration of solfège hand signs as an essential tool for teaching pitch relationships, improving sight-singing, and enhancing overall musical literacy. Below is a detailed discussion of relevant research exploring hand signs in music education and the Kodály method.

Table 2.2 summarizes the main findings and their relevance to this dissertation. These studies provide a strong theoretical foundation for understanding the role of hand signs in music education and practical insights into their application in both traditional and technological contexts.

Table 2.2: Summary of Key Research on Kodály Hand

Author(s)	Title	Key Findings
Marc Leman et al. (2018)	On the Role of the Hand in the Expression of Music [56]	Highlights the cognitive and physical connection facilitated by hand signs in musical learning.
Ferreira & Haworth (2021)	DeepSolfège: Recognizing Solfège Hand Signs Using Convolutional Neural Networks [57]	Proposes AI-based recognition for solfège hand signs, enhancing assessment and accessibility.
Lois Choksy (1988)	Kodály Strategies for Instrumental Teachers [58]	Explores the use of hand signs to bridge pitch understanding in instrumental music education.
McClung (2008)	Sight-Singing Scores of High School Choristers with Extensive Training in Movable Solfège Syllables and Curwen Hand Signs [59]	Demonstrates the positive impact of Curwen hand signs and movable solfège on sight-singing accuracy.

The studies outlined in Table 2.2 contribute valuable perspectives on using hand signs in music education. Marc Leman et al. provide a theoretical framework emphasizing the role of hand gestures as a bridge between motor activity and cognitive learning [56]. Ferreira and Haworth expand this by introducing technology-driven innovations such as DeepSolfège, which has significant implications for the automation of hand sign recognition and its integration into contemporary educational settings [57]. Meanwhile, Choksy demonstrates the versatility of Kodály strategies, including hand signs, in instrumental teaching, supporting adaptability across diverse musical contexts [58]. McClung offers empirical evidence of the effectiveness of Curwen hand signs and movable solfège syllables in improving sight-singing performance among high school choristers [59]. This study highlights the direct impact of hand signs on pitch accuracy and tonal memory, reinforcing their value as a key pedagogical tool in vocal music education.

Together, these studies underscore the importance of Kodály hand signs as a pedagogical tool and a medium for innovation in music education, offering practical, theoretical, and technological pathways for their effective use.

2.6.2. Existing Angklung Training Systems

Current research on angklung training technology has introduced various digital learning tools, but few have incorporated conductor hand-sign guidance, which is crucial for effective angklung instruction. Most existing systems focus on basic digital interaction with angklung instruments but lack structured training that aligns with traditional hand-sign conducting methods.

Table 2.3 summarizes key studies related to angklung and technology to analyze the role of hand signs in existing angklung training systems, highlighting how they provide guidance and their limitations.

Table 2.3: Research Related to Angklung and Technology

No	Research Title	Hand-Sign Integration	Limitations
1	Using Pazia Angklung application in understanding song scores [60]	No hand-sign feature. Users tap the screen to play angklung sounds.	No **cue-guided training**, limited to individual practice.
2	Redesigning and Implementing Traditional Musical Instruments in Integrated Technology Classroom [61]	No hand-sign feature. Digital system connects the angklung to the PC and speakers for learning.	Designed for individual learners, no group training, no conducting cues.
3	The Impact of Implementation of Angklung Learning Application for SLB Part B Deaf using Multimedia-Based Coloring Method on User Satisfaction [62]	No hand-sign integration. Uses visual and color-based cues instead (visual-cue).	Focuses on accessibility for deaf students, not traditional angklung training.
4	Smart Band Technology: A Music-Based Activity for the Thai Elderly [2]	No hand-sign feature. Uses vibration sensors to assist elderly users in playing angklung.	Designed for elderly users, lacks traditional conductor guidance.

The studies presented in Table 2.3 highlight the current approaches to digitizing angklung training while exposing existing training system design gaps. Despite advances in digital tools, none of the existing systems have successfully integrated conductor hand-sign features, which are fundamental for structured angklung learning. Below are some key limitations found in current research.

1. **Using Pazia Angklung Application in Understanding Song Scores** [60]
   Maulana and Julia (2019) developed Pazia Angklung, an Android-based application designed to assist students in understanding song scores. The application allows users to tap the screen to produce angklung sounds. **Contribution:** Introduces a touch-based angklung learning system, providing an alternative way to engage with angklung music; **Limitation:** Does not include conductor hand-sign cues, meaning students do not learn how to follow a conductor, a critical aspect of real angklung training.
2. **Redesigning and Implementing Traditional Musical Instruments in Integrated Technology Classroom** [61]
   Julia et al. (2019) developed a system integrating Makey Makey with a PC and speakers, allowing students to interact with West Java angklung instruments in a digital classroom setting. **Contribution:** Offers a technology-enhanced approach to traditional angklung learning, improving engagement in a classroom setting; **Limitation:** The system is designed for individual users, meaning it does not support synchronized group learning or hand-sign-based conducting cues.
3. **The Impact of Implementation of Angklung Learning Application for SLB Part B Deaf using Multimedia-Based Coloring Method on User Satisfaction** [62]

Effendi et al. (2020) developed an angklung learning application for deaf students, incorporating multimedia-based visual cues instead of conductor hand-sign guidance. **Contribution:** Improves accessibility in angklung education, making it easier for deaf students to engage with music learning; **Limitation:** The system does not replicate traditional angklung training because it relies on color-based learning rather than conductor hand-signs.

4. **Smart Band Technology: A Music-Based Activity for the Thai Elderly [2]** Phoasavadi (2022) introduced a wearable sensor system for elderly users, allowing them to interact with Thai angklung instruments using vibration-based feedback. **Contribution:** Shows how sensor-based technology can assist elderly users in playing angklung; **Limitation:** Does not incorporate conductor hand-sign cues, making it less applicable to structured angklung education for traditional ensembles.

While these studies have contributed valuable insights into digitizing angklung education, none provide a comprehensive solution for simulating conductor-led instruction in individual training contexts. This gap becomes especially critical for novice players who rely on visual cues to develop timing, anticipation, and response behaviors aligned with ensemble-oriented performance. The cue-guided system introduced in this research addresses this limitation by incorporating hand-sign visualizations and note-specific timing cues, enabling structured individual practice that reflects core elements of traditional angklung instruction.

2.7. Musical Training

Decades of research have demonstrated the wide-ranging benefits of musical training on both musical and non-musical domains. Sustained instrumental practice is associated with neuroplastic changes that enhance cognitive functions such as memory, attention, and executive control [63]. For example, children who engage in structured musical activities often develop stronger auditory attention and self-regulation skills compared to those without musical exposure [64]. These cognitive gains are commonly attributed to the consistent, disciplined practice required in learning music, which engages multisensory and motor systems in the brain.

While many studies emphasize the benefits of ensemble-based programs, recent findings suggest that structured individual musical training can also support developmental outcomes when it involves synchronized motor planning, attentional focus, and cue-following. For instruments like angklung, where players typically execute a single pitch in response to visual or gestural cues, the act of learning to anticipate and respond to musical timing provides a form of cognitive training that strengthens temporal attention and motor coordination.

Musical training, even at the novice level, has also been linked to personal traits such as perseverance, goal setting, and reflective learning habits. These qualities are particularly relevant in cue-guided training environments, where learners must independently practice coordination, timing, and rhythm. As such, the structured

repetition and multimodal engagement involved in individual angklung practice may yield musical proficiency and broader cognitive and behavioral benefits.

2.7.1. Musical Training and Angklung Ensemble Education

From a pedagogical perspective, musical training generally involves developing instrumental techniques, timing accuracy, and expressive awareness. While traditional methods emphasize music reading, theoretical instruction, and ear training, ensemble-based approaches such as Kodály, Orff, or Suzuki integrate kinesthetic and participatory elements into learning. In angklung education, however, these methodologies must be adapted to the ensemble-like structure in which each player performs only a single pitch and relies on external cues rather than internal musical reasoning.

In the context of cue-guided angklung training, players are not expected to interpret full musical scores or apply harmonic theory. Instead, they must develop sensorimotor responsiveness to gestural or visual cues, typically delivered by a human conductor in live settings or simulated through digital agents in solo training. This instructional model prioritizes physical timing, cue recognition, and visual anticipation over symbolic interpretation.

Although angklung is physically simple to play—requiring only a shake to produce sound—the core difficulty lies in cognitive and attentional demands. Players must sustain visual attention, detect the correct cue for their assigned note, and execute with moment-specific precision. Since each player only contributes a single note, they cannot rely on melodic memory or improvisation. Instead, they must anticipate their role in the overall structure and synchronize their actions within narrow timing windows. These ensemble-relevant skills—cue-following, rhythmic timing, and note anticipation—represent the true learning objectives of angklung training.

Recent advances in music pedagogy increasingly explore how digital tools can replicate such structured cue environments, particularly for learners who do not have access to live ensemble rehearsal. For instance, remote training systems have been developed for angklung practice to simulate instructional flow and monitor individual performance in technology-supported environments [29]. These systems demonstrate that structured cue delivery can support rhythmic coordination and gesture timing, even when ensemble members are not physically co-located.

Overall, the literature on musical training emphasizes the importance of structured, repeatable tasks and multimodal input to strengthen musical responsiveness. When applied to individual angklung practice, this framework suggests that learners can acquire ensemble-like coordination skills even without a group, provided that the training environment replicates the core features of cue-based instruction.

2.7.2. Ensemble Music Training and One-Note Instruments

Learning in a musical ensemble adds a strong social and collaborative dimension to musical training. Ensemble programs often require students to coordinate timing, listen to peers, and follow a leader, cultivating skills in teamwork and communication. Large-scale initiatives like Venezuela's *El Sistema* (and its adaptations worldwide) have demonstrated that intensive ensemble training can significantly improve children's musical ability, attention, and socio-emotional development [64]. In such contexts, students learn to "fit" their part into a larger whole—developing **auditory executive attention** (i.e., selectively focusing on relevant auditory information) and **self-regulation** (e.g., waiting for one's cue, matching group timing) [64]. These skills are typically less emphasized in solo training, thus highlighting the unique educational value of ensemble-based experiences.

Some ensembles involve an atypical instrumental configuration in which each performer plays only one pitch or note of the musical scale, and the full ensemble collectively produces the complete melody or harmony. The **angklung** is a representative example of this configuration: each angklung instrument produces a single pitch, and coordinated group performance is required to render full musical pieces. Comparable structures can be found in **Western handbell choirs**, where each ringer controls one or two bells and contributes a small fragment of the total composition. In these ensembles, no individual performer can produce a complete musical phrase on their own, making **synchronization and cue-following** fundamental to success [29].

A critical component of one-note-per-person ensembles is the presence of a **conductor** or ensemble leader, who provides **visual cues and timing instructions** to coordinate the performance. Because each player holds only a portion of the musical content, **conducting gestures** become central to maintaining rhythm and structure. Rather than relying on traditional music notation or solo technique mastery, students in such ensembles are trained to **respond to external cues**, such as **hand-signs**, beat patterns, and gesture-based prompts. This shifts the pedagogical emphasis from technical soloism to **collective responsiveness**, making these ensemble forms uniquely suited for exploring **cue-based learning frameworks**.

While traditional one-note ensembles emphasize group rehearsal, this study focuses on the self-training phase. However, ensemble awareness can still be nurtured during individual practice through cue-guided methods. By presenting full melodic contexts and visual timing cues (e.g., via Notebar, HB, or HBP), the system helps players understand when and how their note contributes to the larger musical structure. Practicing a single note in sync with the full score trains timing precision, role anticipation, and responsiveness—essential traits for ensemble participation. Thus, although players are learning alone, the training design encourages ensemble-like thinking and prepares them for future collaborative rehearsals.

2.7.3. Handbells: A Close Match to Angklung Ensembles

Handbell ensembles have been studied as an educational model that shares many characteristics with angklung groups. In a handbell choir, each ringer typically starts with two bells (one in each hand), each bell producing a single pitch. Research has highlighted both the advantages and challenges of this format for musical training. While handbells and angklung differ in musical tradition and context, their structural similarities provide a useful pedagogical comparison for one-note-per-player cue-guided training. This analogy is not intended to shift the focus of this study, but rather to highlight the ensemble-specific coordination and conductor-following behaviors that are central to both instrument types. One significant advantage is accessibility: handbells can serve as an easy entry point for novices, since learners can focus on just a couple of notes and still participate in performing real pieces. Rohwer (2015) found that middle school students viewed handbells as more approachable than band/orchestra instruments – the instrument is immediately in tune, easy to sound, and the note-reading load is initially limited [65]. Past pedagogical reports likewise noted that novices can produce pleasing sounds quickly on handbells and only need to learn a few notes at first, motivating those with little prior musical background [65]. As Bunting (1980) observed, handbells are well-suited to younger learners because they "may need a place to begin" where they can contribute to music-making without extensive prior training [65].

Teamwork and interdependence: On the flip side, this limited individual responsibility means each player must rely on others to complete the music. Students in Rohwer's study emphasized *"ringing exactly together as a group"* as one of the most critical skills they learned in the handbell choir [65]. They reported that the most excellent satisfaction came when *"we are all playing together…when we get it right, it sounds fantastic"*, highlighting the reward of tight ensemble unity [65]. Achieving such unity requires paying close attention to the conductor and each other – one student noted *"I think it's important to work together to get your arms the same motion as your neighbor's…It's easier to do that when you count the beat in your head"*, underscoring the need for shared timing and visual synchronization in performance [65].

Music-reading challenges: Interestingly, while handbell ringing lowers the barrier to entry in some ways, it introduces unique challenges in music reading and notation. Ensemble pieces for handbells are often printed in full score (showing all notes for all bells), which results in a dense notation that can be overwhelming for novices [65]. Each ringer has to scan the music for their two notes amidst many others. Rohwer (2015) reported that several students found reading music to be the most challenging part of handbells (even more so than ringing technique) [65]. Some novices felt comfortable with their limited pitches, but others still struggled to track where their notes occur in a new piece [65]. The case study suggests it would be "beneficial to have additional techniques to ease the transition into note reading" for ensembles like handbells, given the notation

complexity [65]. Despite these difficulties, most students in the study did improve in music-reading over time, and they cited handbell participation as helpful for learning to read rhythms and pitch, even if only for a couple of notes at first [65].

These observations reveal both the opportunities and limitations of one-note ensemble models. They demonstrate how simplified responsibilities can promote accessibility, but also demand high levels of cue sensitivity and group synchrony—pedagogical aspects that cue-guided systems, such as HB and HBP, seek to replicate in angklung training.

Insights from handbell ensembles highlight the importance of cue clarity, visual timing, and conductor-player synchrony—equally critical elements in angklung performance. These findings support the rationale for developing a cue-guided training system that emphasizes single-note responsiveness and ensemble-like coordination through visual conducting gestures. The pedagogical needs observed in handbell contexts—particularly related to cue-following, teamwork, and simplified instruction—further validate the use of structured, gesture-based systems such as HB and HBP for novice angklung learners.

2.7.4. Angklung Ensemble Training and Hand-Sign Cues

Angklung, like handbells, is an ensemble-dependent instrument. An angklung is a bamboo rattle tuned to a single pitch; a full diatonic set is needed to cover a scale, and a group of players is required to perform melodies [66]. Traditional angklung ensemble practice in Indonesia has evolved pedagogical methods to address the challenges of one-note-per-player performance. Notably, many angklung groups use a hand-sign system as a form of *dynamic notation*. A conductor leads the group in an performance or rehearsal by signaling specific solfège syllables (do, re, mi, etc.) with standardized hand gestures [66]. Each gesture corresponds to a pitch, and thus tells the player holding that pitch when to sound their angklung. This method was influenced by the Kodály hand-sign system (a tool from music education that uses hand symbols for scale degrees) [66]. Adapting Kodály signs to the angklung ensemble has effectively replaced the need for players to read conventional music notation during group play [66].

Research presented by Suryani et al. (2021) describes how, before an angklung ensemble session, the instructor explicitly teaches the participants the mapping between each hand sign and their corresponding angklung note [66]. Once this is understood, the conductor's sequential hand signs can communicate an entire melody to the group in real time [66]. Each player watches for the sign that matches their assigned pitch and plays when it appears. This works well because each participant is responsible for only one or two notes. As the study notes, *"the hand sign method will instantly be easy to understand, because each participant involved only plays one or two types of angklung… each participant does not need to read notation, but must read the hand sign demonstrated by the instructor"* [66]. In other words, the cognitive load of reading a musical score is lifted; instead, players develop skill in recognizing the conductor's hand cues and timing their

response correctly. This approach aligns to make ensemble music accessible to those who may not read music – it leverages human visual communication to guide the performance. It's a system that trains *real-time listening and watching*, rather than abstract note literacy.

Using hand-sign cues in angklung ensembles has proven effective as a learning modality. It engages multiple senses: players *see* the visual cue, *hear* the resulting pitch, and *feel* the action of playing the instrument. This multimodal learning helps students internalize high-low pitch relationships (since Kodály signs have a physical height component) and reinforces a steady sense of beat as they must synchronize with the conductor's tempo [66]. Studies have also suggested that such methods can improve a child's ability to distinguish pitch and interval differences [66]. In essence, the hand-sign method trains ensemble skills in a direct, intuitive way – *if you can follow the conductor's hand signals in time, you can successfully make music on the angklung.* This is especially useful in large group or classroom settings (common in Indonesia), where teachers might introduce angklung to dozens of students simultaneously. Rather than teaching full notation, they can get students playing songs relatively quickly through guided gestures. However, reliance on the conductor means students must learn to maintain focus and react promptly to cues, which itself is a skill that requires practice. If a student misses or misreads a cue, their note will be out of place. Thus, even with hand signs, timing and cue comprehension are critical training areas for angklung players.

In this research, the hand-sign system is not used in physical ensemble settings, but digitally simulated through cue-guided methods (HB and HBP) to support individual angklung training. This preserves the pedagogical benefits of conductor cues without requiring a real group or instructor.

In this study, the training methods are designed to cultivate three ensemble-relevant skills that are fundamental [67], [68] to angklung performance: **cue-following, rhythmic timing, and note anticipation**. These skills reflect the real-world demands of ensemble-based instruments, especially those with one-note-per-player configurations. Cue-following refers to the ability to observe and react precisely to the conductor's gestures [69]; rhythmic timing involves internalizing a steady beat and responding at the correct moment [70]; and note anticipation enables players to prepare in advance for their turn, even without seeing the entire score [71], [72]. The cue-guided training system developed in this study—through Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—aims to support the development of these specific skills in an individual learning context, thereby simulating core aspects of ensemble coordination without requiring group rehearsal.

2.7.5. Definition of Training in this Research

In this research, the term *training* refers to a structured practice process that supports novice angklung players in developing specific performance skills through a cue-guided system. It does not involve comprehensive instruction in music theory, sight-reading, or

advanced instrumental technique. Rather, training is defined as a focused activity aimed at helping individuals perform accurately within an ensemble-like framework, despite practicing alone.

The **purpose of training** in this context is to simulate ensemble coordination without requiring a full group or a human conductor. Given that each novice holds only one angklung and is responsible for a single pitch, the training system is designed to replicate the conductor-player interaction through structured visual or gestural cues. By doing so, it enables players to internalize the timing, structure, and response patterns necessary for real-world angklung performance.

The **target skills to be developed** are three ensemble-relevant competencies [67], [68]:

1. **Cue-following** – the ability to track and respond to on-screen instructions, whether in the form of color bars (NB) or animated hand-sign gestures (HB, HBP) [69].
2. **Rhythmic timing** – the internalization of beat structure and accurate execution of note entry [70].
3. **Note anticipation** – the capacity to prepare and respond to cues, especially as developed through HBP, which includes an anticipatory preview mechanism [71], [72].

Each method supports these skills differently. *Notebar (NB)* reinforces visual structure and rhythmic alignment through predictive motion. *Hand-Sign Bot without Preview (HB)* emphasizes recognition of conductor-style gestures in real time. *Hand-Sign Bot with Preview (HBP)* enhances anticipatory readiness by displaying the next cue in advance, thereby scaffolding proactive timing.

This training approach applies **only to the Self-Training phase** of the angklung learning model, which prioritizes independent practice and gradual skill acquisition. It is not intended to replace ensemble rehearsals or formal instruction but rather to prepare learners for those contexts by isolating and strengthening their foundational coordination skills in a simplified and accessible way.

2.7.6. Rationale for Developing Hand-Sign Bot

Given the above insights, there is a clear rationale for developing Hand-Sign Bot as part of this research. Hand-Sign Bot is conceived as an virtual conducting system (a virtual avatar) that can lead angklung players through pieces by providing the same kind of hand-sign cues and timing signals a human conductor would. Several factors motivate its development:

1. **Addressing Ensemble Training Gaps:** Traditional angklung practice requires a skilled human instructor to stand before the group and give cues. A system like Hand-Sign Bot can serve as a stand-in conductor for practice sessions, enabling students to rehearse timing and cues even without their teacher physically there.

This aligns with recent efforts to use technology for independent music learning [29]. Hand-Sign Bot directly addresses this need by providing an automated "coach" that players can practice with anytime.

2. **Improving Timing and Cue-Following Skills:** Because ensemble cohesion is so crucial, learners often need extra practice to react promptly to cues and keep a steady tempo. By focusing the system on timing/cue training (rather than full music education), we ensure it targets the exact skills that one-note instrument players must develop [65]. Essentially, Hand-Sign Bot reinforces the habit of watching the conductor and counting the beat – skills handbell and angklung players themselves have identified as critical [65]. Over time, this should enhance the ensemble's overall tightness.
3. **Lowering the Dependency on Notation:** As discussed, one barrier for novices is reading complex scores [65]. Hand-Sign Bot's design leverages the hand-sign method, meaning it communicates the music through gestures or signals rather than standard notation. This allows even those with minimal sheet music literacy to participate and learn. By doing so, it continues the approach of treating hand signs as a "substitute for notation" for each player [66].
4. **Preserving and Enhancing Cultural Music Education:** The development of Hand-Sign Bot is also driven by a desire to preserve the cultural practice of angklung in modern educational settings. Angklung's value as a tool for teamwork and unity is well recognized, and introducing a fun, tech-assisted way to learn it may attract young learners. A robotic conductor can be an engaging presence – for instance, students might enjoy following a robot's signals, making practice feel like a game. Hand-Sign Bot could encourage more frequent practice and sustained interest in angklung ensembles by enhancing engagement. Additionally, it builds upon prior innovations: for example, researchers have experimented with musical robots in the angklung domain. Budi et al. (2013) created a system where a robot could recognize human conductor gestures in order to play angklung notes on cue [12]. Our project inverts this concept – instead of the robot playing the instrument, the robot conducts the human players. This inversion is novel and pedagogically meaningful: it uses technology to emulate the human leader, reinforcing traditional hand-sign teaching methods through a new medium.

2.8. Cue-Guided System in Music

In traditional orchestras or large ensembles, a cue-guided system refers to a structure in which a conductor leads performers by providing non-verbal cues that guide musical interpretation. These cues coordinate aspects such as tempo, dynamics, articulation, and expression, ensuring ensemble unity and interpretive coherence [73].

Conductors typically employ two primary types of cues to communicate with musicians:

1. **Hand-sign cues**

These involve gestural communication using hand movements, baton techniques, posture, or facial expressions to indicate tempo, phrasing, or expressive intention [74]. In many ensemble settings, these cues require active interpretation by performers, as they convey nuances that go beyond metric precision [66], [75].

2. **Visual cues**
   Visual cues consist of explicitly designed, often digital, visual indicators that provide precise temporal signals—such as metronome flashes, color-coded markers, or animated timing bars [76]. Unlike expressive hand gestures, these cues reduce ambiguity and are particularly effective for novice learners who require structured timing support.

In this study, the concept of a **cue-guided system** is not applied in the context of live ensemble performances. Instead, it is adapted into a digital training model for individual practice. Cue delivery is simulated through screen-based systems (NB, HB, and HBP), enabling novice angklung players to train timing and cue recognition individually while replicating key characteristics of conductor-led ensemble coordination.

2.8.1. Hand-Sign Cues in a Cue-Guided System

Hand-sign cues represent one of the oldest and most expressive methods of musical communication. In a cue-guided system, these gestures function as visual instructions that replace or supplement musical notation, allowing performers to synchronize their actions in real-time. This subsection elaborates on hand-sign cues from three perspectives—traditional orchestral conducting, angklung ensemble practices, and Kodály-based pedagogy—while establishing their relevance for the cue-guided systems implemented in this study.

1. **Orchestral and Choral Conducting**
   In classical orchestral and choral contexts, conductors use a standardized gestural vocabulary to indicate beat patterns, tempo, dynamic shifts, and phrasing. These gestures are delivered through the movement of the hand or baton, supported by facial expressions and posture, forming a non-verbal language that musicians must interpret [75], [76].
2. **Hand-Sign Cues in Angklung Music**
   In angklung performance, where each player is responsible for a single note, conductors employ a specific set of hand gestures to cue players. These gestures communicate pitch (based on solfège), tempo shifts, and expressive interpretation. The clarity and timing of these hand signs are critical to ensure ensemble cohesion, as players depend on accurate visual instructions to enter precisely at the right moment [77].
3. **Kodály Hand-Sign Method**

The Kodály method incorporates hand gestures to represent the relative pitch of solfège syllables (Do, Re, Mi, etc.), facilitating embodied pitch recognition. This approach supports both musical literacy and auditory development, particularly in early-stage learners. Studies show that Kodály-based instruction improves coordination, pitch accuracy, and sight-reading proficiency [78], [79].

In all three cases, hand-sign cues are **expressive rather than prescriptive**. Unlike mechanical cues (e.g., visual metronomes), hand signs require performers to interpret the intention and timing conveyed through dynamic gesture. In this study, these gestural elements are translated into **screen-based simulations** through the Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP). These tools emulate conductor gestures to provide digital cue guidance, allowing players to practice recognition and timing skills individually—thus extending the hand-sign tradition into technology-enhanced angklung training.

While the system does not recognize player gestures, the training specifically targets the player's ability to visually identify and interpret the correct hand-sign cue for their assigned note. In one-note-per-player ensembles like angklung, this skill is essential for precise timing and ensemble cohesion. Therefore, gesture recognition by the player—not the system—is a central learning objective, particularly in the HB and HBP training conditions.

2.8.2. Visual Cues in a Cue-Guided System

Conducting is inherently a visual process, as performers depend on visible gestures for temporal and expressive guidance [13]. In contrast to hand-sign cues, which require interpretation and flexibility, visual cues are structured, predictable, and often encoded in fixed formats. They are especially useful in training environments where precision and repeatability are key learning objectives.

1. **Visual Metronomes and Click-Tracks**
   Visual metronomes and click-tracks are widely used in ensemble and studio settings to maintain rhythmic synchronization. These cues provide continuous timing references that are easy to follow, particularly in large-scale or multimedia performances such as film scoring and live digital productions [69].
2. **Screen-Based Training Systems**
   Many contemporary digital learning systems employ visual guides—including animated note bars, color-coded cues, and flash signals—to enhance rhythm comprehension. These tools are particularly effective for beginners and support timing accuracy without relying on auditory-only instruction [80].
3. **Technology for Hearing-Impaired Musicians**
   A study by Effendi et al. [62] on Angklung training for students with hearing impairments demonstrated that color-based visual cues improved rhythm

recognition and synchronization. This suggests that visual cues can serve not only as a supplement but also as a substitute for auditory feedback in inclusive music education.

In this study, visual cues are implemented through the Notebar (NB) system, which uses an animated color bar to indicate the precise timing of note execution. Unlike hand-sign cues that simulate conductor gestures, NB provides a **fixed, non-verbal timing scaffold** that enables learners to respond in real time without interpretive processing. This makes it especially suitable for **novice angklung players** who benefit from explicit visual timing indicators while learning to coordinate within an ensemble-style structure.
By incorporating visual cues into cue-guided training, this research offers a structured, accessible, and culturally neutral approach to individual angklung practice—facilitating timing accuracy and performance readiness even in the absence of group rehearsal or live conducting.

2.8.3. Visual Approach in Rhythm-Based Video Games

Music-themed video games (rhythm games) illustrate how structured visual cues can effectively replace traditional conductor gestures to guide musical timing. In games such as Guitar Hero, Taiko no Tatsujin, and Rock Band, players respond to on-screen indicators rather than interpretive hand signs or auditory instructions [16].

1. **Structured Cueing through Symbols**
   The gameplay interface typically displays approaching notes in the form of symbols, colors, or lanes that represent pitch or rhythm targets. These visual objects appear in fixed positions and scroll across the screen, instructing players when and how to perform their actions [81].
2. **Synchronization Without Conductors**
   Instead of following a human conductor, players rely on these visual cues to time their input precisely. As notes align with a target line, the player executes a specific action—such as tapping, strumming, or hitting a drum pad—simulating beat-following behavior without the need for musical notation [82]. In this sense, the visual stream of cues functions as a digital conductor, offering a fixed beat reference that standardizes timing across all users.

These rhythm-based games highlight the **pedagogical potential of visual cueing** for rhythm and timing accuracy, particularly in early or non-formal stages of musical training. While they are primarily designed for entertainment, their mechanisms offer insight into how **reactive synchronization skills** can be cultivated through **non-verbal, visual guidance**.

In the context of angklung training, these visual cue systems share similarities with the Notebar (NB) approach used in this study, where **animated bars provide timing**

indicators for note execution. However, unlike rhythm games, cue-guided training in angklung also incorporates aspects of **gesture anticipation and cultural pedagogy**, bridging the gap between structured digital timing and traditional ensemble instruction.

2.8.4. Aligning Hand-Sign and Visual Cues in Cue-Guided Systems

Within Cue-Guided Systems, both hand-sign cues and visual cues operate as timing and coordination tools, but they differ significantly in communicative function and pedagogical application.

1. **Hand-Sign Cues → Expressive and Flexible**
   These cues are typically used in live ensemble settings—such as orchestras or angklung groups—where interpretation, expression, and human responsiveness are critical. Conductors use hand gestures to convey not only timing but also musical nuance, such as phrasing, dynamics, and emotional shading [66], [76].
2. **Visual Cues → Precise and Predefined**
   In contrast, visual cues are structured and consistent. They are particularly effective in contexts where synchronization is prioritized over interpretation, such as in rhythm-based video games, screen-based training systems, or music tools designed for hearing-impaired learners [62], [69], [80].

While visual cues can replace hand-sign cues in certain training or rehearsal scenarios—especially for novice learners or solo practice—traditional ensemble performance still relies heavily on human conductors' adaptive, expressive capabilities. Therefore, a **hybrid approach** that combines the clarity of structured visual cues with the communicative depth of hand-sign gestures may offer the most comprehensive solution for cue-guided learning environments [83].

This alignment becomes especially relevant in the context of angklung education. Since each player is responsible for a single pitch, accurate cue-following is essential. A hybrid cue-guided system—such as those introduced in this study (e.g., HB and HBP)—can preserve the cultural logic of hand-sign-based instruction while leveraging the accessibility and precision of visual delivery formats. This synthesis allows for individual training experiences that reflect the coordination demands of ensemble performance.

2.9. Gesture Recognition in Music and Digital Music Education

Gesture recognition has become a significant research area in human-computer interaction (HCI), particularly in music and digital music education. Systems' ability to recognize and interpret human gestures has broad implications for music learning, conductor training, and digital music instruments. This article explores various aspects of

gesture recognition in music, from foundational research to applications in digital music education and a comparison of gesture recognition levels.

In the context of this study, however, it is important to clarify that the gesture recognition component does not involve interpretation or semantic analysis. The system is designed specifically for novice-level angklung players, who are expected to follow predefined visual hand-sign cues to perform single-note instructions. Consequently, the system does not support multi-note playing or contextual gesture understanding, as the focus lies solely on guiding players through basic angklung performance using visual cues.

2.9.1. Gesture (Hand-sign) Recognition Level in Music Contexts

Hand-sign recognition level refers to the degree to which a system or a person recognizes and interprets hand gestures or signs. In the context of musical training, particularly Cue-Guided Systems, this can be divided into several levels:

1. **Physical Matching (Gesture Detection)**
   The system identifies the shape and movement of the hand without understanding its meaning [84]. Example: A camera-based system that detects whether a clenched fist or raised finger is present, but does not interpret its musical function.
2. **Symbolic Matching (Pattern Recognition)**
   The system recognizes specific predefined gestures and matches them to a corresponding meaning (e.g., "this gesture means DO") [85]. This level is commonly used in music learning applications where students must associate a symbol with a note.
3. **Semantic Understanding (Contextual Recognition)**
   The system understands the meaning of the gesture in a musical context (e.g., interpreting gestures based on tempo, dynamics, or phrasing) [86]. Example: AI-based conducting assistants that adjust their interpretation based on the musical score.

Several studies support the understanding of gesture recognition in music. Marrin and Picard [87] introduced the **Conductor's Jacket**, a device for recording expressive gestures in music performance. Camurri et al. [88] developed the EyesWeb system, which integrates gesture recognition for interaction in music and dance.

The system developed in this study aligns with the ***Physical Matching*** level, wherein visual hand-sign cues are merely displayed for players to observe and follow. No semantic processing or symbolic interpretation of gestures is performed. This approach corresponds directly with the characteristics of novice angklung training, where each player holds and plays only one note. Accordingly, the system is not designed to

accommodate multi-note performance or gesture-based input from players, but rather to support single-note execution through basic visual imitation.

2.9.2. Applications of Gesture Recognition in Digital Music Education

In digital music education, gesture recognition is crucial in various applications, such as learning systems and AI-based teaching aids. Some relevant studies include:

1. **Kodály Gesture Recognition**: Lee et al. [89] developed a computer vision-based system to recognize hand gestures using the Kodály method without background visual modeling.
2. **Virtual Conductor**: Nijholt et al. [18] introduced the Virtual Conductor, an system used in music education, allowing students to learn about conductor movements digitally.
3. **Air Violin**: Dalmazzo and Ramírez [90] developed a machine learning-based system to recognize violin fingering gestures, enabling students to learn playing techniques without direct instrument contact.
4. **Real-Time Conducting Gesture Recognition System**: Fahn et al. [91] used a single-depth camera to recognize conducting gestures in real time with a Dynamic Time Warping (DTW) algorithm.

Compared to the systems mentioned above, the present study does not employ real-time gesture recognition or multi-level gesture analysis. Rather than interpreting user gestures, the system simply displays predefined hand-sign animations for players to observe and follow. This design choice is aligned with the needs of novice angklung players, who are not required to generate or respond to complex gestures, but instead practice single-note execution through visual cue imitation.

2.9.3. Comparative Study on Gesture Recognition Levels

Several studies compare different levels of gesture recognition in music and HCI:

1. **Pavlovic et al.** [92] conducted a comprehensive review of visual gesture recognition for human-computer interaction, highlighting the three primary levels of gesture recognition systems.
2. **Mitra and Acharya** [93] reviewed various gesture recognition techniques and compared Physical Matching, Symbolic Matching, and Semantic Understanding, demonstrating how contextual awareness improves system interpretation accuracy.

This study's HB and HBP systems are situated within the ***Physical Matching (Gesture Detection)*** category, in which gesture input is not required from the user. Players are not

expected to generate gestures, nor does the system provide feedback based on gesture recognition. Instead, players follow pre-animated hand-sign cues passively. Furthermore, each participant performs only one note per session, consistent with the typical configuration of novice-level angklung ensembles. The system is not designed to support multi-note recognition or contextual gesture interpretation. Both in the real-world human conductor setup and in the digital conductor variants, players are not required to comprehend the meaning of hand-signs; they only need to respond by shaking their angklung instruments according to the visual cue. The system does not utilize AI or semantic-level recognition, and all gestures are rendered based on pre-defined rules and sequences.

2.10. Research Gap and Positioning in Instrumental Training

While angklung-specific studies have examined traditional teaching methods and digital adaptations using notational aids or multimedia platforms [60], limited attention has been given to cue-guided approaches that enable **self-guided training for coordination-based instruments such as angklung**. This gap becomes more evident when comparing the angklung context with broader research in digital music education.

Most instrumental training systems fall into three major categories: **notation-based**, **rhythm-based**, and **gesture- or feedback-driven systems**. Notation-based platforms, such as digital piano or guitar applications, focus on note recognition and technical execution through traditional sheet music or tablature [15], [60]. These tools are well-suited for melodic instruments but are not optimized for instruments like angklung, where each player is responsible for only a single pitch in a collectively performed piece.

Rhythm-based training systems—often in the form of interactive games like *Guitar Hero*, *Taiko no Tatsujin*, or *Piano Tiles*—employ **visual cues to guide timing and rhythm** [16], [82], [83]. These platforms are engaging and effective for developing **individual reactive skills**, such as beat matching and tempo consistency. However, they lack **instructional depth**, particularly in teaching cue anticipation or structured performance timing relevant to ensemble-based instruments.

Gesture-driven and AI-based systems offer gesture-driven and interactive systems that offer adaptive cueing or immersive control, yet most are developed for solo performance and lack features for **timing structure simulation** or **conducting role emulation** [17], [18], [91]. Moreover, very few incorporate **culturally specific conducting systems**, such as the hand-sign language traditionally used in angklung instruction.

This study addresses the gap by proposing a **cue-guided training** framework that supports **independent practice** using two digital methods: **Hand-Sign Bot without Preview (HB)** and **Hand-Sign Bot with Preview (HBP)**. HB simulates traditional angklung hand-sign gestures to indicate note execution, while HBP introduces **anticipatory cueing** to help players prepare in advance—bridging reactive and proactive timing strategies.

To the best of the authors' knowledge, this is the **first study to digitize the handsign-based conducting method used in angklung education**, and implement it in a screen-

based self-training environment. While virtual conductor tools exist in orchestral simulations, they are rarely adapted for **single-note instruments**, nor are they designed for **cultural pedagogy** as required in angklung.

By framing angklung not just as a cultural heritage but also as a pedagogical challenge, this research contributes a novel approach to **training for coordination-based instruments**, enabling self-directed learning through structured visual and gestural guidance. **Although angklung is traditionally performed in an ensemble setting, this study limits its focus to individual practice, simulating ensemble-like coordination without requiring group rehearsal or physical conductor presence.**

Chapter 3 Research Methodology

3.1. Four-Phase Research Methodology

This chapter provides a detailed explanation of the four-phase research methodology introduced in **Chapter 1, Section 1.7.** The methodology is carefully structured to ensure a rigorous and systematic evaluation of the proposed **cue-guided training** methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP) (see Figure 3.1).

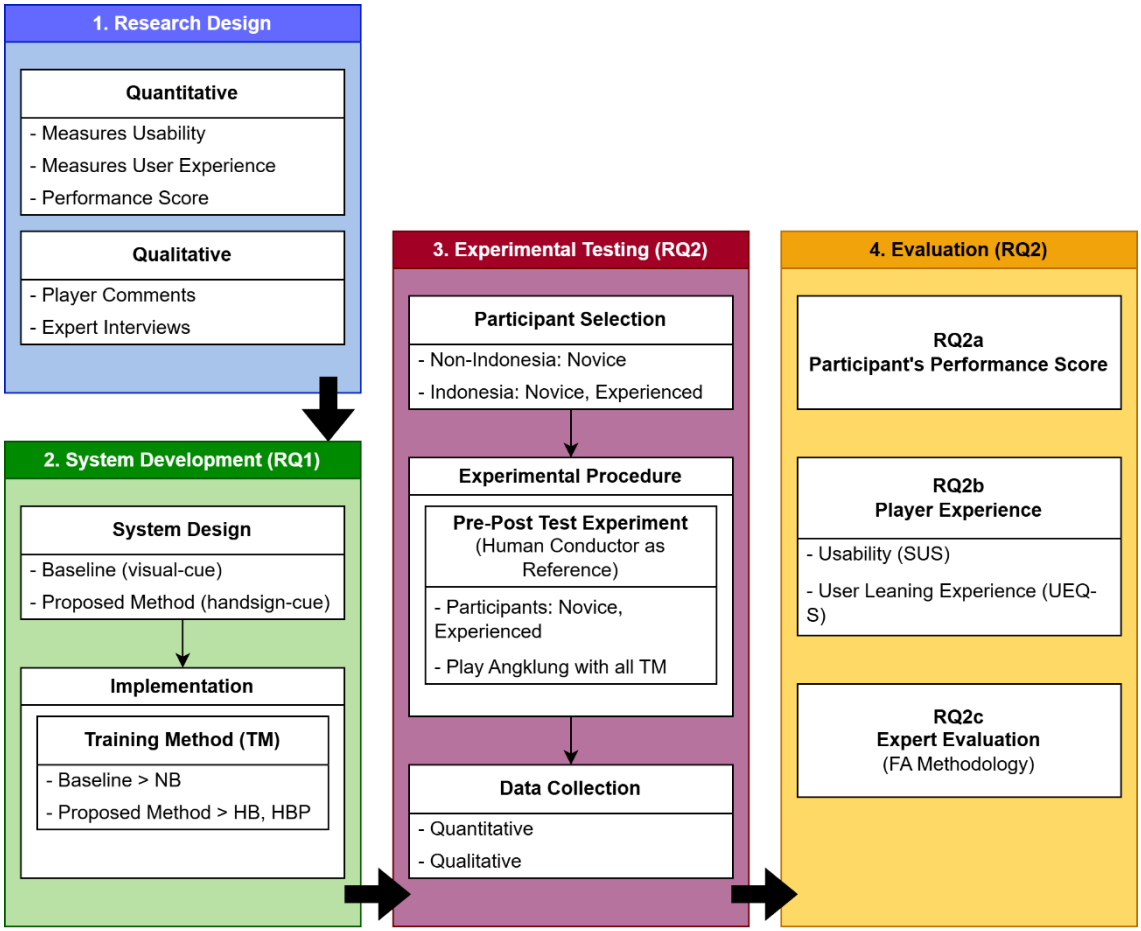


Figure 3.1: Research Methodology

Each method is examined in terms of its effectiveness in supporting angklung learning, its usability for novice players, and its alignment with traditional angklung pedagogy. The methodology consists of four primary phases:

1. **Research Design** – Establishes the experimental framework, combining quantitative and qualitative approaches to evaluate learning performance, user experience, and expert judgment.

2. **System Development (RQ1)** – Describes the design and implementation of NB, HB, and HBP, ensuring that each method accurately simulates traditional conductor gestures through digital interaction.
3. **Experimental Testing (RQ2)** – Explains the participant profiles, experimental procedures, and data collection strategies used to assess how each training method impacts novice and experienced players.
4. **Evaluation (RQ2a, RQ2b, RQ2c)** – Outlines the data analysis techniques, including the Non-parametric Friedman Test for comparing three related training methods and Post-Hoc Wilcoxon Signed-Rank Test, as well as a structured Framework Analysis for expert evaluations.

Each section elaborates on the research procedures, instruments, and analytical approaches used to ensure methodological robustness and relevance to the research objectives.

3.2. Angklung Training Model

Before presenting the technical details of each training method (Notebar, Hand-Sign Bot, and Hand-Sign Bot with Preview), this section introduces the broader framework of the Angklung Training Model. This model defines the overall pedagogical structure guiding the study's system design and experimental scope.

This study proposes a three-stage angklung training model to support angklung players in developing their individual playing skills. The model consists of: (1) Self-Training, (2) Group-Training, and (3) Remote-Training. This dissertation exclusively focuses on the first stage—Self-Training—while the latter two are outlined as future directions. Angklung is inherently an ensemble instrument, requiring multiple players to perform a complete melody, as each instrument holds only a single note. However, the Self-Training phase in this study intentionally does not emphasize the ensemble nature of angklung. Instead, it concentrates on enabling novice players to practice independently using three training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Hand-Sign Bot with Preview (HBP). These methods utilize visual cues (NB) or handsign cues (HB, HBP) to guide individual performance. Each player holds only one note and interacts solely with the training system, without requiring coordination with other players or the presence of a human conductor.

The second stage, Group-Training, extends the individual methods into a collaborative setting. In this mode, multiple novice players train together in the same physical space using NB, HB, or HBP. Performance assessment is conducted at the group level, supported by additional input such as camera and microphone devices to facilitate group evaluation.

The third stage, Remote-Training, is designed to enable distance learning. It simulates the group training environment virtually, allowing players to practice together from different locations. A unique element of this phase is the inclusion of PlayerBot—an AI-based virtual angklung player that replicates human-like behavior based on previously

recorded training data. Remote-Training supports both individual and group assessment features. To maintain clarity and focus, this dissertation evaluates only the Self-Training phase. All experimental results, usability assessments, user engagement analyses, and expert evaluations are strictly limited to the individual learning context.

3.2.1. Overview of the Three-Stage Model

The proposed Angklung Training Model is designed to accommodate the unique characteristics of the angklung instrument, which requires ensemble coordination due to its single-note-per-player nature (see Figure 3.2).

Figure 3.2: Angklung Training Model

To address the practical limitations novice players face—such as the need for a group and a conductor—the model introduces three structured phases:

1. **Self-Training**: This phase enables individuals to practice angklung independently using digital **cue-guided training** methods. It is central to the current study and forms the experimental basis for the research.
2. **Group training:** This supports collaborative learning in a shared physical space, where multiple novice players use the system simultaneously. Additional input devices, such as microphones and cameras, evaluate group-level performance.
3. **Remote-Training**: Extends the training environment into virtual settings, allowing players in different locations to participate together. This stage introduces PlayerBot, a virtual agent designed to emulate angklung player behavior based on prior training data.

3.2.2. Scope of This Study: Focus on Self-Training

While the full training model anticipates multi-user scenarios and remote collaboration, the present dissertation is intentionally limited to the **Self-Training** phase. This decision

allows for a more focused and controlled evaluation of the training methods at the individual level.

In the Self-Training context, each player:

- Holds and plays only one angklung note.
- Follows system-generated cues without interaction with other players.
- Does not rely on a human conductor, but is guided by visual (NB) or handsign cues (HB and HBP).

This structure allows novice angklung players to practice independently, regardless of location or group availability. The methods explored—NB, HB, and HBP—are evaluated in terms of their ability to support individual skill development, particularly in rhythmic accuracy, cue-following, and perceived usability.

All experiments, usability assessments, and expert evaluations in this research are strictly confined to the Self-Training phase. The Group-Training and Remote-Training stages are recognized as future work, to be explored in subsequent studies building upon the foundational insights established in this dissertation.

3.3. Research Design

This section outlines the overall research framework and methodological strategies for evaluating the angklung training system. The research design is aligned with the primary objective of developing and assessing a Cue-Guided Angklung Training System that enables novice players to practice independently through visual and handsign cues. The design integrates quantitative and qualitative approaches to understand system effectiveness, usability, and educational value comprehensively.

3.3.1. Methodological Approach

This study adopts a **mixed-methods approach**, combining **experimental design** for performance evaluation with **user surveys** and **expert interviews** for usability and qualitative feedback. The core strategy is structured around a **within-subject repeated measures design**, where each participant experiences all three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP).

This approach is chosen to:

1. Control for individual differences by comparing each participant's performance across all methods.
2. Evaluate performance improvement through pre-test and post-test measurements.
3. Capture subjective user perceptions through standardized usability and engagement questionnaires.

4. Include professional insights on system authenticity, instructional effectiveness, and refinement opportunities.

3.3.2. Research Questions and Objectives Alignment

The research methodology is directly structured to answer the research questions (RQ) and fulfill the research objective (RO) outlined in Chapter 1. Each component of the research design corresponds to a specific inquiry:

1. **RQ1** is addressed by developing NB, HB, and HBP methods in the System Development phase.
2. **RQ2a** is answered through performance score analysis comparing participant improvement across methods.
3. **RQ2b** is evaluated through user-reported usability and experience metrics (SUS and UEQ-S).
4. **RQ2c** is explored through expert evaluation using a qualitative Framework Analysis approach.

This alignment ensures that every data collection and analysis activity is grounded in the core purpose of the study.

3.3.3. Data Collection Strategy

To assess the system comprehensively, four types of data were collected:

1. **Performance Scores**: Numerical scores from pre-test and post-test sessions, using human conductor benchmarks to assess individual learning outcomes.
2. **System Usability Scale (SUS)**: A ten-item questionnaire to evaluate usability and ease of interaction with each training method.
3. **User Experience Questionnaire – Short version (UEQ-S)**: This questionnaire measures the hedonic and pragmatic quality of the user experience across methods.
4. **Expert Feedback**: Structured interviews with experienced angklung instructors to assess HB and HBP's pedagogical validity and cultural appropriateness.

The data were collected in a controlled experimental setting, ensuring consistency in melody, tempo, instrument handling, and training environment. Each participant was exposed to all three training methods in a counterbalanced order to minimize bias.

3.3.4. Instruments Overview

To comprehensively evaluate the system's usability and user experience, this study combines standardized quantitative instruments and qualitative methods. The selected tools are designed to measure key aspects of interaction, including perceived usability, experiential quality, and expert feedback. The instruments used are as follows:

1. **SUS Questionnaire**: Assesses aspects such as perceived complexity, learnability, confidence, and satisfaction.
2. **UEQ-S Questionnaire**: Evaluates user experience across two dimensions—pragmatic quality (e.g., clarity, efficiency) and hedonic quality (e.g., excitement, inventiveness).
3. **Expert Interview Guide**: Designed to capture expert judgment on the clarity of gestures, training suitability, conductor realism, and suggestions for improvement.

Using standardized and validated instruments enhances the reliability and comparability of results. Quantitative instruments (SUS, UEQ-S, performance scores) are analyzed statistically, while qualitative responses are processed using thematic categorization through Framework Analysis.

3.4. System Development (RQ1)

This section presents the development process of the angklung training system designed to address RQ1: *How can a cue-guided training system be developed to support angklung learning for novice players?* The system aims to support novice players in practicing angklung independently by replicating the role of a conductor through digital methods. Three training approaches were developed: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). Each method incorporates unique cue-based strategies that align with traditional angklung instruction while adapting to an individual learning context.

3.4.1. Development Objectives

The system was developed with the following goals:

- To simulate the function of a human conductor using visual and handsign cues.
- To provide rhythmically accurate and culturally relevant guidance for novice players.
- To ensure the system can be used independently without the need for group practice.
- To accommodate users with no prior angklung experience.

The development prioritized accessibility, intuitive interaction, and accurate timing control, enabling users to focus on the core skill of playing angklung in coordination with external cues.

3.4.2. Notebar (NB): Visual Cue-Based Method

The Notebar (NB) training method serves as the baseline system for this study, providing a fundamental visual cue approach for guiding angklung players in their timing

and coordination. Unlike the Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP), NB does not incorporate any conductor hand-sign movements. Instead, it relies on color-coded note indicators displayed on a screen to help participants anticipate the timing of note execution.

NB is inspired by existing rhythm-based learning tools, such as Piano Tiles and Taiko no Tatsujin, which have been widely used in digital music training [94]. The system is designed to provide a structured and accessible approach for novice players, ensuring they can follow the rhythm of an angklung piece without the added complexity of following a conductor.

NB was developed as a color-coded note guidance system, designed to assist players in following melodies without relying on a human conductor. Unlike HB and HBP, which incorporate hand-sign guidance, NB strictly uses visual indicators to direct players. This method is based on cognitive load theory, which suggests that reducing extraneous cognitive processing can enhance learning efficiency [95].

3.4.2.1. Conceptual Background of Notebar (NB)

The Notebar (NB) system was inspired by game-based rhythm learning applications, such as Piano Tiles and Taiko no Tatsujin, which have been widely used in digital music education [94]. These applications emphasize visual anticipation of musical sequences, allowing users to develop timing accuracy and hand-eye coordination through repetitive engagement with visual cues.

NB was designed to function as a static visual training tool, meaning that it does not provide dynamic feedback or conductor-led timing assistance. Instead, it employs color-coded bars, which move across the screen in a linear timeline format, visually representing the sequence and duration of notes.

This approach was chosen to provide a basic reference for learners, ensuring that improvements in training outcomes could be clearly attributed to HB and HBP when compared to NB. The following principles guided the development of NB:

1. **Visual Reinforcement of Rhythm** – The use of color-coded bars aligns with established music learning methodologies, where visual patterns enhance note recognition and rhythmic accuracy [96].
2. **Predictive Note Timing** – The system was designed to help players anticipate upcoming notes, promoting proactive rather than reactive playing behaviors.
3. **Minimal Cognitive Load** – By eliminating hand-sign instructions, NB allows learners to focus purely on note timing, making it a useful entry-level training method for novice players.

The effectiveness of NB in music training is supported by research in **music cognition and rhythm acquisition**, which suggests that **predictable visual cues can help learners develop internalized rhythmic patterns more efficiently**.

3.4.2.2. Advantages of NB in Angklung Training

The NB training method offers several key advantages, particularly for novice angklung players who are not yet accustomed to ensemble performance. The following benefits highlight why NB is an effective starting point for angklung training:

1. **Visual Reinforcement of Timing:** NB provides clear, color-coded visual indicators that allow players to anticipate note execution. Research in visual learning indicates that color-coded cues improve pattern recognition and reaction times [70].
2. **Reduces Cognitive Load for Novices:** Unlike traditional notation-based training, NB simplifies the learning process by removing the need to decode complex rhythmic symbols. Studies show that novice musicians perform better when visual complexity is minimized [97].
3. **Independent Learning:** NB allows learners to practice angklung without requiring a group setting, making it ideal for self-guided training. This feature aligns with research advocating technology-assisted independent music learning [46].
4. **Consistent and Error-Free Cues:** Unlike human conductors who may introduce slight variations in gesture interpretation, NB provides fixed, precisely timed cues, ensuring consistency across all learning sessions [98].

3.4.3.3. Limitations of NB Compared to HB and HBP

While NB offers several advantages, it has inherent limitations that differentiate it from the **cue-guided training** methods (HB and HBP). The following drawbacks highlight why NB serves primarily as a baseline method rather than a comprehensive training system:

1. **Lack of Expressive Conducting Cues:** Unlike HB and HBP, which provide gestural instructions similar to a human conductor, NB is purely visual and lacks expressive musical communication. This absence limits players' ability to develop ensemble awareness and conductor-following skills.
2. **Potential Over-Reliance on Visual Cues:** Long-term reliance on NB may hinder auditory-based timing development, as players may focus more on visual indicators rather than listening to their ensemble.
3. **Limited Group Training Applications:** NB is better suited for individual practice rather than group coordination training. This limitation means that players trained exclusively with NB may struggle to transition to real-world ensemble settings.

3.4.3.4. Role of NB in This Study

In this research, NB serves as a control condition, allowing for comparative analysis against HB and HBP. The role of NB in this study is defined by the following factors:

1. **Benchmark for Performance Comparisons:** By using NB as a baseline, the study can quantify the added benefits of HB and HBP. Statistical comparisons between NB-trained and HB/HBP-trained participants will highlight the extent to which handsign-based cues improve timing accuracy and coordination.
2. **Isolation of Conductor-Based Guidance Effects:** Since NB does not include conductor hand-signs, any observed performance improvements in HB and HBP groups can be attributed to the presence of structured conductor cues.
3. **Evaluation of Standalone Digital Training Effectiveness:** The study assesses whether NB alone is sufficient for self-guided angklung learning, or if conductor guidance is essential for developing ensemble synchronization skills.

By establishing NB as the baseline, the study ensures that the contributions of HB and HBP can be objectively measured in terms of skill development and usability. While NB serves as an effective tool for individual timing practice, it lacks the expressive and adaptive elements that HB and HBP provide. By using NB as a control condition, this study ensures that the impact of **cue-guided training** methods can be accurately assessed. The next chapter, **Chapter 4**, will provide a detailed discussion on system design and implementation, including the technical architecture and user interface development of NB.

3.4.3. Hand-Sign Bot without Preview (HB): Handsign Cue-Based Method

Hand-Sign Bot without Preview (HB) is one of the two **handsign-cue training** methods introduced in this study, designed to provide structured hand-sign guidance for novice angklung players. Unlike Notebar (NB), which relies solely on visual cues for note timing, HB simulates the hand-sign gestures of a human conductor.

This method is grounded in the traditional angklung conducting techniques used at Saung Angklung Udjo, where players follow a conductor's hand movements to determine when to shake their instruments [13]. HB integrates pre-recorded hand-sign animations, ensuring that players receive consistent and precise gestural guidance throughout their training.

The following sections provide a detailed explanation of HB's conceptual foundation, benefits, limitations, and role in this study, ensuring that its function as a structured **cue-guided training** method is clearly established.

3.4.3.1. Conceptual Background of Hand-Sign Bot without Preview (HB)

The development of Hand-Sign Bot without Preview (HB) as a training method is rooted in the fundamental principles of angklung performance, where players are required to follow a conductor to achieve synchronization and harmony. In traditional angklung ensembles, the **Human Conductor (HC)** plays a critical role in guiding players, especially **novices**, through hand-sign language and gestures that dictate timing, rhythm, and dynamics. However, replicating the precise and nuanced hand-sign language of a human conductor is a significant challenge, particularly for novice players who are still developing their musical and coordination skills. This challenge served as the primary motivation for creating Hand-Sign Bot, an **avatar-based conductor** designed to simulate the role of a human conductor in a more accessible and consistent manner.

The Necessity of a Conductor in Angklung Performance: In angklung ensembles, the conductor is indispensable for maintaining synchronization among players. Unlike solo performances, where the musician has full control over timing and expression, ensemble performances require strict coordination to ensure that all players produce sound in unison. This is especially critical for novices, who often struggle with rhythm and timing. As highlighted by Thompson and Balkwill (2010) [99], synchronization is a key element in group music performance, and the conductor's hand-sign language serves as a visual cue, guiding players on when to play, stop, or adjust their dynamics. Without a conductor, the ensemble risks falling into disarray, resulting in a lack of cohesion and musicality. Although this study does not involve group performance, the ensemble context illustrates why a structured conductor simulation, such as HB, is pedagogically valuable—even in individual training.

While human conductors are highly effective, their availability and consistency can be limiting factors in training scenarios. Human conductors may not always be present during practice sessions, and their hand-sign language can vary in clarity and precision, making it difficult for novices to interpret. Additionally, the subtle nuances of a human conductor's gestures can be challenging to replicate, especially for players who are still learning the basics of angklung performance. These limitations highlight the need for an alternative training tool that can replicate the role of a human conductor in a more accessible and standardized way.

Based on the discussion in **Chapter 2**, particularly in **Table 2.2: Summary of Key Research on Kodály Hand Signs** and **Table 2.3: Research Related to Angklung and Technology**, which explore studies on hand-sign language and the integration of technology in angklung, it is evident that the role of the **Human Conductor (HC)** in demonstrating hand-sign language is crucial for angklung performance. However, the limitations identified in the **Notebar (NB)** method, such as the lack of real-time guidance and the absence of a conductor-like figure, can be effectively addressed by introducing a new training method: **Hand-Sign Bot without Preview (HB)**. Hand-Sign Bot is designed to overcome these limitations by providing a virtual conductor that replicates the hand-

sign language of a human conductor, ensuring that players receive consistent and accurate guidance during practice.

3.4.3.2. Advantages of HB in Angklung Training

HB offers several unique benefits that make it an effective alternative to traditional human conductor-led training. These advantages are particularly significant for novice players who require structured guidance to improve their ensemble coordination.

1. **Conductor-Like Guidance Aligned with Real-World Practice:** Unlike NB, which provides simple static visual cues, HB replicates the conductor-centered nature of real angklung performance. In traditional practice, angklung players are trained to follow a human conductor who uses hand-sign gestures to signal timing and coordination. HB embraces this instructional model by presenting hand-sign cues that closely mirror real-world angklung instruction. As supported by [100], cueing systems grounded in conductor gestures offer more authentic training experiences—especially for instruments like angklung, which are inherently guided by such signals.
2. **Standardized Training Sessions:** One challenge of human conductor-led training is variability in conducting style, which can introduce inconsistencies in tempo and expressiveness. HB eliminates this issue by providing pre-recorded, standardized conducting gestures, ensuring that all participants receive the same level of instruction [101].
3. **Improved Timing Accuracy and Ensemble Awareness:** Research has shown that visual-motor synchronization is enhanced when learners follow dynamic gestural cues, rather than static indicators [102]. While this study does not involve ensemble settings, training with HB may help players develop foundational rhythm and coordination skills that are important for future group performance.
4. **Scalability for Broader Use:** While this study focuses solely on individual training, HB is technically designed to support multiple users simultaneously in future group-training scenarios, such as classrooms or workshops.

3.4.3.3. Limitations of HB Compared to NB and HBP

Despite its advantages, HB also has several limitations that differentiate it from human-led conductor training. Understanding these drawbacks is crucial for assessing when and how HB should be implemented in real-world training programs.

1. **Lack of Responsiveness to Player Input:** Unlike a human conductor who can adjust gestures based on player responses, HB operates on pre-programmed movements. It does not adapt to player errors or timing, and thus offers consistent but non-interactive guidance. This limitation may make it less effective for advanced learners who require adaptive training techniques [103].

2. **No Expressive Variability:** Human conductors communicate not just timing, but also musical expression through gesture intensity, facial expressions, and subtle dynamic shifts. HB lacks expressive flexibility, making it more suitable for rhythmic training rather than musical interpretation [104].
3. **Requires Initial Familiarization:** Novice players may initially struggle to interpret HB's gestures correctly, as verbal explanations do not accompany them. In contrast, human conductors can provide immediate verbal reinforcement, helping learners understand musical phrasing and articulation [105].
4. **Technical Dependence and Accessibility Constraints:** HB requires a stable digital interface, meaning that technological limitations (such as software compatibility issues or screen resolution constraints) could impact its effectiveness. Unlike a human conductor, HB cannot function without its digital framework, making it less accessible in environments with limited technological resources.

3.4.3.4. Role of HB in This Study

HB is critical in this study, functioning as one of the two **handsign-cue training** methods alongside HBP. Including HB allows researchers to examine the impact of structured conductor guidance on timing accuracy and coordination.
Specifically, HB is used for the following purposes:

1. **Comparison Against NB (Baseline Training Method):** This study compares performance outcomes between NB and HB to assess whether structured conductor guidance improves musical coordination beyond basic visual cues.
2. **Focus on Present-Time Cue Following:** Since HB does not include anticipatory movement indicators, it allows researchers to examine how players follow present-time gestural cues delivered in sync with the melody. These cues are pre-programmed and do not adapt to user performance, making them ideal for assessing basic cue-following skills in a controlled setting.
3. **Preparation for Hand-Sign Bot with Preview (HBP) Evaluation:** The study examines whether HB-trained participants transition more effectively to HBP training, where anticipatory cues are added to improve predictive timing abilities.

By establishing HB as a structured **cue-guided training** method, this study provides insights into how digital conducting systems can supplement or replace traditional angklung conducting techniques. The next chapter, Chapter 4, will provide a detailed discussion on system design and implementation, including the technical architecture and user interface development of HB.

3.4.4. Hand-Sign Bot with Preview (HBP): Anticipatory Cue-Based Method

Hand-Sign Bot with Preview (HBP) is an advanced development of Hand-Sign Bot without Preview (HB), designed to further enhance timing accuracy and predictive coordination in angklung training. While HB provides real-time conductor hand-sign guidance, HBP introduces an additional anticipatory feature, allowing players to see upcoming movements before they are executed.

HBP was developed to address a key limitation of HB: while HB effectively guides players through structured hand-sign cues, it does not provide advance notice of the next movement, potentially causing delays in reaction time. In contrast, NB (Notebar) allows players to see the next note in advance, helping them prepare for transitions. HBP combines the strengths of both HB and NB, integrating an additional Sub Hand-Sign Bot (hence the name Hand-Sign Bot with Preview), which displays the next conductor gesture one second before execution.

This section details the conceptual background, advantages, limitations, and the role of HBP in this study, ensuring a clear understanding of how it enhances angklung training beyond HB.

3.4.4.1. Conceptual Background of Hand-Sign Bot with Preview (HBP)

HBP retains the core functionality of HB, using a conductor avatar (Hand-Sign Bot) to provide hand-sign guidance. However, it introduces an additional layer of visual information by integrating a secondary Sub Hand-Sign Bot that anticipates the next conducting movement one second before it happens.

This modification is based on research in predictive motor timing, which suggests that providing anticipatory cues enhances synchronization and reaction speed in ensemble performance settings, although this study focuses solely on individual practice [80]. By allowing players to see both the current and upcoming conductor gestures, HBP helps reduce reaction delays, ensuring smoother transitions between notes. The inclusion of the HBP aims to:

1. Improve player response time by providing early visual guidance.
2. Reduce timing errors caused by late reactions to HB's real-time cues.
3. Help players anticipate note changes, making angklung training more structured and predictable.

Since this approach is new to digital angklung training, part of this study aims to determine which players benefit most from NB, HB, or HBP. Some learners may find HBP's dual-conductor approach intuitive, while others may struggle with processing two sets of visual cues simultaneously.

The introduction of anticipatory motion cues in HBP is grounded in research on motor learning, cognitive anticipation, and ensemble synchronization. Several key findings support HBP's design:

1. **Visual Anticipation Enhances Timing Precision:** Studies show that musicians synchronize more accurately when provided with predictive motion cues rather than reacting in real-time [106]. Anticipatory gestures allow performers to prepare for upcoming actions, reducing reaction delays mentally.
2. **Cognitive Load Theory Suggests Predictive Cues Reduce Processing Time:** Research in cognitive load reduction indicates that pre-loading information allows for smoother task execution [95]. When performers see the next movement in advance, their brains allocate less cognitive effort to real-time decision-making, leading to more fluid execution.
3. **Split-Attention Effect and Individual Learning Differences:** Not all learners process simultaneous information sources equally well [107]. While some players may benefit from predictive hand-sign cues, others may find dual-conductor movements distracting, highlighting the need for personalized training approaches.

HBP is therefore designed not as a universal replacement for HB, but as an alternative option for players who respond better to predictive visual information. The effectiveness of HBP compared to HB is one of the key aspects explored in this study.

3.4.4.2. Advantages of HBP in Angklung Training

HBP offers several unique benefits that set it apart from NB and HB, particularly for players who require additional time to process conductor cues.

1. **Faster Reaction Time and Improved Accuracy:** HBP allows players to see the upcoming movement one second before execution, reducing the need for last-second reaction adjustments. Research in sensorimotor synchronization suggests that predictive visual cues help musicians anticipate beat timing with greater accuracy.
2. **Reduced Performance Anxiety in Novice Players:** One challenge in ensemble training is that real-time demands often overwhelm players. HBP provides a buffer period for processing cues, reducing the stress of immediate execution and improving overall confidence.
3. **More Structured Transition from NB to HB:** HBP helps players who are accustomed to NB's pre-displayed notes transition to HB's real-time conducting gestures more smoothly. It provides an intermediate learning stage where players still receive anticipatory guidance but must also start engaging with live conductor movements.

One of the core assumptions behind the preview design in HBP is its support for mental preparation—a cognitive process in which players anticipate and allocate attention for

their response before the actual cue is delivered. By showing the upcoming gesture one second in advance, the system aims to reduce cognitive load and enable novice players to prepare their motor action and timing more effectively.

3.4.4.3. Limitations of HBP Compared to NB and HB

Although HBP introduces several improvements, it also has limitations that may affect player adaptability.

1. **Potential Cognitive Overload for Some Learners:** Some players may struggle to process two sets of conducting cues simultaneously (the main and sub Hand-Sign Bot). Research suggests that dual visual inputs can sometimes overwhelm cognitive processing, especially for novices.
2. **Requires Additional Training for Interpretation:** Since HBP is a new approach, players may need extra time to learn how to interpret both the real-time and anticipatory gestures. Unlike NB, which is immediately intuitive, HBP requires players to adjust to a dual-visual feedback system.
3. **Unclear Whether HBP is Universally Beneficial:** One of the research questions in this study is to determine which learners benefit most from HBP compared to HB and NB. Some individuals may find real-time HB gestures sufficient, while others may prefer HBP's predictive cues.

This study aims to categorize player responses and determine whether HBP is a viable alternative for all learners or only beneficial to certain learning styles.

3.4.4.4. Role of HBP in This Study

HBP plays a critical role in this study by allowing researchers to compare how different learners respond to predictive cues versus real-time conductor guidance. The key objectives of HBP evaluation are:

1. **Determining the Effectiveness of Anticipatory Hand-Sign Cues:** Does providing a one-second preview significantly improve timing accuracy and coordination? Does HBP reduce reaction time errors compared to HB?
2. **Identifying Which Players Benefit Most from HBP:** Are certain learners better suited for anticipatory cues while others prefer real-time conducting gestures? How does prior musical experience impact the ability to use HBP effectively?
3. **Comparing HBP to HB and NB in Individual Practice Scenarios:** Does HBP serve as a helpful bridge between visual cue-based (NB) and handsign-based (HB) methods? How effectively does it support novice players in developing internal timing and cue-following accuracy?

By investigating these research questions, this study provides insights into how different angklung players engage with various training methods, ensuring that the most effective instructional techniques are identified. The next chapter, Chapter 4, will provide

a detailed discussion on system design and implementation, including HBP's technical architecture and user interface development.

3.5. Experimental Testing (RQ2)

This section outlines the experimental procedures conducted to evaluate the **cue-guided training** methods introduced in this study: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The experimental testing phase is designed to answer **RQ2**: *How do players and experts perceive the angklung-playing experience using a Cue-Guided System?* More specifically, it addresses sub-questions RQ2a (performance) and RQ2b (usability and engagement) and provides the foundational data for RQ2c (expert evaluation, described in the next section).

3.5.1. Target User Profile and Playing Complexity Levels

To ensure that the design of the proposed cue-guided angklung training system aligns with the specific needs of its intended users, it is crucial to examine the playing characteristics and training requirements of angklung players across different skill levels. Angklung playing involves a gradual progression in complexity, ranging from single-note performance at the novice level to multi-instrument mastery at the advanced stage. Each level requires different levels of technical ability, conductor interaction, and practice intensity. These differences directly influence the kind of support system required for training. **Table 3.1 illustrates the fundamental distinctions** between novice, intermediate, and advanced angklung players in terms of melody coverage, instrument handling, conductor role, sound support, and practice requirements.

Table 3.1: Player Level Comparison in Angklung Performance

Category	Novice	Intermediate	Advanced
Melody Range	One octave of melody	Full melody with major and minor chords	Full set of melody
Instrument per Player	1 player = 1 instrument	1 player = 2–3 instruments	1 player = 3–8 instruments
Conductor Role	Saung Udjo handsign (most difficult)	Custom handsign (medium difficulty)	Custom handsign (difficult)
Number of Conductors	1 conductor	1–2 conductors	1–3 conductors
Instrumental Distribution	Melody: player; Other sound: external	Other instruments assist melody	Almost all sound fully produced by angklung
Practice Requirement	Instant perform	Requires practice	Requires extensive practice

As shown in Table 3.1, novice players operate under a strict one-player-one-instrument structure and rely heavily on a single conductor using the traditional Saung Udjo hand-sign method. Interestingly, while the technical requirement per player may seem simple, the challenge lies in the player's dependence on immediate visual cues, making the conductor's role extremely critical. Furthermore, novice players generally only handle one octave of melody and are expected to instantly follow cues without deep musical rehearsal, especially in performance settings.

In contrast, intermediate players manage multiple instruments (2–3 per player), use custom hand-signs from conductors, and perform with more harmonic depth (major and minor accompaniment). These players still benefit from supplementary instruments, but the conductor's role becomes more distributed. Advanced players, however, take on a high degree of instrumental and musical responsibility, often performing without non-angklung accompaniment and requiring long, intensive practice sessions. They may follow multiple conductors depending on the complexity of the arrangement.

These distinctions support the validation that the **target user for this study is novice-level angklung players.** This group is uniquely characterized by high dependency on conductor cues, minimal technical skill, and a need for systems that allow them to perform individually without requiring full ensemble settings. A notable subtype of novice players is the **"Instant Player"** — an individual with no prior angklung-playing experience who can immediately participate in a performance with only brief instruction and visual guidance from a conductor. By replicating the essential cue-following environment of ensemble angklung performance, the proposed Cue-Guided Angklung Training System specifically addresses the learning needs and limitations of this group. Hence, system features such as handsign cues and visual rhythms are designed with novice player constraints in mind, ensuring accessibility, clarity, and ease of practice in solo or small-group formats.

3.5.2. Participant Selection

The selection of participants plays a critical role in ensuring that the study effectively evaluates the impact of different angklung training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). This section explains the criteria and rationale for selecting participants, ensuring that the findings are valid, reliable, and applicable to the research objectives.

Although this study includes both novice and experienced players, the primary focus remains on novice players. The inclusion of experienced players is to provide a comparative analysis, allowing the research to determine whether HB and HBP are beneficial only for novices or if they also enhance the skills of more experienced angklung players.

3.5.2.1. Criteria for Selecting Participants

To ensure that the study is comprehensive and applicable to real-world angklung training, participants were selected based on the following criteria:

1. **Experience Level** – Participants were divided into novice players (the main research focus) and experienced players to analyze how different skill levels respond to HB and HBP training methods.
2. **Cultural Background –** The study included Indonesian and non-Indonesian participants to evaluate whether cultural familiarity with angklung influences training effectiveness.
3. **Adaptability to Digital Training**—Since HBP introduces a new anticipatory conducting method, participant selection also considered whether certain learners might benefit more from predictive cues than real-time conducting gestures.

These criteria were established to ensure that the study captures meaningful performance differences across diverse learner profiles. This enables researchers to draw conclusive insights into which training method is best suited for different types of players.

3.5.2.2. Participant Groups

Participants were divided into three distinct groups based on experience level and cultural background to ensure a diverse and comprehensive evaluation. This grouping structure allows the study to assess how different participant characteristics influence training effectiveness, particularly in adapting to Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP) as angklung training methods.

While the study primarily focuses on novice players, an experienced group was included for comparison, allowing for an analysis of whether structured digital training tools can also benefit experienced angklung players.

To facilitate meaningful analysis, **36 participants** were divided into **three groups**:

1. **Non-Indonesian Novice Players (NIN)**: Conducted individually, ensuring that each participant performs alone without observing others. 18 participants from China, India, Japan, Pakistan, South Korea, and Vietnam, aged 26-30 years, with no prior experience playing angklung.
2. **Indonesian Novice Players (INA)**: This activity is conducted in small groups (3 participants per group), where each group performs together in real time. Nine participants are from Indonesia, aged 21-25, with limited exposure to angklung.
3. **Indonesian High School Players (SMA)**: Same as INA's group who conducted in small groups. 9 high school students from Indonesia, aged 16-20 years, with prior angklung ensemble experience.

Despite these differences in experiment structure, all data is analyzed individually, ensuring a fair performance evaluation. Each group was assigned a balanced distribution of training methods (NB, HB, HBP) to assess how participants adapted to each training approach; see Table 3.2 for more details.

Table 3.2: Participant Grouping Overview

Group	No. of Participants	Location	Experience Level	Experiment Format
NIN (Non-Indonesian Novice Players)	18	JAIST (Japan)	Novice	Individual (one participant at a time)
INA (Indonesian Novice Players)	9	Indonesia	Novice	Group-based (3 participants per session)
SMA (Indonesian Experienced Players)	9	Indonesia	Experienced	Group-based (3 participants per session)

Note: All participants played the same angklung piece ("Burung Kakak Tua") and followed the same experimental procedure (pre-test → training → post-test), ensuring consistency in the study design.

Reason for Group Testing in Indonesia:

1. **Cultural Familiarity with Angklung:** Even novice Indonesian participants (INA group) had at least heard of angklung, making it more practical to test them in a group setting. Unlike non-Indonesian participants, Indonesian players were more accustomed to ensemble-based music learning, making the group format more applicable.
2. **Time Constraints:** The SMA group was only available for testing **during extracurricular class hours**, making individual testing impractical. The group setting allowed for efficient time management, ensuring that all participants could complete the experiment within the limited schedule.
3. **Realistic Ensemble Simulation:** Since angklung is traditionally played in an ensemble, group testing allowed researchers to assess how players interacted in small groups. Even though **analysis was conducted per individual**, testing in groups provided insights into real-world angklung performance scenarios.

Although the main focus of this research is on novice players, experienced players were included to provide a comparative analysis, helping to answer several key questions:

1. **Are HB and HBP more beneficial for novice players than experienced ones?** Novice players may require stronger visual reinforcement (HBP), whereas experienced players may already be accustomed to following real-time conductor cues (HB).
2. **Do experienced players adapt better to HB than novices?** Experienced players have prior ensemble training, which may make them more responsive to HB's real-time conducting gestures. Novices may struggle with immediate conductor-following, making HBP's anticipatory cues more useful.

3. **Is HBP beneficial for all players, or only for novices?** HBP offers predictive conducting gestures, which might be helpful for novice players but could be redundant or even distracting for experienced players.

By comparing novice and experienced players, this research can determine:

1. Should HBP be explicitly designed for novices or enhance learning for advanced players?
2. Whether HB remains the preferred method for experienced musicians, reinforcing traditional conductor-led training.
3. Whether NB, despite being a simpler method, is sufficient for self-learning, or if players need structured conductor cues to improve.

3.5.2.3. Justification for Two Experiment Locations (JAIST & Indonesia)

To ensure that the study captures cultural and experience-based differences, experiments were conducted in two locations:

1. **Experiment at JAIST (Japan)**: Involving 18 Participants (All Novice & Non-Indonesian): This experiment focused on absolute novices (**NIN group**) with no prior exposure to angklung or traditional conductor-led training. This setting was used to assess whether HB and HBP can be effective for international learners with no angklung background.
2. **Experiment in Indonesia:** Involving 18 Participants (9 Novice, 9 Experienced): **The INA group** (Indonesian Novice) represented local learners with minimal angklung exposure (novice). **The SMA group** (Indonesian Experienced) allowed the study to analyze whether HB and HBP also benefit experienced players.

By including both Indonesian and non-Indonesian players, the study ensures that the results are globally applicable, rather than being limited to a single cultural context. Although both experiments followed the same testing procedure, this division of participants allows the study to:

1. Compare how absolute novice vs. culturally familiar players adapt to each training method.
2. Identify whether HB and HBP provide advantages for experienced musicians or are primarily beneficial for novices.

3.5.3. Experimental Testing Framework

To ensure a structured and standardized experimental process, this study implements a systematic testing framework that enables a valid comparison of training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). This framework defines the testing methodology, standardizes training conditions, and selects test material, ensuring that all participants undergo consistent and unbiased evaluation.

The main goals of this framework are to:

1. Establish a pre-test and post-test structure to measure learning improvement.
2. Ensure standardized training sessions, eliminating variations in external conditions.
3. Use a single, carefully selected angklung piece, ensuring that all participants are evaluated on the same musical material.

This section details the pre-test and post-test methodology, standardization of training sessions, and selection of the angklung piece for testing, providing a foundation for the experimental procedures discussed in **Chapter 5**.

3.5.3.1. Pre-Test and Post-Test Methodology

The pre-test and post-test methodology is designed to evaluate how each training method (NB, HB, HBP) improves a participant's ability to follow a Human Conductor (HC), representing the real-world performance condition for angklung players. The testing sequence follows a three-phase structure:

1. Pre-Test Procedure (Before Training)

The pre-test is conducted with a **Human Conductor (HC)** to measure how well participants can follow traditional angklung conducting cues before training. Participants perform the selected angklung piece ("Burung Kakak Tua") by following a live HC, without assistance from any training methods.

The pre-test format differs based on experiment location:

a. **JAIST (Japan)** – Individual Pre-Test: Each participant performs alone to ensure an isolated baseline measurement.
b. **Indonesia** – Group Pre-Test: Participants perform in a 3-person group, with each player assigned one note (Re, Fa, or Do').

By using HC as the standard conductor in both cases, the study ensures that training effectiveness is measured against real-world performance conditions.

2. Training Session (Using NB, HB, and HBP)

Following the pre-test, participants are divided into groups that train using one of the three training methods. Each participant is assigned a specific order of training methods and notes (Re, Fa, Do'), determined using a counter-balanced design. Counter-balance is applied to reduce bias, ensuring that the order of training methods and note assignments does not systematically favor one method over another. The detailed counter-balance group allocation is presented in **Chapter 5**.

a. NB (Notebar): A color-coded visual cue system that provides note anticipation cues.
b. HB (Hand-Sign Bot): A digital avatar replicating a human conductor's real-time hand movements.
c. HBP (Hand-Sign Bot with Preview): A digital avatar providing anticipatory conducting cues (one second ahead of execution).

Each training session consists of:

a. Pre-Test with HC → Playing the test piece following an HC.
b. Training with the assigned method (NB, HB, or HBP) for three repetitions.
c. Post-Test with HC → Playing again with an HC to assess improvement.
d. Completing SUS and UEQ-S Questionnaires for that training method.

A full explanation of how training method and note assignments were counter-balanced is provided in **Chapter 5**.

3. Post-Test Procedure (After Training)

After completing training, participants undergo a post-test, which is identical to the pre-test:

a. They must follow **Human Conductor (HC)** while playing angklung.
b. Training methods (NB, HB, HBP) are no longer available during the post-test.
c. Performance improvement is measured by comparing post-test scores to pre-test scores. The difference between pre-test and post-test scores **(D = T2 - T1)** serves as the primary metric for evaluating training effectiveness.

This ensures that the training effects are sustainable and transferable to real-world angklung performance conditions.

Although the same song was used in both tests, the system focused on skill development—particularly cue-following and timing—rather than melodic memorization. This design ensured that any improvement was due to enhanced response to visual or gestural cues, not song familiarity.

3.5.3.2. Standardization of Training Sessions

To ensure consistent conditions across all participants, all training sessions follow a standardized format, eliminating external variables that could influence results. Each participant undergoes 120 minutes (2 hours) of testing, divided into three main activities:

1. Introduction Session (15 minutes)
   a. Completing Consent Form and Pre-Experiment Questionnaire.
   b. Explanation of the experiment and basic angklung playing techniques.
2. Angklung Playing Experience (90 minutes total)
   a. Training Method-1 (30 minutes)
      - Pre-Test with HC
      - Training with the assigned method (NB, HB, or HBP) for three repetitions
      - Post-Test with HC
      - Filling out SUS and UEQ-S for that method
   b. Training Method-2 (30 minutes) → Same sequence with a different training method and note.

c. Training Method-3 (30 minutes) → Same sequence with a different training method and note.

3. Questionnaire Session (15 minutes)
   a. Completing "Questionnaire to Improve the Training Method".
   b. Open-ended feedback about HC, NB, HB, HBP, and the feel of playing angklung.

Key Standardization Elements:

1. Each training method (NB, HB, HBP) is practiced for an equal duration (30 minutes).
2. Each participant experiences all three methods in a counter-balanced order.
3. Each session is structured identically to prevent variations in learning exposure.

By maintaining this structured and time-controlled session, the study ensures that:

1. Every participant receives an equal amount of training.
2. Performance differences are attributed to the training method, not session structure.

3.5.3.3. Selection of Angklung Piece for Testing

A single standardized angklung piece, "**Burung Kakak Tua**," was chosen for both pre-test and post-test, ensuring that all participants were tested on the same material. Reasons for Choosing "Burung Kakak Tua", this song was selected because:

1. **Novice-Friendly Design** – The piece was arranged specifically for novice players, allowing even those who have never played angklung before to follow along.
2. **Balanced Difficulty** – The chosen notes ensure equal difficulty across all players, avoiding notes like So, which require more advanced shaking techniques.
3. **Predictability for Testing Purposes** – The song follows a repetitive rhythm, making it easier to measure timing accuracy and reaction speed without interference from complex melodies.

Counter-Balance in note assignments to prevent bias, each participant plays all three notes (Re, Fa, Do') across different training methods. The specific note order is randomized to prevent familiarity effects. By ensuring that all participants perform the same piece, performance differences reflect training effectiveness rather than song difficulty. Every note assignment follows a counter-balanced design, eliminating systematic advantages or disadvantages. The detailed counter-balanced allocation of training methods and note assignments is provided in Chapter 5.

The decision to use only Re, Fa, and Do' was made based on:

1. Equal difficulty balance – Ensuring that no participant has an advantage or disadvantage based on note complexity.
2. Avoiding coordination bias – Notes like So require a more refined technique, which could introduce unequal difficulty levels in the test.

3. Simplicity for novice players – Keeping the note range small helps reduce cognitive load, allowing participants to focus on learning conductor-following techniques.

Using a single song with controlled note selection ensures that:

1. Performance variations are due to training effectiveness, not song difficulty.
2. Both novice and experienced players can be evaluated fairly.
3. This selection ensures that the test piece is accessible, structured, and designed to provide clear performance metrics.

3.5.4. Task Content and Note Allocation

The training tasks were standardized across all participants to ensure experimental consistency and minimize external variables. A counterbalanced design was employed to control for order effects, ensuring that each training method (NB, HB, HBP) and note assignment (Re, Fa, Do') was equally distributed across sessions.

3.5.4.1. Octave and Note Range

The training content was confined to one octave (C4–C5) to reflect authentic *angklung* playing while maintaining feasibility for novice learners. Each participant was assigned **only one note per session** (Re, Fa, or Do'), simulating real-world conditions where each player is responsible for a single pitch.

- This constraint ensured participants focused solely on **cue-following and timing accuracy**, rather than melodic interpretation or note-switching.
- The same angklung tube instrument was used throughout the experiment, but the assigned note varied per session based on the counterbalancing scheme.

3.5.4.2. Counterbalanced Note and Method Allocation

To avoid bias, a structured counterbalancing strategy was applied:

- Training methods (NB, HB, HBP) and notes (Re, Fa, Do') were systematically rotated across participants.
- Each participant experienced all three methods and notes in a predetermined order, ensuring balanced exposure.

This approach ensured that:

1. Order effects (e.g., learning fatigue or practice benefits) were minimized.
2. Note difficulty bias (e.g., Re vs. Do') was evenly distributed.
3. Method comparisons (NB vs. HB vs. HBP) remained fair.

More details in this section can be found in Chapter 5.

3.6. Evaluation (RQ2a, RQ2b, RQ2c)

This section presents the evaluation phase of the study, which integrates quantitative and qualitative analyses to answer Research Question 2 (RQ2) and its sub-components. The evaluation focuses on three key aspects: (1) performance outcomes across training methods (RQ2a), (2) usability and user engagement (RQ2b), and (3) expert perspectives on the Cue-Guided Systems (RQ2c).

The analyses conducted in this phase are grounded in data collected from pre- and post-tests, usability questionnaires, user experience ratings, and expert interviews. Each sub-section outlines the analytical methods, instruments, and rationale for interpreting findings relevant to the research objective.

3.6.1. RQ2a – Participant Performance Score

To evaluate whether the different training methods (NB, HB, HBP) affected participants' musical performance, pre-test and post-test scores were compared.

3.6.1.1. Assessment Criteria and Scoring Method

This study employs a structured manual performance evaluation system to assess the effectiveness of HB and HBP compared to Notebar (NB) and Human Conductor (HC). Each participant's pre-test and post-test performance was evaluated based on five key criteria:

1. **Perfect (P):** The participant played perfectly, following the conductor exactly. (+3 points)
2. **Great (G):** The participant played correctly but not perfectly. (+2 points)
3. **Late (L):** The participant played late but within an acceptable tolerance. (+1 point)
4. **Miss (M):** The participant did not play at all. (0 points)
5. **Wrong Note (WN):** The participant played the wrong note. (-1 point)

Unlike automated scoring systems, human raters conducted this evaluation manually, following the above predefined scoring criteria. Trained evaluators assigned scores based on real-time observation and video recordings, ensuring that each performance was assessed fairly and consistently.

3.6.1.2. Formula for Score Calculation

The total pre-test (T1) and post-test (T2) scores were calculated using the formula:

$$T = \sum (P.3 + G.2 + L.1 + M.0 + WN.(-1))$$

Where:

- **T1 (Pre-Test Score):** The participant's score before training.
- **T2 (Post-Test Score):** The participant's score after training.
- **D (Score Difference):** The performance improvement, calculated as D = T2 - T1.

This study ensures consistent and objective evaluation across all training conditions by structuring the scoring calculation.

3.6.1.3. Data Analysis Method

The Friedman Test is a non-parametric alternative to one-way repeated-measures ANOVA, ranking within-subject scores to detect differences across conditions [108]. A **Non-parametric Friedman Test for comparing three related training methods** was conducted to assess differences in post-test scores across NB, HB, and HBP. This statistical test was chosen because:

- The data were ordinal and not normally distributed.
- The same participants experienced all three methods (within-subject design).
- The sample size was relatively small.

In cases where the Friedman Test yielded a statistically significant result ($p < 0.05$), **Post-Hoc Wilcoxon Signed-Rank Tests** were applied for pairwise comparisons (NB vs. HB, HB vs. HBP, NB vs. HBP) to determine which specific methods differed significantly [109].

3.6.1.4. Purpose and Relevance

This analysis directly addresses **RQ2a**:
How does player performance change when using a Cue-Guided System?
By comparing performance across methods, the analysis determines whether HB and HBP offer measurable improvements over the visual-only baseline (NB) in terms of timing precision and note execution.

3.6.2. RQ2b – Player Experience

To assess how users perceived the usability and user experience of each training method, two standardized questionnaires were administered after each training phase:

1. System Usability Scale (SUS) – Evaluates perceived ease of use, confidence, and learnability across the ten-item Likert-scale instrument.
2. User Experience Questionnaire – Short Version (UEQ-S) – Measures two dimensions of user experience.

3.6.2.1. SUS and UEQ-S

The System Usability Scale (SUS) and User Experience Questionnaire - Short Version (UEQ-S) were used to assess participant experiences and perceptions of NB, HB, and HBP. These surveys were conducted after participants completed each training session, allowing them to provide feedback on each method's ease of use, efficiency, and overall experience.

a. System Usability Scale (SUS)

SUS is an industry-standard tool for evaluating the usability of systems, interfaces, and products [110]. SUS is a reliable and quick-to-administer questionnaire comprising ten items scored on a Likert scale. The tool provides a single usability score ranging from 0 to 100, making it easy to interpret and compare across different systems [111]. SUS is highly versatile and has been applied across various domains, including software development, consumer electronics, and instructional tools. This study used SUS to measure participants' perceptions of ease of use, learnability, and overall satisfaction with the training methods. A SUS score above 68 is typically considered "above average," indicating good usability, while lower scores suggest areas for improvement [112]. The insights from SUS helped identify how effectively each training method supported novice Angklung players in their learning process.

The SUS score was used to measure:

- Learnability – How easy it was for participants to understand and use NB, HB, and HBP.
- Effectiveness – How well did each training method help participants improve their angklung-playing skills?

The SUS questionnaire consisted of 10 standardized questions, with responses rated on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). The final SUS score was calculated using the standard formula, where higher scores indicate better usability.

b. User Experience Questionnaire - Short Version (UEQ-S)

UEQ-S is a streamlined tool designed to measure user experience across eight core dimensions: attractiveness, clarity, efficiency, dependability, stimulation, and novelty [113]. It was derived from the complete User Experience Questionnaire (UEQ) to offer a quicker and more focused assessment while retaining reliability and validity [114], [115], [116]. The UEQ-S enables researchers to capture the pragmatic (e.g., efficiency, dependability) and hedonic (e.g., stimulation, attractiveness) aspects of user experience. This makes it particularly valuable in contexts where subjective emotional and cognitive reactions to systems, such as learning tools, play a critical role. In this study, the UEQ-S provided a detailed evaluation of how participants emotionally and cognitively interacted with each training method, complementing the usability findings from SUS and the performance data from pre-and post-tests.

The UEQ-S was used to assess:

- Attractiveness – How engaging and enjoyable each training method was.
- Efficiency – How well each method supported learning without causing confusion.
- Clarity – How clear and easy it was to follow the visual and gestural cues in NB, HB, and HBP.

The UEQ-S responses were collected using an opposing adjective scale (e.g., “Complicated” vs. “Simple”), with scores ranging from -3 (very negative) to +3 (very positive).

3.6.2.2. Data Analysis Method

As with performance scores, SUS and UEQ-S results were analyzed using the **Friedman Test** due to:

1. Ordinal nature of the data (Likert scale).
2. Repeated measures from the same participants.
3. Relatively small sample size.

Where significant differences were found, **Wilcoxon Signed-Rank Tests** were conducted to identify which training methods differed in perceived usability or engagement.

3.6.2.3. Purpose and Relevance

This analysis directly addresses **RQ2b**:

How do players experience usability and user engagement when using a Cue-Guided System?

By combining objective statistical outputs with subjective user feedback, the study evaluates how each method supports independent learning from the user's perspective. Insights from this analysis inform design implications for improving angklung learning systems.

3.6.3. RQ2c – Expert Evaluation

To explore professional perspectives on the cue-guided methods—particularly HB and HBP—a series of **semi-structured interviews** were conducted with four experienced angklung instructors. Their evaluations were analyzed using **Framework Analysis (FA)** to identify recurring themes and assess the pedagogical suitability of the digital training methods.

3.6.3.1. Overview of Expert Evaluation

Expert evaluation plays a vital role in determining HB and HBP's feasibility and practical impact in angklung training. The primary objective of this phase is to collect expert opinions regarding the advantages, limitations, and potential improvements of these digital training methods, particularly in comparison to traditional Human Conductor (HC)-led instruction.

In this study, **four angklung experts** participated in structured interviews. These experts were selected based on their extensive experience in angklung education, covering a wide range of instructional approaches, from handsign-based teaching to orchestral angklung training. By involving experts from diverse teaching backgrounds, this study ensures that HB and HBP are evaluated from both traditional and modern pedagogical perspectives.

Framework Analysis (FA) was used to categorize expert responses based on predefined Research Questions (RQ) to ensure a structured and systematic assessment. This method allows for a direct mapping of expert opinions to the key objectives of the study, ensuring that their insights contribute to a deeper understanding of how HB and HBP can be integrated into angklung training. The following sections provide details on the selection criteria for experts, the methodology of the interviews, and key findings from the evaluation.

3.6.3.2. Selection of Experts and Their Backgrounds

Four angklung instructors were selected based on their years of teaching experience and their familiarity with different angklung training methodologies. Each expert brings a unique perspective on angklung education, covering traditional, modern, and hybrid teaching methods. The following table (table 3.2) summarizes their backgrounds:

Table 3.3: Selection of Experts and Their Backgrounds

Expert Name	Affiliation	Experience (years)	Expertise
Muhammad Naufal Hafizah Setiawan	AngklungKita Community	5	Handsign and sheet music methods
Frederik Jonathan A.	ES Maria Bintang Laut	28	Handsign development (created 60 handsign gestures)
Eddy Permadi	STBA Yapari Aba Bandung	54	Orchestral partiture and traditional angklung methods
Mutiara Dwi Salma	Angklung DWP POLBAN	2	Sheet music-based angklung teaching

Each expert was provided with structured interview questions to evaluate the strengths and limitations of HB and HBP as digital training methods, particularly for novice angklung players.

3.6.3.3. Interview Methodology and Research Alignment

Structured **interviews were conducted in person**, allowing for real-time discussions and deeper insights into each expert's perspective. Each interview lasted approximately **45 to 60 minutes**, during which experts provided qualitative feedback based on their personal teaching experiences. To align expert evaluations with the research objectives and Research Questions (RQ), the following structured interview questions were used:

A. Regarding Angklung Teaching and Learning

1. How long have you been teaching angklung? (Provides context on the expert's level of experience.)

2. What are the differences in teaching angklung at novice, intermediate, and advanced levels? (Reveals how HB and HBP can support novice learners.)
3. What are the main challenges in teaching angklung, and how do you overcome them? (Identifies whether HB and HBP address real teaching challenges.)
4. What techniques do you use to keep students engaged and motivated in learning angklung? (Explores engagement strategies that could be enhanced with HB and HBP.)

B. Regarding the Human Conductor (HC)

5. How many people can be effectively managed when playing with an HC? (Provides a benchmark for HB and HBP scalability.)
6. In your opinion, what are the limitations of the HC method? (Identifies gaps in HC that HB and HBP could potentially address.)

C. Regarding the Training Methods (NB, HB, HBP)

7. What are your thoughts about my Training Method (NB, HB, HBP)? (General evaluation of effectiveness and usability.)
8. Do you have any suggestions for each Training Method? (Gathers direct recommendations for improvement.)

3.6.3.4. Framework Analysis (FA) Methodology

Framework Analysis (FA) was used to analyze the expert responses systematically. This method ensures the findings are structured while allowing for an in-depth understanding of expert perspectives. FA is particularly suited for applied research where the goals are clearly defined, and the analysis needs to be systematically organized around predefined themes or research questions [117], [118], [119].

The analysis followed five structured steps:

1. **Familiarization**
   Transcribing interview responses and initial reading to gain an overview of expert perspectives.
2. **Identifying a Thematic Framework**
   Expert insights were categorized into four central themes:
   - *Gesture clarity and accuracy*: How well HB and HBP replicate traditional hand-sign gestures.
   - *Effectiveness for novice training*: How suitable are the methods for novices without human guidance.
   - *Realism and resemblance to a human conductor*: The extent to which HB and HBP mimic natural conductor behavior.
   - *Limitations and areas for future improvement*: Perceived weaknesses and recommendations for enhancement.
3. **Indexing and Coding**

Each statement from the experts was mapped to the thematic framework and coded accordingly.

4. **Charting**
   Responses were organized into a matrix that allowed comparison across themes and participants.
5. **Mapping and Interpretation**
   Emerging patterns were interpreted in relation to **RQ2c**:

What are experts' perspectives on the challenges and advantages of handsign-based approaches as angklung training methods?

3.6.3.5. Relevance and Contribution

The expert evaluation contextualizes the quantitative results with professional judgment. It also contributes to validating HBP and HB as pedagogical tools and identifies specific considerations for future system improvements.

Chapter 4 System Design and Implementation

4.1. Introduction

This chapter presents the technical design and implementation of the angklung training system developed for this study. The system is designed to support **self-guided learning** for novice players using a digital cue-guided framework. It consists of three distinct training methods: **Notebar (NB)**, **Hand-Sign Bot without Preview (HB)**, and **Hand-Sign Bot with Preview (HBP)**, each offering a different approach to guiding timing and note anticipation in angklung performance.

While angklung is traditionally taught in ensemble settings under the direction of a human conductor, this research focuses exclusively on **individual training scenarios**. The goal is to replicate key instructional elements—such as rhythm, cue-following, and gesture recognition—through a screen-based digital environment that enables players to practice independently.

The chapter begins with an overview of the system architecture and continues with a detailed explanation of the proposed **Angklung Training Model**, which outlines three stages of implementation: self-training, group-training, and remote-training. This dissertation focuses solely on the first stage, self-training. Subsequent sections describe the design rationale, user interface components, and functional features of each training method (NB, HB, HBP). The chapter concludes with a summary of the technical implementation process, including software and hardware considerations used to build and deploy the training system.

4.2. Angklung Training Model

To provide a structured framework for supporting novice angklung players, this study proposes a **three-stage Angklung Training Model** (see Figure 4.1), consisting of:

1. **Self-Training**
2. **Group-Training**
3. **Remote-Training**

Figure 4.1: Angklung Training Model

This model reflects a progressive learning path—starting from individual mastery of timing and cue-following, then advancing to ensemble coordination, and eventually to technology-supported remote collaboration. The focus of this dissertation is **exclusively on the first stage, Self-Training**, as outlined below.

4.2.1. Self-Training

This stage represents the first phase of the angklung training model, focusing on individual practice without the presence of a human conductor or ensemble. The system delivers structured cues through three methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—to guide players in learning when to shake their instrument.

In this context, each player holds only one note and follows screen-based instructions to develop three core skills: **cue-following, rhythmic timing, and note anticipation**. These ensemble-relevant skills are critical for angklung performance, where precise coordination depends on reacting to the conductor's cues. Self-training allows novice players to build these competencies independently in a simplified, distraction-free environment, laying the groundwork for future ensemble readiness.

4.2.2. Group-Training (Future Work)

In the second stage, multiple players train together in the same physical space using the same cueing systems (NB, HB, HBP). Unlike self-training, group-training requires synchronization across players and may involve additional tools such as cameras or microphones to assess ensemble coordination. This stage represents a bridge from individual practice to ensemble rehearsal and is proposed as a future extension of the current system.

4.2.3. Remote-Training (Future Work)

The third stage aims to simulate group practice over distance. In this mode, players from different locations can perform together using synchronized playback and digital cues. An additional feature, **PlayerBot**, is introduced as a virtual angklung player that can simulate human responses based on recorded data. This stage supports both individual and ensemble interaction in distributed learning environments and is intended for future development.

For the purposes of this study, all experimental tasks, usability evaluations, and expert assessments are confined to the **Self-Training** phase. Group and remote modes are only discussed as **future directions** and are not included in the evaluation process.

4.3. System Overview

The cue-guided angklung training system is designed to simulate the instructional role of a human conductor through two digital cueing approaches: a **visual-cue method** (Notebar) and a **handsign-cue method** (Hand-Sign Bot and Hand-Sign Bot with Preview). Both approaches aim to guide novice players in practicing independently while still developing essential timing, anticipation, and cue-following skills relevant to angklung performance.

The system operates through a modular process, as illustrated in **Figure 4.2**, which shows the overall system architecture. The process begins with a digital music file, such as a MIDI format, which is converted into a structured text format using a **Music Converter** module. This text file contains time-aligned note data that serves as the input for all cue-generation modules.

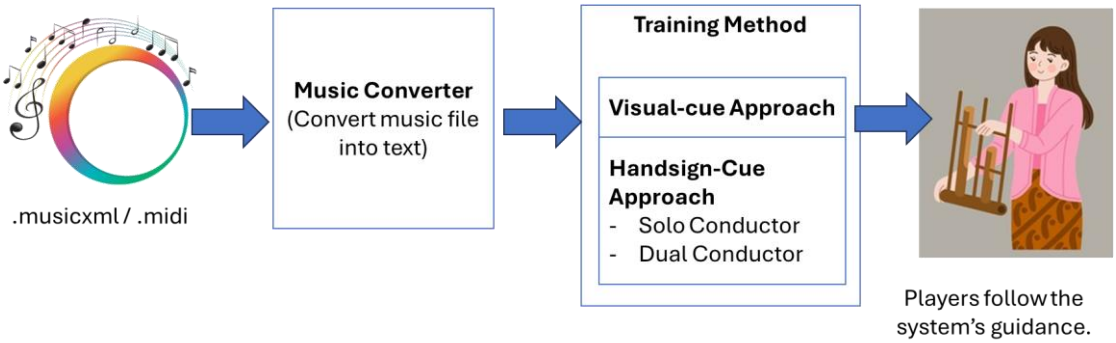


Figure 4.2: Cue-Guided System Overview

The converted text is then processed by one of two **cue-guided training** approaches:

1. **Visual-Cue Approach (Notebar)**: This method displays upcoming notes as color-coded bars moving along a linear timeline. It emphasizes note anticipation

and timing alignment using simplified visual representation, without incorporating conductor gestures.

2. **Handsign-Cue Approach (HB and HBP)**: This method animates a conductor avatar that uses predefined hand-sign gestures to indicate when to play each note. Two variations are implemented:
    - **Solo Conductor (HB)**: A single digital conductor provides real-time gestures.
    - **Dual Conductor (HBP)**: An additional anticipatory conductor is introduced to display upcoming gestures one second in advance, helping players prepare for the next note.

Both approaches ultimately aim to support **self-training** in a culturally grounded yet accessible way. Players interact with the system via screen-based interfaces, holding a single angklung tube and following the visual or gestural cues to perform melodies independently. This modular and scalable architecture ensures that musical content can be dynamically converted and visualized, making the system adaptable to different compositions and training levels without requiring human instruction or group participation.

4.4. Music Converter Architecture for Angklung Training System

The Music Converter serves as a crucial component of the Angklung Training System, supporting three primary training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). These methods rely on the text-based output generated by the Music Converter to guide players through note progressions, timing, and conductor gestures. Without this system, none of the training methods would function effectively [120].

The Music Converter transforms musical notation from MusicXML or MIDI files into a structured, text-based format that the system can process. This conversion ensures that the training methods can generate accurate visual guides, conductor cues, and anticipatory gestures. The architecture of the Music Converter follows a structured pipeline, as depicted in Figure 4.3.

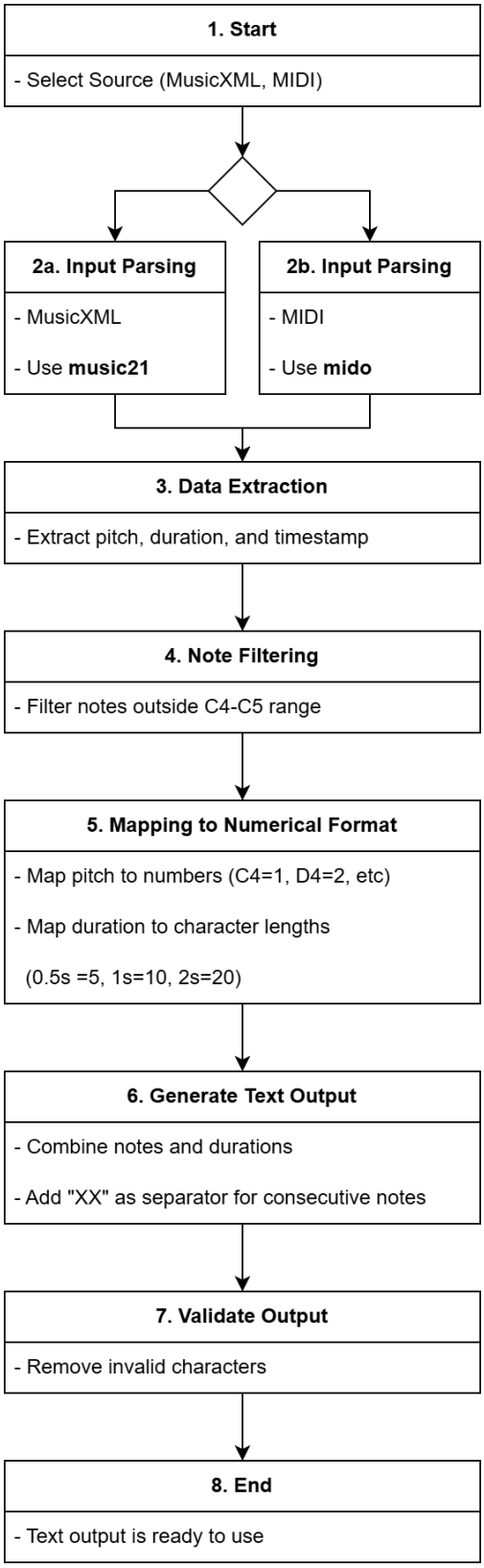


Figure 4.3: Music Converter Architecture

The Music Converter architecture consists of the following key components and processes:

1. Input Parsing

The system processes input files in MusicXML or MIDI format, using specific libraries for extraction:

a. MusicXML Files: The music21 library is utilized to parse structured XML data [121].
b. MIDI Files: The mido library is used to extract note and timing information from MIDI messages [122].

If the input is MusicXML, it follows path 2a, and if it is MIDI, it follows path 2b before merging into a unified extraction process.

2. Data Extraction

Once the file is parsed, the system extracts essential musical attributes, including:

a. Pitch: The musical note (e.g., C4, D4).
b. Duration: The length of each note (e.g., 0.5 seconds, 1 second).
c. Timestamp: The exact timing of the note within the composition.

This step ensures that only the necessary musical data is retained for further processing.

3. Note Filtering

The system filters out any notes outside the C4 to C5 range to maintain relevance to Angklung training [120]. This restriction aligns with the standard octave range used in novice-level Angklung practice, ensuring that players only focus on applicable notes.

4. Mapping to Numerical Format

To simplify processing, each musical note is mapped to a numerical representation:

$$C4 = 1, D4 = 2, E4 = 3, F4 = 4, G4 = 5, A4 = 6, B4 = 7, C5 = 8$$

Similarly, note durations are converted into character lengths for consistency:

$$0.5\ seconds = 5\ characters$$
$$1\ second = 10\ characters$$
$$2\ seconds = 20\ characters$$

This step ensures uniformity and enables easy text-based manipulation for training.

5. Generate Text Output

The system compiles the numerical values and formatted durations into a structured text string, making it easier for the training modules to process. Notes are separated using the delimiter "XX" to indicate transitions between them.

Example Output:

$$555XX333XX888$$

This structure enables smooth integration with Notebar, Hand-Sign Bot, and Hand-Sign Bot with Preview training methods.

6. Validate Output

Before finalizing the output, the system performs a validation process:

a. Invalid characters (e.g., spaces, tabs) are removed.
b. Only valid elements (0-8 and "X") are retained.

7. End of Process

Once validated, the final text-based music representation is ready for use in the Angklung Training System. This structured format ensures smooth functionality in visual-cue and handsign-cue training method.

Integration with Training Methods

The text-based output generated by the Music Converter is the foundation for all training methods:

1. Notebar (NB): Uses the text output to render note progressions and timing guides.
2. Hand-Sign Bot without Preview (HB): Relies on the text output to generate conductor gestures and cues.
3. Hand-Sign Bot with Preview (HBP): Utilizes the text output to generate handsign conductor and anticipatory gestures.

Without the Music Converter, the system would lack the structured data required to drive these training methods, rendering them non-functional. Thus, the Music Converter is a critical component that bridges the gap between musical notation and interactive training.

Future Extensibility

Although the current Music Converter focuses solely on pitch, timing, and duration for novice-level angklung training, the architecture is designed to support future extensions. For example, expressive parameters such as dynamic intensity or articulation could be encoded through additional metadata or symbolic tags in the input file. In Notebar, this might be visualized using thicker bars, waveform overlays, or motion-based effects to represent shaking strength. In HB and HBP, gesture expressiveness could be reflected through avatar motion intensity, hand size, or labeled cues. These enhancements would allow the system to gradually incorporate expressive control for intermediate learners, while still maintaining the cue-guided design structure.

4.5. Implementation of Training Methods

The angklung training system incorporates three primary training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—to simulate cue-guided learning and improve timing accuracy, coordination, and real-time response among novice players. Each method provides a structured, progressive learning

approach, allowing players to transition from visual guidance to real conductor cues gradually.

Implementing these training methods ensures that novice players can develop fundamental skills before transitioning to live conductor-led performances. Each training method is optimized to support different aspects of the learning process, ensuring that users receive real-time visual cues, structured hand-sign guidance, and anticipatory gestures for predictive training. The training system's execution is structured around three progressive training approaches as illustrated in Figure 4.4.

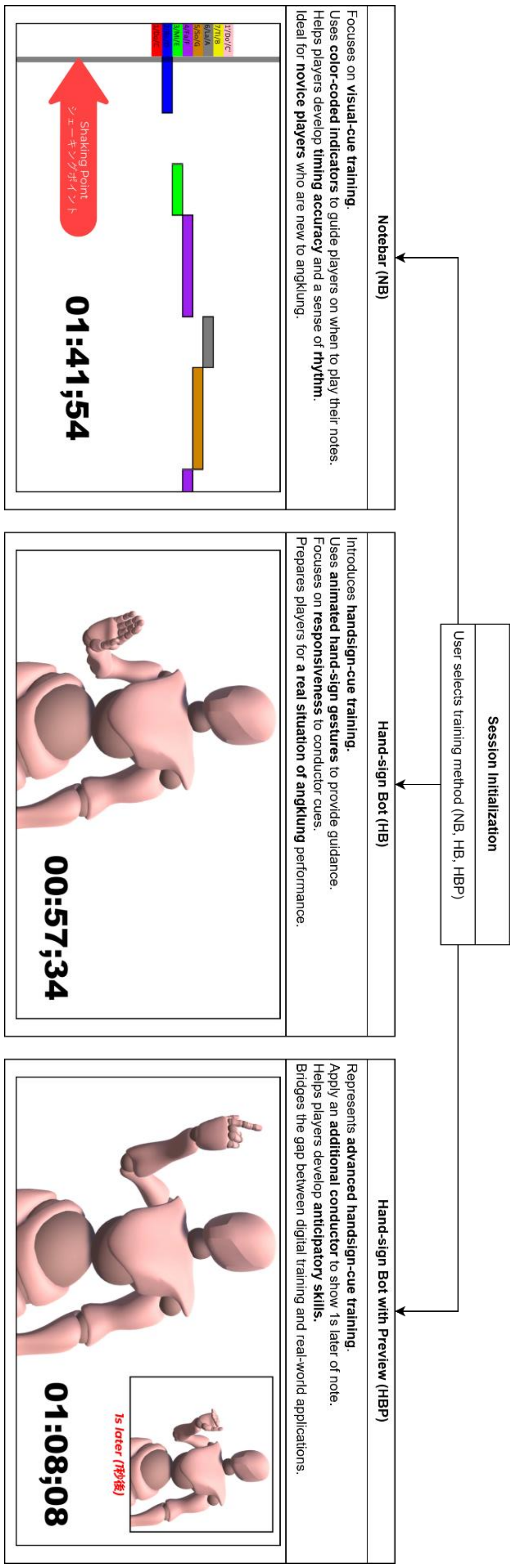


Figure 4.4: Training Method Implementation Flow

4.5.1. Notebar (NB) – Baseline Visual-Cue System

The Notebar (NB) method serves as the baseline visual training guide, allowing novice players to follow color-coded indicators to anticipate note timing and duration. This method is particularly effective for novices who have no prior experience with angklung playing, as it provides a structured visual representation of the melody.

Unlike HB and HBP, which rely on conductor gestures, NB is entirely based on color-coded cues, helping players identify when to play their assigned notes without requiring extensive **cue-guided training**. The technical implementation of NB ensures that the visual cues are synchronized with the song's tempo, providing a clear and structured training experience.

Figure 4.5 illustrates the Notebar architecture. It represents how music notation is converted into a structured format that the training system can visually process.

4.5.1.1. NB - Technical Implementation

1. Music Converter Module: Converts traditional music notation (MusicXML or MIDI) into a text-based format that aligns with the Notebar system. Extracts note pitch, duration, and timing to ensure accurate training.

2. Notebar Color Rule Mapping: Each musical note is mapped to a specific color, following a predefined system:

C (Do) = Red; C' (Do') = Light Red (Pink)
D (Re) = Blue
E (Mi) = Green
F (Fa) = Purple
G (Sol) = Orange
A (La) = Yellow
B (Ti) = Grey

This visual representation ensures that players can easily distinguish between different notes.

3. Training Interface and Interaction: The Note Spawner generates visual note bars based on the timing and pitch of the converted music. Players follow the moving color bars and shake their angklung at the Shaking Point, ensuring that they play at the right time. A timer is displayed to provide a sense of rhythm and coordination.

This method's execution and timing structure are illustrated in Figure 4.5.

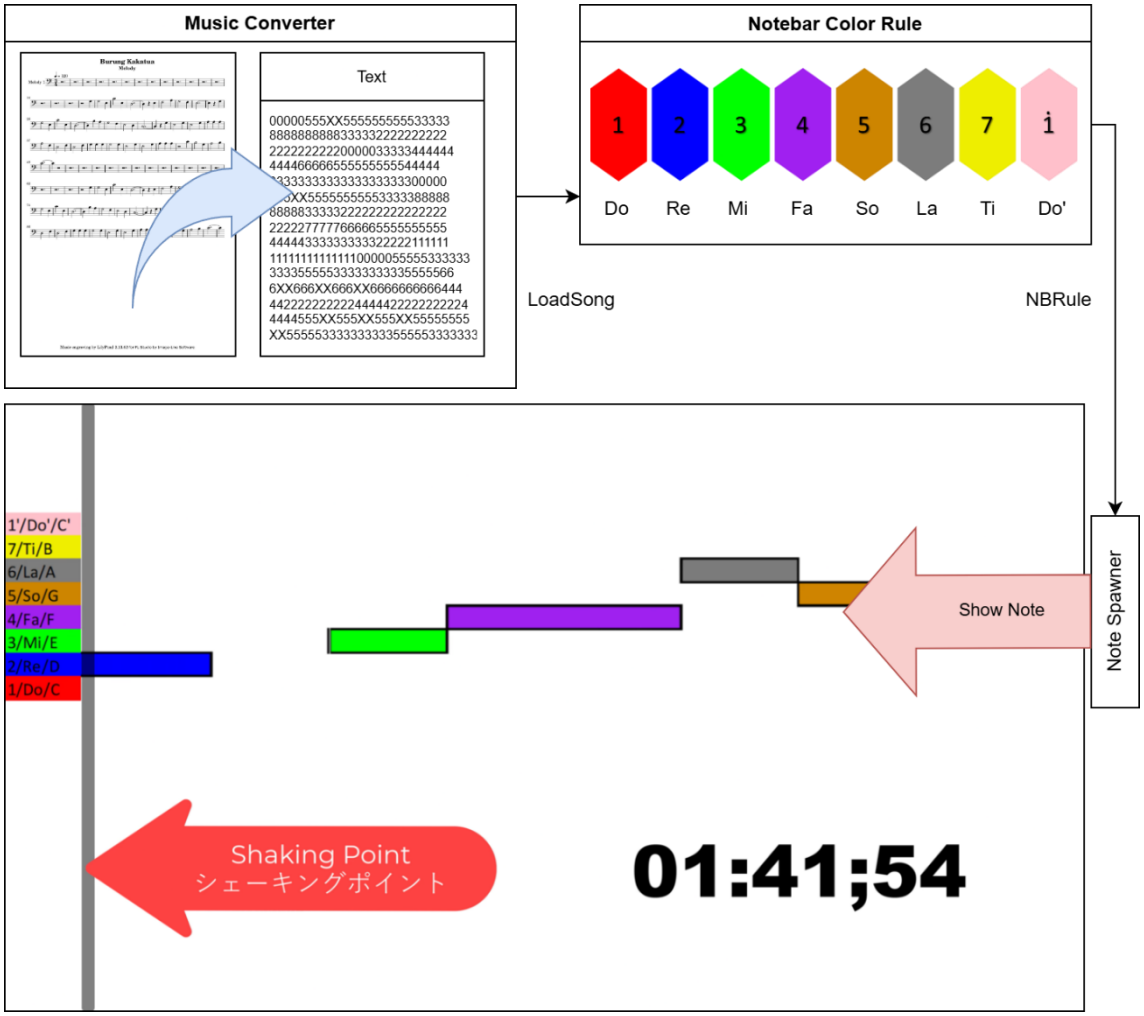


Figure 4.5: Notebar (NB) Training System Flow

The Notebar (NB) training method is a visual cue-based approach that helps novice angklung players improve their timing and note recognition. Each musical note is represented in this method by a unique color displayed on a horizontal bar. As the bar progresses, the player must observe when the colored segment reaches a designated area on the screen called the "shaking point." This visual indicator cues the player to shake their angklung instrument at the correct time. The combination of color differentiation and visual rhythm guidance allows learners to easily identify notes and practice individually without needing a full ensemble or human conductor. This method was designed to support intuitive learning, especially for novices unfamiliar with music notation, and to provide a more accessible training experience.

4.5.1.2. NB - Design Concept

Notebar draws inspiration from popular rhythm-based learning tools such as *Piano Tiles* and *Taiko no Tatsujin*, which rely on scrolling or falling visual indicators to signal timing. This system represents notes as **color-coded vertical bars** that move across the

screen. When the bar reaches a designated activation line, the player is expected to shake the angklung.

Each bar is assigned a unique color corresponding to a specific note. The movement of the bar provides **predictive timing**, allowing players to prepare their actions in advance. The system is designed to maintain a fixed tempo and interval spacing, ensuring clarity and reducing cognitive load.

Beyond its technical structure, Notebar plays an important pedagogical role. It supports novice players in developing internal rhythmic timing and note anticipation by providing a clear and predictable visual environment. Rather than merely teaching cue-following, NB prepares learners to internalize timing and coordinate actions in ensemble-like contexts. Its simplicity and low cognitive demand make it an effective entry point for those with no musical background, serving as a scaffold for more complex cue-guided systems like HB and HBP.

4.5.1.3. NB - Functional Role

NB is an **entry-level training tool**, especially suitable for players unfamiliar with conductor gestures. NB does not simulate the presence of a conductor; instead, it emphasizes consistency and simplicity. The static, repetitive nature of its visual cues helps players internalize rhythmic sequences through visual pattern recognition.

4.5.1.4. NB - Limitations

While Notebar supports independent training, it has several limitations when compared to cue-guided methods:

- It lacks **expressive or instructional gesturing**, making it unsuitable for developing conductor-following skills.
- It does not reflect tempo flexibility or dynamics commonly used in live performances.
- Long-term reliance on NB may reduce adaptability in real ensemble settings, where visual predictability is often absent.

Due to these limitations, NB is used in this study primarily as a **control condition** to measure the relative effectiveness of the cue-guided methods (HB and HBP). All performance comparisons are anchored to NB as the baseline visual-cue method.

4.5.2. Hand-Sign Bot without Preview (HB) – Handsign Digital Conducting System

The Hand-Sign Bot without Preview (HB) method is a digital replication of a human conductor, following the Saung Udjo hand-sign language. It enables players to train with structured conductor-led guidance, allowing them to develop timing accuracy and synchronization skills while following digital hand-sign cues. This method bridges the gap between visual note-based training (Notebar - NB) and real-world ensemble performances, ensuring players can transition smoothly from digital training to traditional angklung performance settings.

4.5.2.1. HB - Technical Implementation

The Hand-Sign Bot system operates **based on the Saung Udjo hand-sign language**, essential in angklung training. The architecture of the HB system, as illustrated in Figure 4.6, consists of the following components:

1. Music Converter Module: This module converts MusicXML or MIDI files into a structured text format for further processing. It extracts tempo, pitch, and timing to ensure correct synchronization with Hand-Sign Bot movements.
2. Hand-Sign Bot Rule Processing (HBRule): This function maps extracted musical data to the predefined Saung Udjo hand-sign rules. It uses pre-recorded human conductor hand gestures as a reference for generating digital animations.
3. Frame-by-Frame Hand-Sign Animation Generation: This function generates sequential animations of hand movements to provide clear conducting cues. Each hand gesture synchronizes with the musical tempo, ensuring accurate execution.
4. Player Interaction with Hand-Sign Bot: Players follow animated hand signs displayed by Hand-Sign Bot. A countdown timer is shown to help players anticipate the next cue. Movements mimicking the precision of a human conductor.
Figure 4.6 illustrates the HB execution process, including the frame-by-frame generation of animated hand-sign cues.

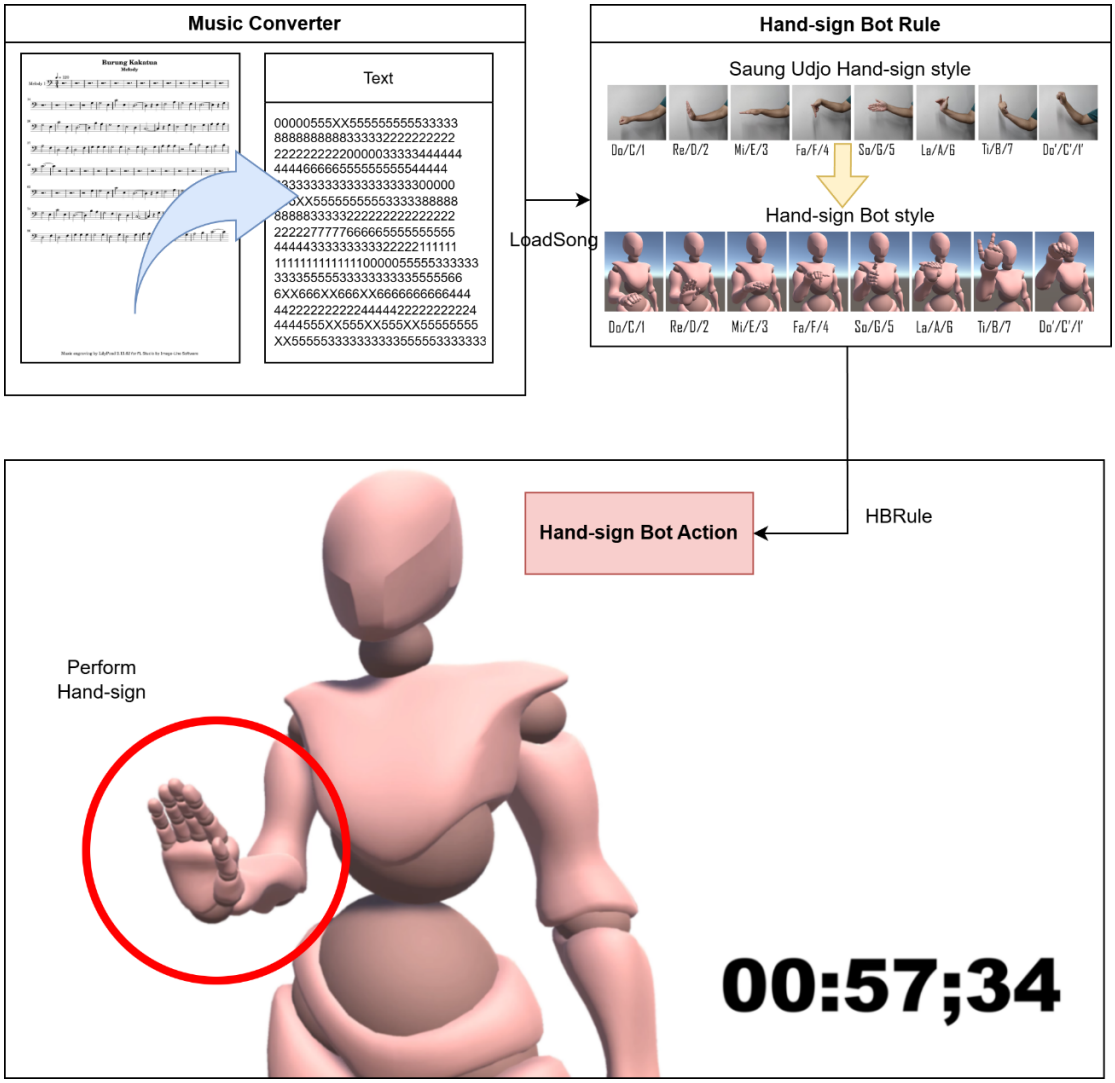


Figure 4.6: Hand-Sign Bot without Preview (HB) Hand-Sign Animation Process

The Hand-Sign Bot without Sub-Hand-Sign Bot without Preview (HB) training method is a cue-guided approach that utilizes Saung Udjo hand-sign language to guide novice angklung players. Each musical note is represented by a distinct hand gesture, mirroring real-world angklung performances led by a human conductor. During practice, players are instructed to shake their angklung instruments only when the hand-sign gesture corresponding to their assigned note is performed. This method replicates the natural pacing and timing challenges found in live ensemble settings, as players are not given advance notice of upcoming notes. As a result, the HB method trains learners to focus on the present cue, reinforcing attentiveness and improving synchronization skills in a realistic, performance-like environment.

4.5.2.2. HB - Concept and Pedagogical Basis

HB is inspired by the hand-sign system used in **Saung Angklung Udjo**, where a human conductor visually guides angklung players through gestures that represent individual notes. Hand-Sign Bot digitizes these hand gestures using an animated avatar rendered on screen. The avatar performs **note-specific cues** in real-time, synchronized with the underlying musical score. Each gesture is displayed just before the expected note onset, requiring the player to **react in time** with the virtual conductor's motion.

To improve gesture clarity and cultural authenticity, the conductor is visualized as a **full-body avatar** rather than disembodied hands. This approach reflects real-world angklung instruction, where players follow the conductor's gestures in relation to the body posture and orientation. **A full-body representation also helps novice players interpret directional hand movements more intuitively, reducing ambiguity in gesture recognition.** This approach aligns with the principle of **visual-motor synchronization**, where learners follow gestural cues to enhance timing and coordination—essential skills in ensemble settings.

As shown in Figure 1.2, each musical note is represented by a distinct hand-sign gesture. For example, the note "Do" and the higher octave "Do'" are demonstrated with different hand positions, where "Do'" is performed with a higher arm angle compared to "Do." It is important to note that in angklung performance, **conductors are allowed to interpret and perform hand signs freely**. This means that each conductor may develop a personal style in presenting the gestures.

In Figure 4.7, we can observe this variation: (A) Mr. Frederik demonstrates the "Do" note at chest level, while (B) he performs the "Do'" (high Do) note with his hands positioned above his head. In contrast, (C) Mr. Udjo Junior performs the "Do" note with a hand position below the waist.

(A) - Do (B) – Do' (High Do) (C) – Do

Figure 4.7: Example of demonstrating handsign

All figures referenced are part of the author's personal documentation and have been published with the individuals' permission for research purpose.

Based on this observation, we conducted expert interviews to gather further insights. As a result, we decided to display **a full-body conductor view**, showing the body from head to below above the knees (**approximately two-third of the body**). This design choice is consistently applied across the Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP) training methods to enhance gesture clarity and player understanding.

4.5.2.3. HB - Implementation and Functionality

HB was implemented using a set of pre-recorded hand-sign animations for each angklung note. During playback, the system selects and displays the appropriate gesture based on the parsed note sequence generated by the music converter. The output is rendered on-screen using a full-body avatar to ensure clarity in vertical hand positioning, which is essential for distinguishing similar hand-signs (e.g., low *Do* vs. high *Do'*).
Key features of HB include:

- **Note-Specific Gestures**: Each angklung note is linked to a culturally standardized hand-sign adapted from the Saung Udjo conducting method.
- **Consistent Tempo**: All motions are synchronized with a predefined beat grid, ensuring precise timing and repeatable training conditions.
- **Gesture-Based Instruction**: Instead of abstract notation, players follow structured motion cues to learn when to execute a note.

The player is expected to observe the avatar's cue and respond by shaking the angklung at the appropriate moment. This simulates the visual-following behavior found in traditional angklung training, adapted here for an individual digital learning environment.

4.5.2.4. HB - Limitations

Despite its instructional value, HB has several limitations from both a usability and design perspective:

- **Split Attention Requirement**: Players must divide their attention between observing gestures and timing their responses, which may be challenging for novices with lower visual-motor coordination.
- **Interpretation Difficulty**: Without verbal explanation or prior exposure, some players may find it difficult to understand the intended meaning of each gesture.
- **Lack of Anticipation**: HB displays only the current cue in real-time. For learners who require extra preparation time, the absence of anticipatory information may hinder response accuracy.

These limitations position HB as a more advanced option than NB but less supportive than HBP for users who benefit from predictive visual scaffolding.

4.5.2.5. HB - Role in This Study

HB serves as a foundational cue-guided training method and plays a central role in evaluating the effect of gesture-based learning on novice angklung players. Specifically, it contributes to:

- **Isolating Real-Time Gesture Effects**: By excluding anticipatory cues, HB allows researchers to examine how learners respond to moment-by-moment gestural instruction.
- **Benchmarking Against Visual-Cue and Predictive Models**: HB serves as the mid-point between NB (visual cue without gesture) and HBP (gesture with anticipation), enabling comparative analysis across three distinct cue strategies.
- **Testing the Viability of Digital Handsign Instruction**: HB provides a controlled model of hand-sign delivery, allowing the study to assess how digital gestures can replicate traditional instructional roles in a solo training context.

This role aligns directly with RQ1 and RQ2a/RQ2b by examining how structured hand-sign cues influence learning effectiveness, usability, and user engagement.

4.5.3. Hand-Sign Bot with Preview (HBP) – Anticipatory Conducting System

Hand-Sign Bot with Preview (HBP) builds upon Hand-Sign Bot without Preview (HB) by adding a second visual layer—an anticipatory cue system that displays **upcoming hand-sign gestures** one second before execution. This dual-conductor approach is designed to help novice players prepare for transitions by bridging the gap between static visual cues (as in Notebar) and real-time gestures (as in HB). Similar to HB, HBP uses a full-body conductor avatar for both the main and sub-conductors. This design preserves cultural fidelity and supports better visual anchoring for players. Full-body gestures provide a clearer reference for interpreting movement direction, timing, and continuity—especially when two conductors are displayed simultaneously. This visual consistency helps minimize confusion and reinforces the player's familiarity with traditional conducting forms.

4.5.3.1. HBP - Technical Implementation

The architecture of Hand-Sign Bot with Preview (HBP), as illustrated in Figure 4.8, consists of the following components:

1. Music Converter Module: This module converts MusicXML or MIDI files into a structured format that aligns with Hand-Sign Bot training rules. It also extracts timing and pitch information to ensure proper gesture mapping.

2. Hand-Sign Bot Rule Processing (HBRule): This function maps extracted musical data to the Saung Udjo hand-sign rules and generates conducting gestures in synchronized animation frames.

3. Dual Hand-Sign Animation System:

a. Main Hand-sign Bot Action: Displays the conducting gesture for the current note.

b. Sub Hand-sign Bot Action: Displays the conducting gesture for the next note, 1 second earlier.

This anticipatory visualization helps players adjust their movements more smoothly.

4. Player Interaction with HBP System: Players follow the primary Hand-Sign Bot gesture while simultaneously observing the anticipatory cue from Hand-Sign Bot with Preview.

The system ensures that both gestures are synchronized to maintain rhythmic accuracy. The predictive visualization mechanism used by HBP is illustrated in Figure 4.8.

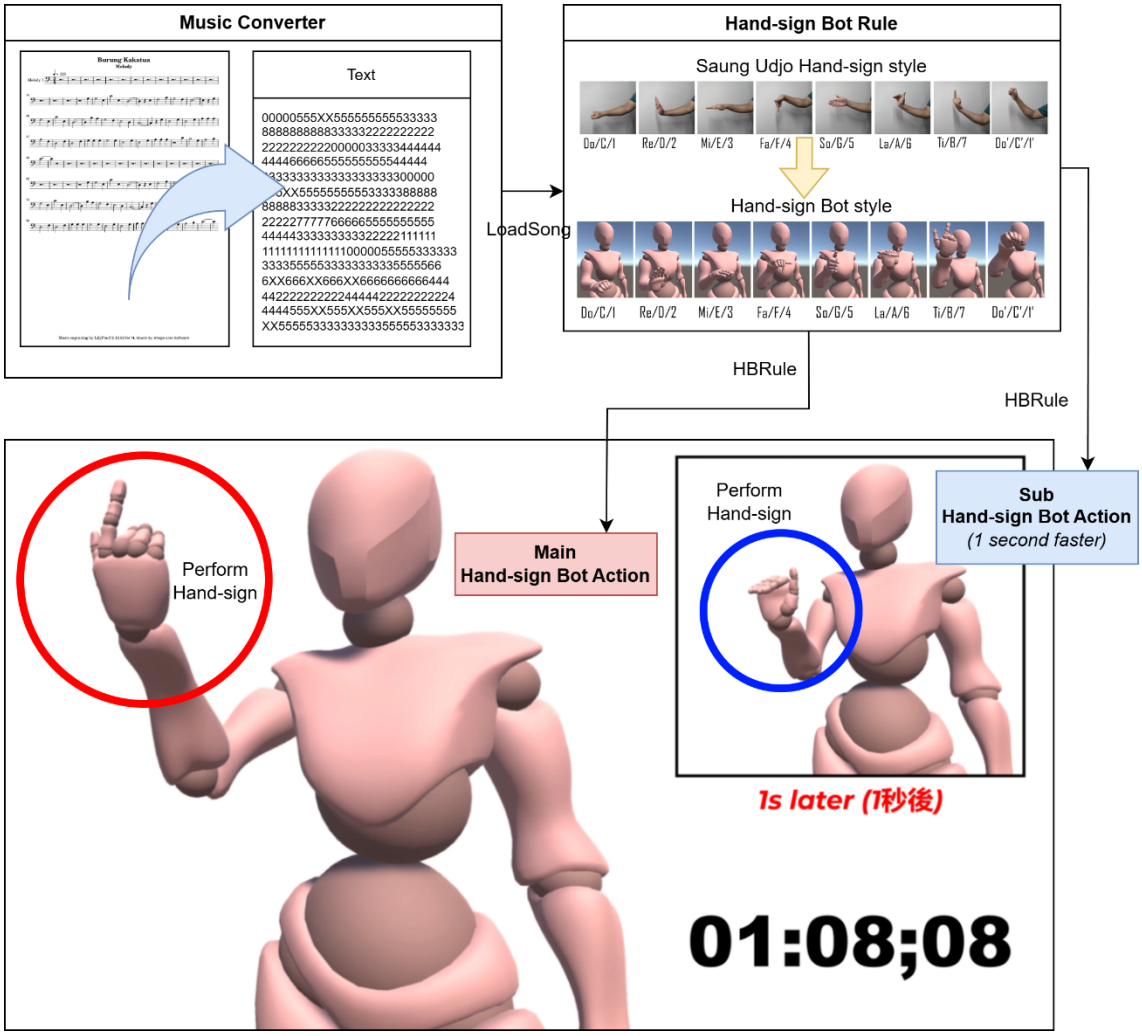


Figure 4.8: Hand-Sign Bot with Preview (HBP) Anticipatory Cue System

The Hand-Sign Bot with Hand-Sign Bot with Preview (HBP) training method extends the Hand-Sign Bot without Preview (HB) approach by introducing an additional conductor element designed to support note anticipation. Similar to the HB method, players shake their angklung when they observe the hand-sign gesture that corresponds to their assigned note. However, the HBP method provides an anticipatory visual cue through a Hand-Sign Bot with Preview that displays the upcoming note shortly before the main hand-sign gesture appears. This anticipatory feature is intended to assist novice players in preparing for their part in advance, thus reducing hesitation and promoting smoother transitions during practice. By combining real-time gesture recognition with a preview mechanism, the HBP method offers a more guided experience while preserving the core elements of human-conductor interaction.

4.5.3.2. HBP - Rationale and Pedagogical Basis

While HB provides real-time hand-sign cues, novice players often experience delayed responses due to unfamiliarity with the gestures and limited reaction time. In contrast, Notebar (NB) supports visual anticipation but lacks the cultural and instructional depth of traditional hand-signs. The Hand-Sign Bot with Preview (HBP) addresses both of these limitations by integrating:

- A **main conductor avatar** that displays the current hand-sign cue (same as in HB).
- A **sub-conductor avatar** that displays the next gesture one second in advance.

This design draws upon principles from predictive timing and cognitive load theory, which suggest that early visual exposure to upcoming cues can support more effective motor planning in learning contexts.

4.5.3.3. HBP - System Behavior

HBP was developed by modifying the HB framework to include an anticipatory cue stream, using the same parsed note sequence but with a one-second offset for the sub-conductor.

During training:

- The player sees two avatars: the **main conductor** in the foreground and a **smaller, sub-conductor** in the background.
- The **sub-conductor** previews the next hand-sign cue, while the **main conductor** executes the current gesture in synchrony with the beat.

This configuration creates a dual-layered guidance system that enhances both anticipation and execution, supporting smoother transitions across note changes.

4.5.3.4. HBP - Advantages of HBP

HBP offers several instructional advantages, especially for players who require additional preparation time:

- **Improved Reaction Time**: By previewing the next cue, players can initiate motor planning earlier, reducing delays in note execution.
- **Enhanced Transition Fluidity**: The visual overlap between current and upcoming gestures supports more coordinated timing without overwhelming the player.
- **Support for Progressive Learning**: HBP functions as a transitional model for users moving from static visual cues (NB) to real-time hand-sign cues (HB), making it particularly useful in stepwise skill development.

4.5.3.5. HBP - Limitations

Despite its benefits, HBP presents certain constraints:

- **Increased Visual Complexity**: The simultaneous display of two gesture sources may lead to cognitive overload for players who are not yet familiar with the system.
- **Higher Learning Curve**: Players must learn to manage attention across layered cue streams, which may require additional practice compared to NB or HB.
- **Not Universally Preferred**: Due to individual learning styles, some participants may find HBP beneficial, while others may perform better with simpler cue models.

These limitations reflect the importance of tailoring cue-guided strategies to individual needs, which is further examined through user and expert evaluations in this study.

4.5.3.6. HBP - Role in This Study

HBP represents the most complex and feature-rich cue-guided method evaluated in this research. It serves several important roles:

- **Measuring the Effectiveness of Predictive Cues**: The study investigates whether anticipatory hand-signs significantly enhance timing accuracy compared to NB and HB.
- **Identifying Suitable Learner Profiles**: HBP allows exploration into which types of users—such as those with musical backgrounds or stronger visual-spatial skills—benefit most from predictive guidance.
- **Exploring Pedagogical Potential**: Expert interviews assess whether HBP represents a viable digital model for traditional conductor-led instruction in angklung training.

The findings drawn from HBP help clarify whether predictive cue delivery can improve self-training outcomes and whether it can function as a culturally respectful, pedagogically sound alternative to human conductor interaction.

4.5.4. How Training Methods Address Novice Challenges

To better understand how each training method addresses the specific challenges faced by novice angklung players, Table 4.1 provides a summary mapping between the six core challenges (CN1–CN6) and the training methods (NB, HB, HBP). The table illustrates which methods provide effective solutions ("+") and which do not directly address the corresponding issue ("–"). This mapping is based on the conceptual design and pedagogical functions of each method.

Table 4.1: Summary of How Training Methods Address Novice Challenges

Challenge Code	Challenge Description	NB	HB	HBP
CN1	Difficulty understanding hand-sign conductors	-	+	+
CN2	Struggle to anticipate the next note	+	-	+
CN3	Lack of synchronization in group play	-	+	+
CN4	Low confidence in playing	+	-	-
CN5	Difficulty adapting to tempo changes and dynamics	-	-	+
CN6	Limited access to human conductors	-	+	+

As shown above, each method offers strengths in different areas, reinforcing the idea that no single method is universally superior, but rather serves a specific instructional role.

4.5.5. Training Usage for Novice vs. Advanced Players

While the system is primarily designed for novice angklung players, its usability and learning mechanisms are also relevant for more experienced individuals. In actual practice, novice and advanced players engage with angklung training and performance differently. Understanding these differences is crucial to understanding how each training method—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—can be effectively adopted across varying skill levels.

Training Characteristics of Novice Players

Novice players typically enter angklung practice without experience interpreting hand-signs or reading musical notation. Because angklung is played as a one-note instrument, novice participants can immediately contribute to a performance by simply shaking the instrument at the correct cue. In many public and cultural performances—especially in ensemble settings involving novices—it is common for multiple novice players to share responsibility for the same note, ensuring tonal strength and reducing individual pressure.

The system provides structured self-training tools to support gradual skill development. NB offers a color-coded timeline that enables players to anticipate timing and melodic transitions visually. This clear and repetitive structure builds familiarity with rhythm and melody. HB and HBP further facilitate novice learning by simulating the traditional hand-

sign system used in Saung Angklung Udjo. These methods help players transition from following visual symbols to interpreting hand gestures, bridging the gap toward real ensemble readiness.

Training Characteristics of Advanced Players

Advanced players typically undergo formal training using musical notation (partitur) rather than hand-sign cues. In Indonesia, particularly in West Java, this level of training is more readily available. However, most angklung training is designed for novices outside Indonesia, and partitur-based instruction is rare. Despite this, advanced players often participate in spontaneous and unrehearsed performances, such as official events or cultural exhibitions. In such scenarios, experienced players often take on leadership roles—guiding novice players and ensuring synchronized execution using hand signs or visual cues.

How the System Supports Advanced Players

Although HB and HBP are primarily designed to train novices in following hand signs, they also offer benefits for advanced players. By using HB or HBP, experienced players can familiarize themselves with the gestures commonly used in novice-oriented training, which is useful when they are required to lead spontaneous group performances involving novices. Additionally, understanding how the system guides novice behavior enables advanced users to better anticipate and coordinate ensemble interactions.

Thus, the training system facilitates individual learning among novices and enhances cross-skill-level collaboration, especially in contexts where advanced players must adapt to lead or integrate with less experienced performers. This dual-purpose utility broadens the pedagogical reach of the Cue-Guided System, reinforcing its applicability beyond introductory angklung education.

4.6. System Usability and Interface Design

The angklung training system's user interface (UI) is designed to provide an intuitive and effective learning experience for novice players. Each UI element is developed to align with pedagogical principles, ensuring that users can easily follow visual instructions and enhance their angklung playing skills.

This system features three main training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—each with a dedicated UI designed to facilitate structured training. Additionally, a "How to Play" section is provided to guide users through the training process before they begin.

4.6.1. UI Overview and Navigation

The system's main menu serves as the central navigation point, allowing users to select their preferred training method. As shown in Figure 4.9, the main menu consists of four primary options:

1. Notebar (NB)
2. Hand-Sign Bot (HB)
3. Hand-Sign Bot with Preview (HBP)
4. How to Play

This interface is designed for ease of use, ensuring that users can quickly navigate and select their desired training method without confusion.

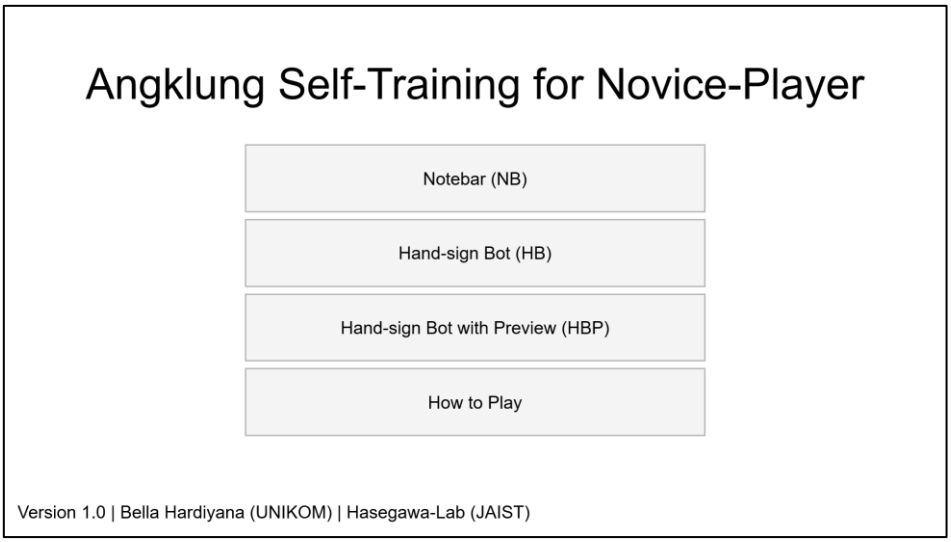


Figure 4.9: Main Menu Interface

The minimalist design and clear layout ensure an accessible and user-friendly experience, reducing cognitive load for novice users.

4.6.2. Notebar (NB) Interface

The Notebar (NB) method employs a scrolling note system to visually guide players in timing their angklung shakes. As illustrated in Figure 4.10, the interface presents a color-coded notation system where notes descend towards a designated Shaking Point. Players must shake their angklung precisely when the note reaches this point.

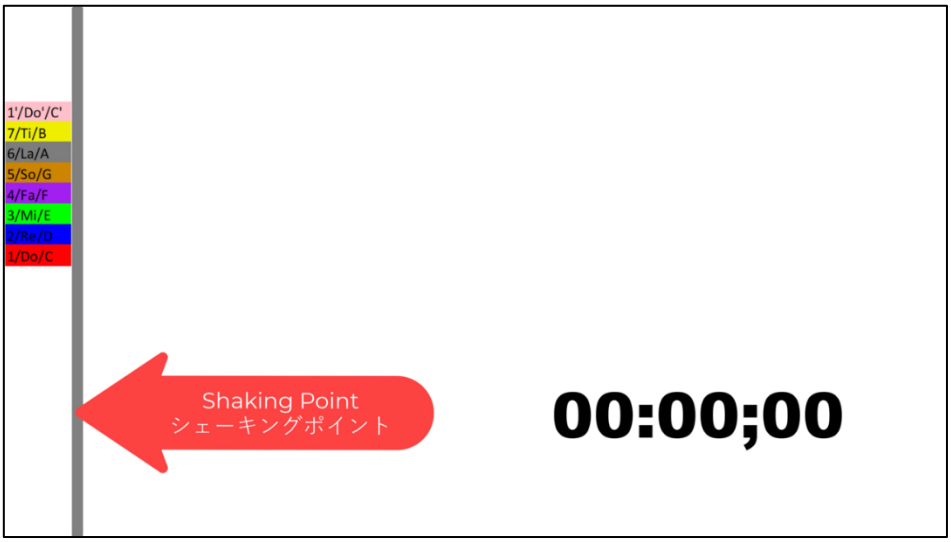


Figure 4.10: Notebar Interface

This method is designed to simplify rhythm recognition for novice players. The use of color-based note identification is inspired by rhythm-based digital learning methods, ensuring an intuitive approach for users unfamiliar with musical notation.

4.6.3. Hand-Sign Bot without Preview (HB) Interface

The Hand-Sign Bot without Preview (HB) method replaces a human conductor by utilizing a 3D animated avatar to demonstrate the correct hand movements for each note. As shown in Figure 4.11, the avatar visually represents the standard angklung conducting gestures, guiding players in timing and coordination.

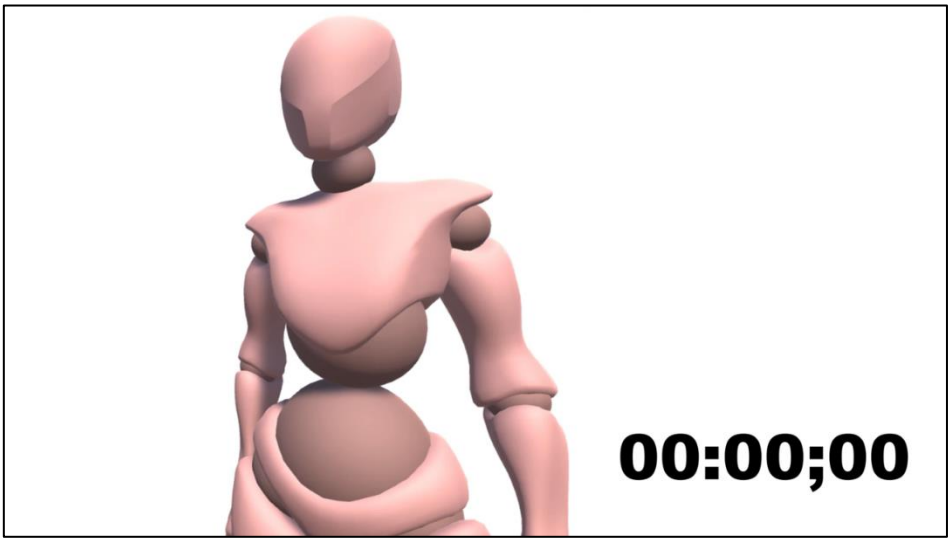


Figure 4.11: Hand-Sign Bot Interface

This approach ensures that players receive consistent and accurate visual cues, reinforcing traditional conducting methods while providing a structured learning experience.

4.6.4. Hand-Sign Bot with Preview (HBP) Interface

The Hand-Sign Bot with Preview (HBP) method builds upon HB by introducing a preview of the next movement to assist players in anticipating transitions. As depicted in Figure 4.12, the HBP interface includes a secondary preview box in the top-right corner that displays the upcoming hand movement one second in advance.

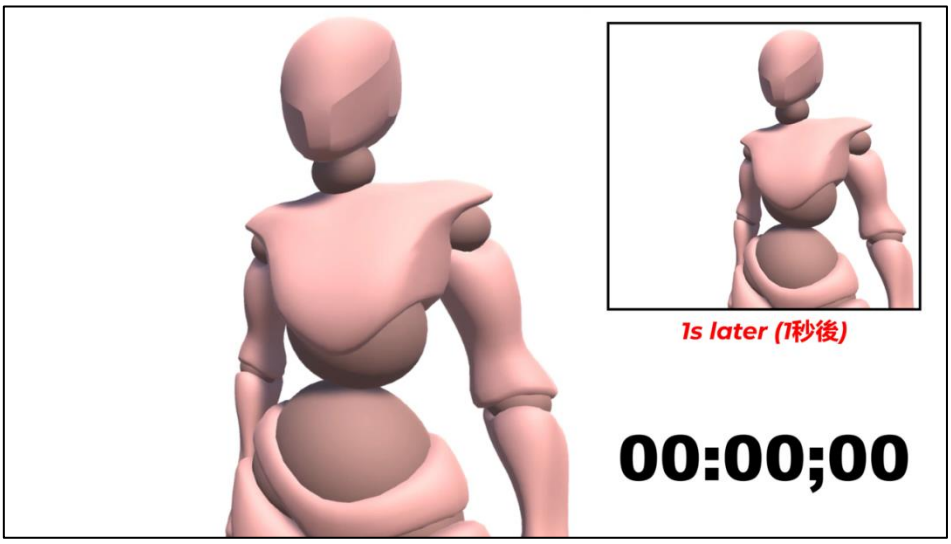


Figure 4.12: Hand-Sign Bot with Preview Interface

This feature is particularly useful for pieces with rapid note transitions, allowing players to prepare in advance and maintain performance accuracy.

4.6.5. How to Play Section

To help users familiarize themselves with the system before beginning their training, a "How to Play" section provides essential guidelines. As illustrated in Figure 4.13, this section includes:

1. Instructions on how to use the application.
2. Recommendations for an optimal learning experience, such as using a large screen and maintaining proper distance.
3. A color-coded note reference, helping players associate angklung notes with corresponding hand-sign gestures.

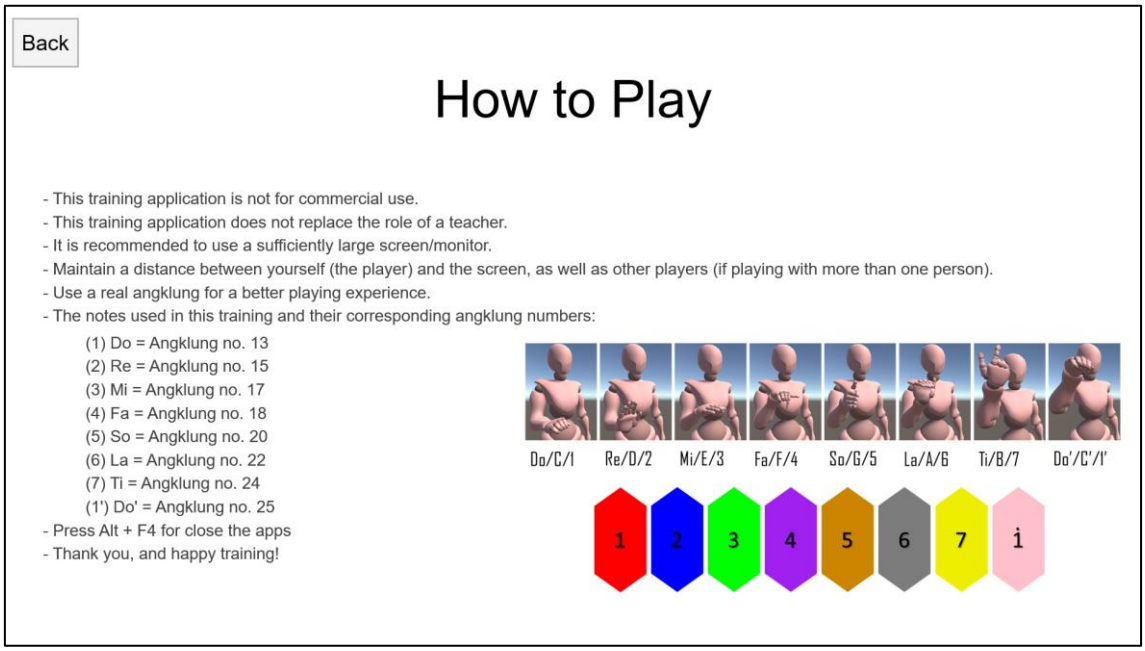


Figure 4.13: How to Play Interface

By providing this reference, players better understand the system's structure, ensuring a smoother transition into the training process.

4.7. System Requirements

To ensure that NB, HB, and HBP function effectively as digital training tools, the system was designed with a focus on technical stability, accessibility, and performance optimization. Each training method leverages Unity as the development platform and currently supports Windows as the operating system. The technical requirements are carefully structured to ensure that animations run fluidly without lag, maintaining the necessary precision for conducting-based angklung training. This section outlines the hardware and software requirements and the core system components that enable smooth and accurate execution of training sessions.

The system has specific hardware and software requirements to ensure seamless animation operation and real-time conductor guidance. Table 4.1 presents the minimum and recommended specifications for running NB, HB, and HBP effectively.

Table 4.2: System requirements

Component	Minimum Specification	Recommended Specification	Purpose
Display Device	1080p Full HD (FHD), 60Hz, Color Display	1080p FHD or higher, 120Hz+	Ensure smooth animations and accurate visual cues.
Operating System	Windows 10 (64-bit)	Windows 11 (64-bit)	Unity-based software compatibility.
Processor (CPU)	Intel Core i3 (8th Gen) / AMD Ryzen 3	Intel Core i5 (10th Gen) / AMD Ryzen 5	Handles Unity-based animations and computations.
Memory (RAM)	8GB RAM (Windows 10)	16GB RAM (Windows 11)	Ensures smooth playback of animations and real-time rendering.
Graphics (GPU)	Integrated Graphics (Intel UHD 620 / AMD Vega 8)	Dedicated GPU (NVIDIA GTX 1650 / AMD Radeon RX 570 or better)	Accelerates rendering and animation processing.
Storage	10GB free SSD space	15GB free SSD space	Reduces loading times and improves software responsiveness.
Audio System	Basic stereo speakers	High-quality speakers	Provides clear playback of conductor cues and training audio.

Key Notes:

- The system is built using Unity, meaning it is currently limited to Windows-based environments.
- Windows 11 requires a minimum of 16GB RAM for smooth animation playback; otherwise, system performance will be compromised.
- Refresh rate must be at least 60Hz to avoid lagging animations, as lower refresh rates disrupt the fluidity of conductor gestures.

In addition to meeting basic technical specifications, the system was developed with a strong emphasis on timing precision and visual clarity—two critical aspects for cue-guided training. Smooth animation rendering, particularly for hand-sign gestures in HB and HBP, is essential to ensure players receive cues at the correct moment without latency or visual lag. The system was benchmarked to maintain frame stability and fluid transitions under standard educational hardware conditions.

To ensure accessibility, the minimum and recommended requirements were aligned with commonly used laptops among students in Indonesia. This alignment was validated through direct testing during the field experiments conducted in Bandung, where the system functioned effectively on entry-level educational laptops. While specific brand

names are not disclosed, the successful deployment demonstrates that the system operates reliably on locally available hardware within the typical computing environment of novice learners.

4.8. Pre-conditions for Training Methods

Each training method—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—has distinct characteristics that require specific forms of user readiness. However, it is important to clarify that **these pre-conditions do not define a fixed learning sequence**. The experimental design in this study used a **counterbalanced setup**, allowing participants to start with any of the three methods. As will be shown in later chapters, statistical analysis revealed no significant performance differences between the methods, indicating that **learners may begin with whichever method suits their preference or learning style**. Instead of defining a progression path, the following pre-conditions serve as **functional readiness indicators**, ensuring that users understand how to interact with each system effectively.

1. Notebar (NB): Visual Recognition and Timing Awareness

NB requires minimal musical background, but assumes the following:

- The user is **not color-blind**, as note identity is distinguished using color-coded bars.
- The user understands that a bar must reach the **shaking area** before triggering action.
- The user knows to remain still when no cue is present.
- Basic **visual tracking skills** are helpful to follow the scrolling notes in time.

NB is well-suited for users who prefer or require **predictable visual structure** and a simple interface that does not involve gesture interpretation.

2. Hand-Sign Bot without Preview (HB): Note Ownership and Gesture Interpretation

To use HB effectively, participants must understand:

- Which **note they are responsible for** (e.g., G note).
- That each gesture from the conductor corresponds to a specific note.
- That action is only required when the gesture **matches their assigned note**.
- That silence (no gesture match) means the player should **remain still**.

Although HB does not require prior angklung experience, it assumes basic **recognition of hand-sign cues** and the ability to map gestures to musical response.

3. Hand-Sign Bot with Preview (HBP): Dual-Cue Awareness and Anticipation
HBP introduces a more complex interaction, combining a main conductor (real-time cue) and a sub-conductor (anticipatory cue displayed one second in advance). Players should be able to:

- Distinguish between the two avatars: **main conductor** and **sub-conductor**.
- Interpret the anticipatory cue as a **preview of the upcoming gesture**.
- Respond only to the **main conductor**, while using the sub-conductor for preparation.
- Manage split attention across **two sources of information**.

HBP is most effective for users who are comfortable with HB-style cueing and are cognitively ready to handle predictive visual input. However, depending on their visual processing style, some learners may find HBP intuitive even without prior use of HB.

4.9. Ergonomic Considerations in System Design

Although the primary focus of this study is on training effectiveness, usability, and user engagement, ergonomic aspects were also taken into account in the system design, particularly in terms of visual clarity, cognitive processing, and practical applicability in real training environments. These considerations are crucial to ensure that the proposed system can be comfortably used by novice angklung players during actual practice sessions.

All three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—were developed with an awareness of the unique physical demands of angklung playing. The angklung instrument, made of bamboo and designed to be shaken rhythmically, can be relatively heavy, especially for younger players or those new to the instrument. Based on interviews with angklung instructors and observations conducted at Saung Angklung Udjo, it was found that players can generally maintain playing posture for a maximum of 30 minutes before experiencing fatigue. This limitation applies regardless of whether the training is traditional (with a human conductor) or digital (using the proposed system).

In typical angklung extracurricular programs in West Java, a full practice session usually lasts around two hours. **Within this timeframe, players are given multiple breaks—typically four short rests distributed evenly throughout the session—to reduce physical strain.** This practice has become a standardized routine across schools and art institutions, including Saung Udjo. **These findings were incorporated into the system design process to ensure that the training methods align with real-world conditions.**

While the system does not aim to eliminate physical strain entirely—an unrealistic goal given the nature of the instrument—it does address ergonomic needs in several ways. First, the NB method uses a simplified, color-coded bar interface that reduces visual complexity and helps players quickly recognize the note and duration. Second, the HB

and HBP methods use digital hand-sign animations that closely replicate real angklung conductors' gestures. These animations were designed to be smooth, predictable, and easy to follow, reducing the cognitive load associated with interpreting rapid hand movements. HBP further assists players by providing an anticipatory cue, giving one-second notice before the next note, allowing for better preparation and reducing rushed transitions.

In short, although physical comfort cannot be fully controlled by the digital system alone, the system has been carefully designed to support the mental and perceptual ergonomics of novice players. By aligning with established practices such as regular rest periods and by minimizing visual and cognitive strain, the system supports sustainable and realistic training sessions. This ensures that the proposed methods are not only effective but also feasible and comfortable for novice players in actual educational settings.

4.10. System Development - Answering RQ1

This chapter has detailed the technical and conceptual foundation of the cue-guided angklung training system developed in this study. The system was designed to support individual learning, enabling novice players to train without relying on human conductors or ensemble coordination. Three training methods were implemented—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—each offering different forms of instructional guidance.

NB represents the **visual-cue approach**, using color-coded bars to provide clear, anticipatory timing information. It serves as a baseline training method to assist players in understanding rhythm and note sequence visually. HB and HBP represent the **handsign-cue approach**, which digitally replicates the traditional human conductor's gestures used in Saung Angklung Udjo. HB provides a single real-time conductor, while HBP extends this with a second anticipatory conductor to help players prepare for upcoming transitions.

Each method was implemented using a unified technical framework, with a MIDI-to-text parser, cue scheduler, and full-body conductor animations, ensuring consistency in tempo and musical structure across the training modules.

From an Information Science and Human-Computer Interaction (HCI) perspective, the core challenge addressed in this system lies in designing an interface that communicates musical timing and gesture cues through structured visual presentation, without relying on symbolic notation or real-time user recognition. The training modules are optimized to present these cues clearly and predictably, simulating ensemble-style timing behavior through individual interaction.

In response to RQ1: How can a cue-guided training system be developed to support angklung learning for novice players?

The system developed in this study introduces two distinct cue-guided approaches for angklung performance:

1. **Visual-Cue Approach**
   Implemented as Notebar (NB), this method uses color-coded bars to guide players through a predictive, screen-based visualization of musical timing.
2. **Handsign-Cue Approach**
   Implemented as Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP), these methods replicate the Kodály-inspired hand-sign language from Saung Angklung Udjo.
   - HB employs a single conductor for real-time instruction.
   - HBP introduces dual conductors: a main conductor and a sub-conductor that provides anticipatory gestures.

Together, these approaches demonstrate how digital systems can simulate the core instructional elements of angklung training—timing, anticipation, and cue recognition—thus enabling players to learn individually, without the presence of a human conductor or full ensemble. This development contributes not only to digital music pedagogy but also to cue-based interface design for novice-level ensemble-style instruments.

This concludes the development phase and addresses the first research question (RQ1). The following chapters will focus on evaluating how these training methods affect player performance, usability, and learning experience.

Chapter 5 Experiment

5.1. Overview and Objectives of Experiment

This chapter describes the experimental setup designed to evaluate the effectiveness of three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—for novice angklung players. The experiment aimed to assess the impact of these training methods on timing accuracy, coordination, and user experience. The experimental framework was carefully structured to ensure consistency across different participant groups while minimizing potential biases.

The experiment was conducted in two locations: JAIST (Japan) and Indonesia, involving a total of 36 participants. The participants were divided into three groups based on their background and experience:

1. NIN (Non-Indonesian Novice) – Novice players with no prior angklung experience (conducted in Japan).
2. INA (Indonesian Novice) – Novice players from Indonesia with little or no experience in playing angklung.
3. SMA (Indonesian High School Advanced Players) – Experienced angklung players from an Indonesian high school angklung group.

Each participant underwent a structured training session consisting of pre-test, training, and post-test phases, ensuring a systematic evaluation of their progress. The training sessions were conducted individually in Japan, while in Indonesia, participants were tested in small groups (three participants per session). Despite these differences in execution, all participants were evaluated individually to maintain consistency in the data analysis.

To ensure counterbalance and reduce learning order bias, the sequence of training methods (NB, HB, and HBP) and the assigned notes (Re, Fa, Do') varied among participants. Additionally, a standardized test song, "Burung Kakak Tua," was used across all sessions, providing a consistent basis for measuring participant performance. This section provides an overview of the experimental objectives, participant grouping, training methodology, and performance assessment framework, which are further detailed in the following subsections.

Objectives of the Experiment

The primary objective of the experiment was to evaluate how different **cue-guided training** methods influence the skill acquisition of novice angklung players. Specifically, the experiment aimed to answer the following questions:

1. **Training Effectiveness:** Compare the performance of Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP) against Notebar (NB) in improving the accuracy and coordination of novice players. Demonstrate measurable improvements in participants' playing skills following training with HB and HBP.

2. **Comparative User Experience:** Assess the usability and learning experience offered by HB and HBP relative to NB from the perspective of novice players. Identify the training method that delivers the most intuitive and engaging experience for new learners.
3. **Comparative Performance of Novice and Experienced Players:** Evaluate the differences in perceptions and performance between experienced players and novice players when using HB and HBP.
4. **Expert Validation:** Gather evaluations from angklung instructors and experts regarding the realism, applicability, and limitations of HB and HBP, and determine the extent to which these methods effectively replicate human conductor cues in angklung training.

5.2. Participant Group Assignments

The selection and grouping of participants were carefully designed to ensure a balanced and representative evaluation of the training methods. The study aimed to compare how novice and experienced players respond to different training approaches, as well as how cultural familiarity with angklung influences training effectiveness. This section details the participant recruitment process, criteria for selection, grouping methodology, and justification for these decisions to maintain the validity and reliability of the experimental results.

The participants in this experiment were novice players and/or individuals who had never touched an angklung before and experienced players. Therefore, the participants acted as novice angklung players who only played one note/performance based on the conductor's instructions.

We outline the experiment setting, focusing on the recruitment and preparation of participants. We describe the procedures and criteria used to select participants, ensuring that the sample is representative and suitable for the study's objectives [123]. This setup is crucial for maintaining the experimental design's integrity and ensuring the results' validity.

Participants were recruited from two distinct locations—JAIST (Japan) and Indonesia—to account for cultural and experience-based differences in angklung learning. The recruitment process involved the following steps:

1. **Japan Experiment (JAIST):** Recruitment targeted international students at Japan Advanced Institute of Science and Technology (JAIST). Participants had no prior experience with angklung to ensure a novice learning environment. A total of 18 participants were selected, forming the **Non-Indonesian Novice (NIN)** group.
2. **Indonesia Experiment:** Recruitment included students and angklung enthusiasts from Indonesian institutions. A total of 18 participants were selected, with 9 in each group. Participants were categorized based on experience level into:
    a. **Indonesian Novice (INA) group** – students with little to no prior angklung experience.
    b. **Indonesian High School Advanced Players (SMA) group** – experienced players from a high school angklung club.

To ensure gender and age diversity, recruitment included individuals across various age ranges and genders, though the study primarily focused on skill level differences.

5.2.1. Participant Group

The study on angklung participants explored the impact of player level, nationality, gender, and age group on their performance and interaction with the traditional Indonesian musical instrument. The experiment involved 36 participants divided into three distinct groups based on their skill levels and backgrounds: INA (Indonesian novice players), NIN (non-Indonesian novice players), and SMA (Indonesian high school students with advanced skills). Of the total participants, 27 individuals (75%) were categorized as novices (INA and NIN), while the remaining 9 participants (25%) were experienced players from the SMA group. INA: Comprised 9 novice participants (25%) from Indonesia, aged 21-25 years, with a gender composition of 44% male and 56% female; NIN: Included 18 novice participants (50%) from various countries such as China, India, Japan, Pakistan, South Korea, and Vietnam, aged 26-30 years, with a gender distribution of 72% male and 28% female; SMA: Consisted of 9 experienced participants (25%) from Indonesia, aged 16-20 years, all of whom were female. Participant Distribution by Nationality and Player Level is detailed in Table 5:1 below, providing a comprehensive view of the demographic and skill-based diversity within the experiment.

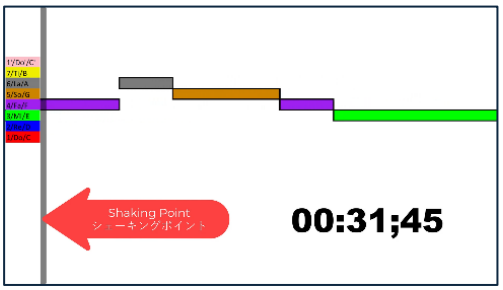
Table 5.1: Participant Distribution by Nationality, and Player Level

Nationality	Player Level	Count
Indonesia	Novice	9
Indonesia	Experienced	9
China	Novice	8
India	Novice	5
Japan	Novice	2
Pakistan	Novice	1
South Korea	Novice	1
Vietnam	Novice	1

The **list of participants** can be found in **Appendix B:** List of Participants, and for more detailed information about **participant demographics**, please refer to **Appendix C:** Participant Demographics.

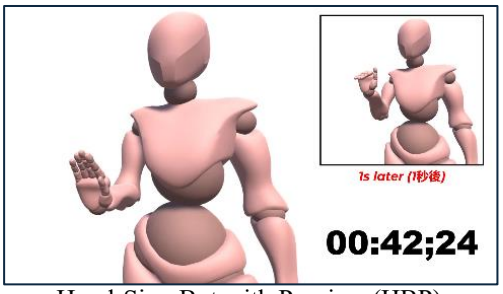
In each Angklung session, system users acted as novice players, each responsible for playing only one note at a time. When a note appeared on the screen, the player would shake the Angklung; otherwise, they would refrain. Each of these instructional methods is illustrated in Figure 5 below.

Human Conductor (HC)



Notebar Color (NB)

Hand-Sign Bot without Preview (HB)



Hand-Sign Bot with Preview (HBP)

Figure 5.1: The Instructional Method: Human Conductor and three Training Method

5.2.2. Counterbalanced Approach

Since different participants were assigned different training orders, a counterbalancing approach was used to ensure an equal distribution of training sequences across groups. To minimize order bias, a counterbalanced approach was used when assigning training methods (NB, HB, HBP) and angklung notes (Re, Fa, Do'). In accordance with the explanation provided in **Chapter 3**: Research Methodology—specifically in Section 3.2: Experimental Testing and **Table 3.1**: Participant Grouping Overview—the experimental procedure was divided into two phases. In the first phase, participants from JAIST, identified by the participant code "**NIN**," were involved. The experiment was conducted individually. A total of 18 participants were divided into 9 data groups (see Table 5.2 below), with each group consisting of 2 participants following a distinct sequence of activities. Despite three participants performing the same pattern, the data remained valid due to the implementation of counterbalancing.

Table 5.2: Experiment NIN Group Data (JAIST Student participants)

Group	Participant No	1st Turn	2nd Turn	3rd Turn
A	P01 – P02	NB: Re	HB: Fa	HBP: Do'
B	P03 – P04	NB: Fa	HB: Do'	HBP: Re
C	P05 – P06	NB: Do'	HB: Re	HBP: Fa
D	P07 – P08	HB: Re	HBP: Fa	NB: Do'
E	P09 – P10	HB: Fa	HBP: Do'	NB: Re
F	P11 – P12	HB: Do'	HBP: Re	NB: Fa
G	P13 – P14	HBP: Re	NB: Fa	HB: Do'
H	P15 – P16	HBP: Fa	NB: Do'	HB: Re
I	P17 – P18	HBP: Do'	NB: Re	HB: Fa

In the second phase, experiments were conducted with participants from Indonesia in a group setting. Three participants were invited to play the angklung concurrently. These participants were categorized under the codes **INA** and **SMA**. A total of 18 participants were involved in this phase, with the group configurations outlined in Table 5.3. Despite having three participants playing simultaneously at the same time and space, the data remained valid owing to the application of counterbalancing.

Table 5.3: Experiment INA and SMA Group Data (Indonesian participants)

Group	Participant No	1st Turn	2nd Turn	3rd Turn
A	P01	NB: Re	HB: Fa	HBP: Do'
A	P02	NB: Fa	HB: Do'	HBP: Re
A	P03	NB: Do'	HB: Re	HBP: Fa
B	P04	HB: Re	HBP: Fa	NB: Do'
B	P05	HB: Fa	HBP: Do'	NB: Re
B	P06	HB: Do'	HBP: Re	NB: Fa
C	P07	HBP: Re	NB: Fa	HB: Do'
C	P08	HBP: Fa	NB: Do'	HB: Re
C	P09	HBP: Do'	NB: Re	HB: Fa

In summary, a total of 36 participants took part in the experiments, representing a mix of individuals from Indonesia and abroad, as well as both novice and experienced players. By implementing this approach, each training method was equally represented in every possible position (first, second, or third) among participants. This ensures that the improvements observed were due to the effectiveness of the methods rather than the order in which they were experienced.

5.3. Experiment Session Structure

The experiment session structure was carefully designed to ensure consistency and control over the learning conditions for all participants while allowing for meaningful evaluation of the training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The session was divided into three primary phases: introduction, angklung playing experience, and post-experiment questionnaires. This section details the sequence of activities, time allocation, and standardized procedures followed during the experiments in both Japan (JAIST) and Indonesia.

5.3.1. Experiment Phase

Each participant underwent a 120-minute (2-hour) experimental session, structured into three main activities, as illustrated in Figure 5.2. This framework ensures consistency while allowing flexibility in participant group settings.

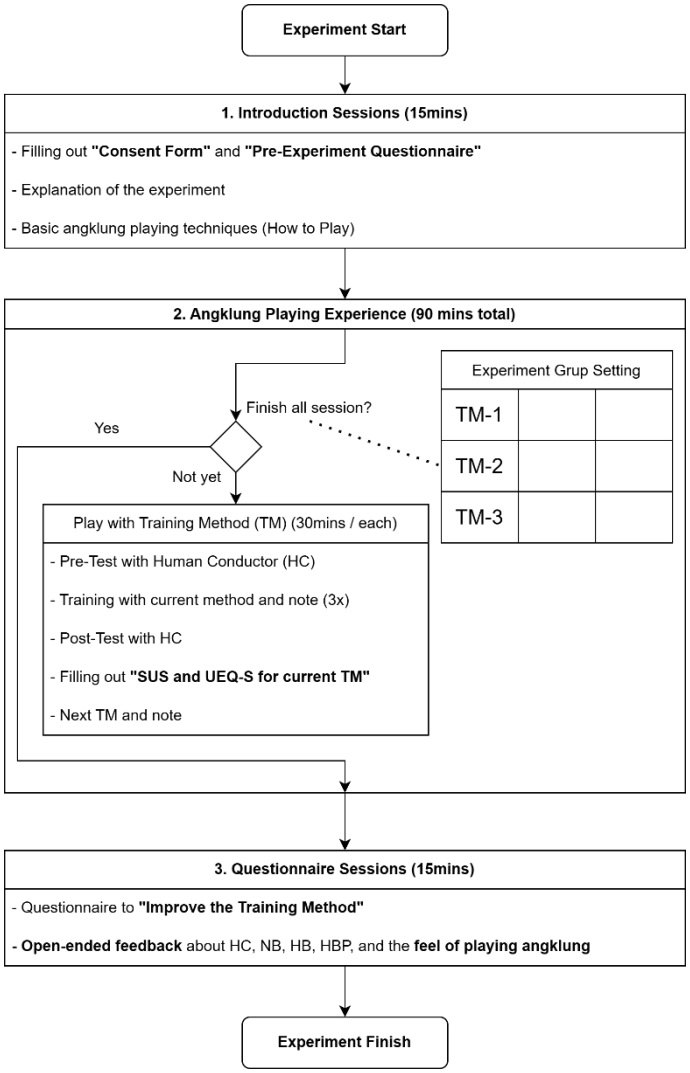


Figure 5.2: Experiment Phase

The session was divided into the following key components:

1. Introduction Session (15 minutes)

Participants began the experiment with an introduction session designed to familiarize them with the angklung playing methods and the experiment procedures. This session ensured that all participants, regardless of prior musical experience, had a clear understanding of how to interact with the training system.

a. Step 1: Completing the Consent Form and the Pre-Experiment Questionnaire to collect demographic data (age, gender, musical background, and familiarity with angklung).
b. Step 2: Explanation of the experiment procedures, expectations, and objectives using instructional slides.
c. Step 3: Basic training on how to play the angklung and follow conductor hand-sign cues to ensure that participants were prepared for the upcoming sessions.

2. Angklung Playing Experience (90 minutes total)

The core part of the experiment involved three distinct training sessions (NB, HB, and HBP), with each method lasting 30 minutes. The sequence of training methods and assigned notes was determined through a counterbalanced experimental design, as outlined in Table 5.2 (JAIST Participants) and Table 5.3 (Indonesian Participants) to minimize learning order bias.

Each training session consisted of the following steps:

a. Training Method-1 (30 minutes)

- Step 1: Pre-Test with Human Conductor (HC) – Participants played a pre-test using the traditional HC method before engaging with the training system.
- Step 2: Training Phase (NB, HB, or HBP) – Participants underwent three repetitions of training using the assigned method.
- Step 3: Post-Test with Human Conductor (HC) – Participants played again under HC to assess improvements.
- Step 4: Usability and Experience Evaluation – Participants completed the System Usability Scale (SUS) and User Experience Questionnaire Short (UEQ-S) to evaluate their interaction with the method.

b. Training Method-2 (30 minutes)

The process above was repeated with a different training method and assigned note.

c. Training Method-3 (30 minutes)

The process was repeated one last time, ensuring each participant experienced all three training methods in a controlled sequence. The training method order and assigned notes followed a counterbalanced setting, where participants underwent different sequences of NB, HB, and HBP to ensure fairness and mitigate bias. The full assignment details are documented in Table 5.2 and Table 5.3.

3. Questionnaire Session (15 minutes)

After completing all three training methods, participants proceeded to the final session, where they provided additional feedback about their experiences.

a. Step 1: Completing the "Questionnaire to Improve the Training Method" to gather insights into usability, strengths, and areas for improvement.
b. Step 2: Open-ended feedback on HC, NB, HB, and HBP, including which method felt most like real angklung playing and any additional comments regarding training effectiveness.

5.3.2. Differences in Experimental Setup and Execution

The execution of the experiment varied significantly between the Japan (JAIST - NIN Group) and Indonesia (INA & SMA Groups) due to differences in cultural context, available resources, and experimental settings (see Table 5.4). These variations were not only influenced by the participants' familiarity with the angklung—a traditional Indonesian musical instrument—but also by the logistical and environmental conditions of the testing locations. In Japan, the experiment was conducted in a highly controlled environment with access to advanced equipment, reflecting the technological infrastructure available at JAIST. In contrast, the experiment in Indonesia was carried out in more typical classroom settings, with limited resources and equipment, reflecting the real-world conditions of educational institutions in the region. Understanding these differences is essential for interpreting the results of the study, as they highlight how cultural, environmental, and logistical factors can influence the dynamics and outcomes of cross-cultural research. The following sections provide a detailed comparison of the experimental setups in both locations, emphasizing the unique challenges and advantages encountered in each context.

Table 5.4: Differences in Experiment Execution

Factor	Japan (JAIST - NIN Group)	Indonesia (INA & SMA Groups)
Test Setting	Individual	Group (3 participants per session)
Participant Experience	No prior knowledge of angklung	Some cultural familiarity with angklung
Performance Observation	Independent play, no external influence	Group setting, participants observed each other
Experimental Constraints	Conducted in studio room	Conducted in a classroom setting
Equipments	sufficient equipment	insufficient equipment

5.3.2.1. Japan (JAIST - NIN Group)

The experiment conducted in Japan (**JAIST - NIN Group**) was characterized by an individual test setting, where each participant performed the task independently without interaction with others. This approach ensured that the performance of each participant was free from external influences, allowing for a clear assessment of individual capabilities. Participants in this group had no prior knowledge of the angklung, as the instrument is not part of their cultural context. This lack of familiarity provided a unique

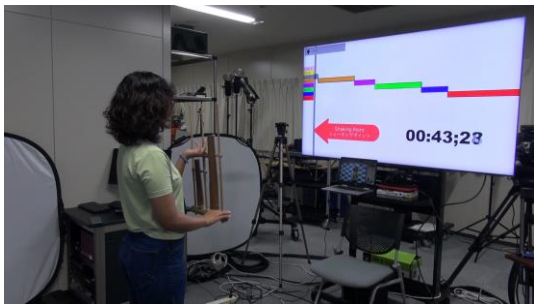
perspective on how individuals with no prior exposure to the instrument interacted with it.

The experiment took place in a studio room, which offered a controlled and quiet environment, minimizing external distractions and ensuring consistency in the testing conditions. The equipment used in this setting was of high quality, as we were able to borrow several pieces of equipment from JAIST. The monitors used had large screens with high refresh rates, ensuring clear visual feedback for participants. Additionally, we utilized the following equipment to enhance data collection:

1. Camera Camcorder (1080p, 60fps): Two cameras were positioned at the front to record the participant's front view, and one camera at the back to evaluate their angklung performance.
2. Microphone with Noise Cancelling: A high-quality microphone was used to capture the characteristics of novice players while playing the angklung.

The availability of sufficient and high-quality equipment ensured that each participant had access to the necessary tools, facilitating the smooth execution of the experiment. High-resolution video and audio recordings were stored needed for analysis and future research [124]. Examples of the front and back views are shown in Figure 5.3 below.


Camera Frontview



Camera Sideview

Figure 5.3: Experiment in JAIST (Japan)

5.3.2.2. Indonesia (INA & SMA Groups)

In contrast, the experiment in Indonesia (**INA & SMA Groups**) was conducted in a group setting, with three participants per session. This approach allowed participants to interact and observe each other during the task, introducing a social dynamic that may have influenced their performance. Participants in this group had some cultural familiarity with the angklung, as it is a traditional Indonesian instrument. This familiarity likely affected their interaction with the instrument, as they may have had preconceived notions or prior experience with it.

Unlike the experiment in JAIST, the equipment used in Indonesia was more limited. We did not use high-quality equipment such as Camera Camcorders or High-Quality Microphones as in Japan. Instead, we relied on smartphone cameras with decent quality for recording. The experimental settings also varied between the two Indonesian groups (see Figure 5.4):

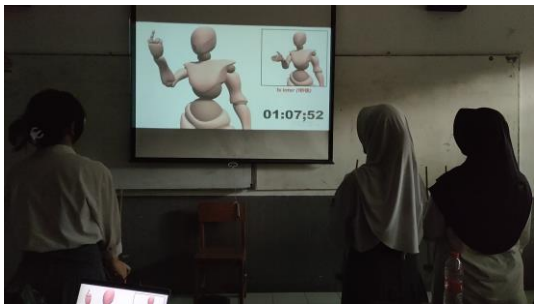
1. INA Group:

- The experiment was conducted in a well-lit classroom equipped with a projector of reasonably good quality.
- Recordings were made from two angles (front and back) to capture the participants' performance.

2. SMA Group:
   - The experiment was conducted in a dimly lit classroom that lacked a built-in projector. To address this, we used a personal projector, although its quality was not as good as the one used in the INA group.
   - Due to the small and cramped classroom, recordings could only be made from one angle (back).
   - The whiteboard and screen used for projection were of average quality, **reflecting the typical conditions of classrooms in Indonesia**.

Despite these technical limitations, the experiment proceeded smoothly, particularly because the SMA group consisted of **experienced angklung players**. Their familiarity with the instrument and the task compensated for the lack of advanced equipment, ensuring that the quality of the experiment was not significantly compromised.

INA Group Experiment



SMA Group Experiment

Figure 5.4: Experiment in Indonesia

The evaluation process was conducted manually in both the JAIST (Japan) and Indonesia (INA & SMA Groups) experiments. This was a necessary approach due to the absence of an automated scoring system in the experimental setup. Manual evaluation ensured that each participant's performance was carefully assessed, although it required more time and effort compared to an automated system.

5.4. Experimental Instruments

In order to conduct a structured and controlled experiment, several essential instruments were used throughout the study [125]. These instruments ensured uniformity in the training process, provided measurable outcomes, and allowed participants to experience angklung learning under different conditions. The key experimental instruments consisted of the selected song arrangement, standardized documents, and questionnaires that facilitated performance evaluation and user feedback [126].

This experiment uses angklung, a musical instrument, as the medium for playing music. Each angklung produces only one note, so a complete set of players is usually required

for practice and performance on stage [61]. One of the primary experimental instruments was the novice-friendly arrangement of Burung Kakak Tua, a traditional Indonesian song that was adapted for novice angklung players. The song selection and arrangement process are detailed in Section 5.4.1, while the documentation and evaluation materials are explained in Section 5.4.2.

5.4.1. Song for Novice Angklung Player - Burung Kakak Tua

The song **"Burung Kakak Tua"** was selected as the test piece for this study due to its simple melody, repetitive rhythmic structure, and cultural significance in Indonesian music education. This song is widely used in early music training programs, making it an ideal candidate for assessing novice angklung players' ability to follow **cue-guided training**.

Historical and Cultural Significance

"Burung Kakak Tua" is a well-known Indonesian folk song that originates from the Maluku Islands [127]. The song is traditionally sung by children and features a cheerful melody that is easy to follow. The lyrics depict the image of a cockatoo (kakak tua) perched on a window, symbolizing warmth and familiarity in Indonesian folklore. Though the song's exact composer remains unknown, it has been passed down through generations as part of Indonesia's rich oral tradition.

In the **1950s, Pak Daeng Soetigna**, the pioneer of modern diatonic angklung, arranged this song to be playable on the angklung. Pak Daeng was instrumental in transforming the angklung from a pentatonic instrument into a diatonic ensemble, allowing it to perform a wider range of musical compositions, including Western classical pieces and Indonesian folk songs like Burung Kakak Tua. His arrangement ensured that the song remained true to its cultural essence while being accessible for angklung ensembles.

Today, **Edi Permadi** (one of Expert in this research), the only surviving direct student of Pak Daeng Soetigna, continues his legacy by preserving and teaching his angklung methodologies. Edi Permadi participated in this study, providing valuable insights into the arrangement and execution of angklung music. He also granted permission and gave his blessing for the adaptation of Burung Kakak Tua into a novice-friendly version, ensuring that it aligns with the traditional principles of angklung education.

Novice-Friendly Arrangement for Angklung Training

For the purpose of this study, the Burung Kakak Tua arrangement was slightly modified to better suit novice angklung players. The primary goal of this adaptation was to maintain the original musical integrity while simplifying the execution for learners with no prior angklung experience (see Table 5.5 below).

Key adaptations made to the novice-friendly arrangement include:

1. Limited Number of Notes: The song was arranged to use only one octave for melody, minimizing cognitive load while maintaining the melodic structure.
2. Balanced Note Difficulty: The chosen notes were selected based on their equal difficulty level, ensuring that no single participant faced a significantly harder challenge.

3. Preserving Traditional Conductor-Based Playing: The adaptation ensured that players would still follow a human conductor (HC) while training with digital methods (NB, HB, HBP), maintaining an authentic angklung playing experience.

Table 5.5: Angklung "Burung Kakaktua" song detail

Note	Angklung Number	Total Play
Do'/C'/1'	**18**	**8**
Ti/B/7	17	6
La/A/6	15	20
So/G/5	13	34
Fa/F/4	**11**	**12**
Mi/E/3	10	22
Re/D/2	**8**	**12**
Do/C/1	6	2

The **original arrangement** by Pak Daeng Soetigna is preserved in **Appendix D**, while the **novice-friendly arrangement** used in this research is documented in **Appendix E**. This arrangement was the standardized piece used across **all experimental sessions, ensuring fair comparison between training methods**. Thus, the version of Burung Kakak Tua used in this study represents a balance between tradition and adaptation, maintaining Pak Daeng Soetigna's legacy while optimizing the song for novice angklung education.

5.4.2. Document and Questionnaire in Experiment

To ensure systematic data collection and evaluation, a set of standardized documents and questionnaires were used throughout the experiment. These materials served three primary purposes:

1. To gather demographic and background information on participants.
2. To assess user experience and the usability of the training methods.
3. To collect qualitative feedback for further system improvement.

Each participant was required to complete different documents at various stages of the experiment. The following sections provide an overview of the key documents used. Each document was completed at a specific phase of the experiment, as illustrated in Figure 5.1 (Experiment Phase). Additionally, Table 5.2 and Table 5.3 (Experiment Setting for JAIST and Indonesian Participants) provide details on the sequence in which these documents were administered. By structuring the documentation process in this manner, the study ensured consistency in data collection, enabling both quantitative and qualitative analysis of user performance, usability, and engagement.

1. Pre-Experiment Documents

Before starting the experiment, participants were required to complete the following documents:

1. **Consent Form (Appendix F):** Acknowledges participants' voluntary involvement in the study and ensures ethical research compliance.

2. **Pre-Experiment Questionnaire (Appendix G):** Collects background information on participants, including age, gender, nationality, previous experience with angklung or other musical instruments.

These documents helped categorize participants into groups based on their experience level and cultural background (See Appendix B: Participants Data and Appendix C: Participants Demographics).

2. Experiment Session Documents

During the experiment, participants underwent three training sessions using different methods (Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)). After each session, they were required to complete usability and experience evaluations:

a. **System Usability Scale (SUS) Questionnaire (Appendix H):** A standardized 10-item survey assessing the usability of each training method. Participants rated statements such as:
   - "I found this training method unnecessarily complex."
   - "I felt confident using this training method."
   - "I think I would like to use this training method frequently."

b. **User Experience Questionnaire - Short Version (UEQ-S) (Appendix H):** Evaluates perceived user experience across eight dimensions, including clarity, efficiency, and intuitiveness. Participants provided ratings on a 7-point Likert scale, contrasting adjectives such as:
   - Obstructive vs. Supportive
   - Complicated vs. Easy
   - Boring vs. Exciting

Each participant completed SUS and UEQ-S three times—once after each training method (NB, HB, HBP). This ensured fair comparative analysis between the different approaches.

3. Post-Experiment Feedback Documents

After completing the training sessions, participants provided additional feedback regarding their experience:

a. **Questionnaire to Improve the Training Method (Appendix I):** Participants were asked:
   - "Do you have any suggestions for improving the NB method?"
   - "Do you have any suggestions for improving the HB method?"
   - "Do you have any suggestions for improving the HBP method?"

b. Open-Ended Feedback Collection (Appendix J): Participants responded to general questions about their training experience, such as:
   - "How did you feel playing angklung using a human conductor (HC)?"
   - "Which method (NB, HB, HBP) felt closest to a real angklung playing experience?"

These responses were analyzed in Chapter 6 to identify usability trends and player preferences.

5.4.4. Data Collection

To comprehensively evaluate the effectiveness of the training methods proposed in this study, three primary data collection tools were utilized: Score Performance, the System Usability Scale (SUS), and the User Experience Questionnaire - Short Version (UEQ-S). Each tool provided a distinct perspective on the participants' learning outcomes, usability perceptions, and overall user experience.

1. **Score Performance:** Pre-test and post-test scores were collected to assess the participants' learning outcomes. The pre-test was administered before participants were introduced to any training method, establishing a baseline for their initial skill levels. Following the completion of the training sessions, a post-test was conducted to measure the improvement and effectiveness of the instructional methods. This quantitative comparison enabled an objective analysis of each method's impact on performance.
2. **System Usability Scale (SUS):** is an industry-standard tool for evaluating the usability of systems, interfaces, and products [110]. SUS is a reliable and quick-to-administer questionnaire comprising ten items scored on a Likert scale. The tool provides a single usability score ranging from 0 to 100, making it easy to interpret and compare across different systems [111]. SUS is highly versatile and has been applied across various domains, including software development, consumer electronics, and instructional tools. This study used SUS to measure participants' perceptions of ease of use, learnability, and overall satisfaction with the training methods. A SUS score above 68 is typically considered "above average," indicating good usability, while lower scores suggest areas for improvement [112]. The insights from SUS helped identify how effectively each training method supported novice Angklung players in their learning process.
3. **User Experience Questionnaire - Short Version (UEQ-S):** is a streamlined tool designed to measure user experience across eight core dimensions: attractiveness, clarity, efficiency, dependability, stimulation, and novelty [113]. It was derived from the complete User Experience Questionnaire (UEQ) to offer a quicker and more focused assessment while retaining reliability and validity [114], [115], [116]. The UEQ-S enables researchers to capture the pragmatic (e.g., efficiency, dependability) and hedonic (e.g., stimulation, attractiveness) aspects of user experience. This makes it particularly valuable in contexts where subjective emotional and cognitive reactions to systems, such as learning tools, play a critical role. In this study, the UEQ-S provided a detailed evaluation of how participants emotionally and cognitively interacted with each training method, complementing the usability findings from SUS and the performance data from pre-and post-tests.

5.5. Ergonomic Considerations During Experiment

In designing and conducting the experiment, special attention was given to the physical limitations commonly experienced by novice angklung players. As established in prior interviews with angklung instructors and observations at Saung Angklung Udjo, players—especially novices—are generally able to maintain playing posture for only about 30 minutes before requiring a break. This is due to the physical effort involved in holding and shaking the angklung, which is not only relatively heavy but also requires

repetitive hand and arm movements. **This limitation is not exclusive to digital training systems but is equally applicable to traditional angklung practice sessions with a human conductor.**

In real-world practice settings across schools in West Java, angklung extracurricular activities typically span two hours per session. Within this duration, it is standard practice to incorporate at least four rest periods to manage physical fatigue. This practice has also been formally adopted in training sessions held by cultural institutions such as Saung Angklung Udjo.

To ensure that the experiment mirrored these authentic training conditions, the total session duration was set to two hours. However, active angklung playing time was limited to approximately 90 minutes, as the remaining time was allocated for instruction, explanation, and rest. **Participants were given three breaks during the session, each strategically placed between testing blocks.** These breaks were intended not only to minimize fatigue but also to maintain the validity of performance and usability data collected throughout the session.

Importantly, the need for rest was not introduced because of the digital training system itself. **Rather, it was a necessary ergonomic consideration due to the nature of the instrument and the physical requirements of playing it.** This distinction reinforces that while the system aims to provide a more accessible and engaging training experience, it does not override the inherent physical characteristics of angklung performance.

By embedding scheduled breaks and limiting active playtime, the experiment was designed to balance physical endurance with data collection accuracy. This approach ensured that evaluations of player performance (RQ2a), usability, and engagement (RQ2b) were not confounded by excessive fatigue, thereby preserving the reliability of the findings and aligning with established training norms in Indonesia.

Chapter 6 Results and Analysis

6.1. Introduction

This chapter presents the results of the experimental and qualitative evaluations conducted to address the second research question (RQ2) and its sub-questions. Building on the system development phase discussed in Chapter 4, this stage focuses on assessing how novice and experienced players interact with the three **cue-guided training** methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The evaluations aim to explore differences in user performance, usability, engagement, and expert insights. The results are structured to provide clarity in how each method contributes to self-guided angklung learning and how participants and experts perceive the system.

6.1.1. Research Objectives and Questions Overview

As outlined in Chapter 1, the overarching research objective (RO) of this study is:
To develop and evaluate a cue-guided angklung training system using visual-cue and handsign-cue approaches for novice players, focusing on individual learning and performance assessment based on player experience, usability, engagement, and expert evaluation.

To achieve this objective, this chapter addresses explicitly **Research Question 2 (RQ2)** and its subcomponents:
RQ2: *How do players and experts perceive the angklung-playing experience using a Cue-Guided System?*

a. **RQ2a**: *How does player performance change when using a Cue-Guided System?*
b. **RQ2b**: *How do players experience usability and user engagement when using a Cue-Guided System?*
c. **RQ2c**: *What are experts' perspectives on the challenges and advantages of handsign-based approaches as angklung training methods?*

Each of these questions is answered through a combination of quantitative performance data, user experience evaluations, and qualitative expert interviews. While RQ2a and RQ2b are examined using performance metrics and standardized usability instruments (SUS and UEQ-S), RQ2c is addressed using structured thematic analysis through expert interviews.

6.1.2. Connection to Experimental Design and Data Collection

The analysis presented in this chapter is directly connected to the experimental procedures and data collection strategies discussed in Chapter 3. The study employed a **within-subject experimental design** with counterbalanced order to ensure that each participant experienced all three training methods (NB, HB, and HBP), minimizing order effects. Data were collected across two participant groups—novice and experienced players—providing comparative insights into different user backgrounds.

To assess **player performance (RQ2a)**, pre-test and post-test timing accuracy scores were recorded and analyzed. For **usability and engagement (RQ2b)**, participants completed the **System Usability Scale (SUS)** and the **User Experience Questionnaire – Short Version (UEQ-S)** after using each method. For **expert evaluation (RQ2c)**, structured interviews were conducted with experienced angklung instructors, and their feedback was analyzed using **Framework Analysis**.

All data were processed and analyzed in accordance with the methodological structure defined in Section 3.6, ensuring alignment between research design and the insights presented in this chapter.

6.2. Data Processing and Analysis Methods

This section outlines the procedures used to prepare, clean, and analyze the data collected during the experimental and evaluative phases of the study. The analysis addresses the three subcomponents of RQ2—player performance (RQ2a), user experience and usability (RQ2b), and expert perspectives (RQ2c)—by applying both quantitative and qualitative methods. Given the modest sample size and the ordinal nature of the collected data, **non-parametric statistical techniques** were employed to ensure methodological validity. Specifically, the **Friedman Test** and **Wilcoxon Signed-Rank Test** were selected for performance and usability-related comparisons, while **Framework Analysis** was used to interpret expert interview data.

6.2.1. Data Cleaning and Preprocessing

Before conducting statistical and qualitative analysis, all experimental data were subjected to a structured cleaning process to ensure their reliability and consistency. This process applied to all relevant data sources—participant performance scores, usability questionnaire responses (SUS and UEQ-S), and expert interview transcripts. Figure 6.1 illustrates the sequential stages of the data preparation pipeline.

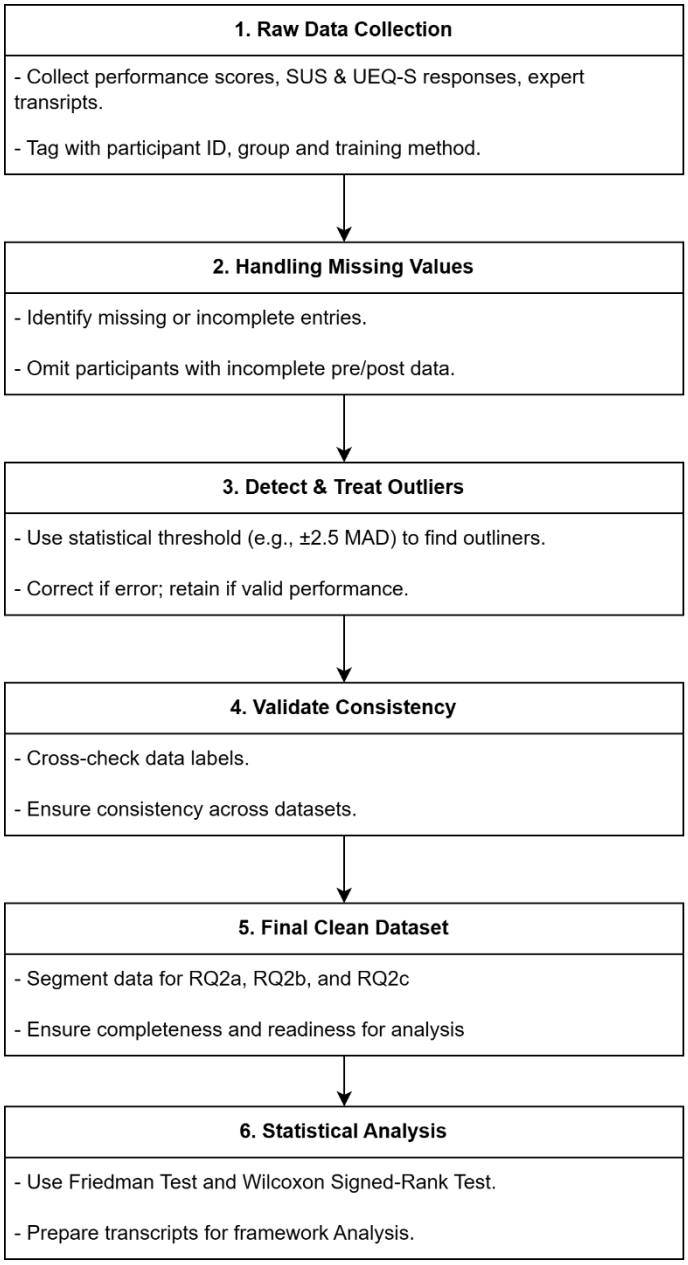


Figure 6.1: Data Cleaning & Processing Steps

Description of Data Cleaning Steps:

Step 1: Raw Data Collection

- Raw data were collected from three distinct sources:
  - Pre-test and post-test performance scores for each participant using all training methods (NB, HB, HBP).
  - Standardized usability and user experience questionnaire responses (SUS and UEQ-S).
  - Expert interview transcripts used for qualitative evaluation.
- Each entry was tagged with participant ID, group (novice or experienced), and the training method applied.

Step 2: Handling Missing Values

- Records were scanned for missing or incomplete entries.
- Isolated cases of missing questionnaire items were excluded from analysis for that specific method only.
- If a participant lacked complete performance data (e.g., pre-test but no post-test), the entry was omitted from RQ2a analysis to maintain consistency in within-subject comparison.

Step 3: Detect and Treat Outliers

- Outliers in timing scores were identified using a statistical threshold (e.g., extreme gaps beyond ±2.5 MAD or obvious recording inconsistencies).
- If the outlier was due to an input error or logging anomaly, it was corrected manually using session notes.
- If the outlier reflected actual performance behavior (e.g., hesitations, skipped notes), it was retained and noted for discussion.

Step 4: Validate Consistency

- All entries were checked for consistency of labels across datasets:
    - Matching participant ID with training session order (due to counterbalanced design).
    - Ensuring questionnaire data (SUS and UEQ-S) aligned with the respective training method.
    - Verifying that HB and HBP were correctly tagged as handsign-cue methods, while NB as visual-cue.

Step 5: Final Clean Dataset

- After cleaning, the datasets were categorized based on their role in addressing the research questions:
    - **RQ2a**: Final dataset included only participants with complete pre–post score pairs for all three training methods.
    - **RQ2b**: Usability and engagement scores (SUS, UEQ-S) were retained only for participants who completed all items.
    - **RQ2c**: Transcripts were finalized for Framework Analysis by removing verbal fillers and anonymizing identities.

Step 6: Statistical Readiness

- Given the small sample size and non-normal distribution of ordinal data:
    - **Friedman Test** was selected for within-subject comparison across NB, HB, and HBP for both RQ2a and RQ2b.
    - When needed, **Wilcoxon Signed-Rank Test** was used as a post-hoc analysis to explore pairwise differences.
    - Qualitative responses from experts were prepared for coding using a structured framework aligned with RQ2c.

6.2.2. Statistical Methods for RQ2a and RQ2b

To answer RQ2a and RQ2b, this study applied **non-parametric statistical methods** appropriate for small sample sizes and ordinal data. Unlike parametric techniques such as ANOVA or paired t-tests, which assume normal distribution and interval data, the methods used here are more robust for handling the types of measurements collected (e.g., timing accuracy scores, SUS and UEQ-S responses).

RQ2a: Participant Performance Score

Each participant's timing accuracy score was collected in a pre-test and post-test to assess performance improvements across the three training methods (NB, HB, HBP).

- **Friedman Test** was used to compare the three related groups (i.e., the same participants trained with all three methods). This test evaluates whether there are statistically significant differences in **median performance ranks** across the three methods.
- **Rationale**: The dataset violated assumptions for parametric tests due to small sample size and lack of normality. The Friedman Test is the non-parametric equivalent of the repeated-measures ANOVA and is suitable for within-subject comparisons.
- **Post-Hoc Analysis**: If the Friedman Test result approached significance, **Wilcoxon Signed-Rank Test** was used for pairwise comparisons (e.g., NB vs HB, HB vs HBP, NB vs HBP) to explore which methods differed significantly.

RQ2b: Player Experience (Usability and User Engagement)

To evaluate the usability and user experience of each training method from the player's perspective, two standard instruments were used:

1. **System Usability Scale (SUS)**
2. **User Experience Questionnaire – Short Version (UEQ-S)**

These instruments produced ordinal scores for each method (NB, HB, HBP), allowing for within-subject comparison.

- The **Friedman Test** was again used to detect any significant differences in SUS and UEQ-S scores across the three methods.
- As with performance data, **Wilcoxon Signed-Rank Tests** were employed post-hoc when necessary to explore the nature of any differences between training methods.
- **Data Grouping**: Responses were analyzed separately for novice and experienced participants, allowing insights into whether player background influenced their usability and engagement perceptions.

6.2.3. Framework Analysis for RQ2c

To address RQ2c—**"What are experts' perspectives on the challenges and advantages of handsign-based approaches as angklung training methods?"**—this study employed a qualitative approach known as **Framework Analysis (FA)**. This method is well-suited for applied research where structured comparisons and policy-relevant insights are needed, particularly when multiple evaluators provide feedback on a defined intervention such as HB and HBP.

6.3. Results for RQ2a: Participant Performance Score

This section presents the results of the quantitative analysis of participants' performance scores, obtained from pre-test and post-test experiments using three training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The primary objective is to address RQ2a:
RQ2a: How does player performance change when using a Cue-Guided System?
The analysis used the Friedman Test, with the Wilcoxon Signed-Rank Test as a post-hoc follow-up to compare pairwise differences when necessary.

6.3.1. Performance Measurement System

The following section presents the evaluation of participants' performance, highlighting the effectiveness of the various methods tested in this study. These findings offer valuable insights into the participants' progress and the overall impact of the applied training methods. The performance results are summarized in Table 6.1 below (see Appendix K for more detail).

Table 6.1: Participants Performance Score Instances

P Code	PM	TM	Note	T1	T2	D
INA-P01	PM-1	NB	Re	81	86	6
INA-P01	PM-2	HB	Fa	75	94	19
INA-P01	PM-3	HBP	Do'	88	83	-4
…						
SMA-P09	PM-1	HBP	Do'	88	88	0
SMA-P09	PM-2	NB	Re	100	94	-6
SMA-P09	PM-3	HB	Fa	78	69	-8

According to the data in the "D" column of the table, 66 activities (61.1%) demonstrated improvement, 17 activities (15.7%) remained unchanged, and 25 activities (23.1%) showed a decline. Further analysis of these results is provided in the subsequent sections.

The PGLMWN (Perfect, Great, Late, Miss, Wrong Note) scoring system is applied to measure training effectiveness. Table 6.1 defines the scoring criteria used in both pre-test and post-test assessments.

Table 6.2: PGLMWN Scoring System Definition

Score Category	Definition
Perfect (P)	Note is played with precise timing.
Great (G)	Note is slightly off but within an acceptable range.
Late (L)	Note is played after the expected time window.
Miss (M)	Expected note is not played.
Wrong Note (WN)	Incorrect notes are played instead of the expected note.

The total pre-test (T1) and post-test (T2) scores were calculated using the formula:

$$T = \sum (P.3 + G.2 + L.1 + M.0 + WN.(-1))$$

where:

- **T1 (Pre-Test Score):** The participant's score before training.
- **T2 (Post-Test Score):** The participant's score after training.

D (Score Difference): The performance improvement, calculated as D = T2 - T1.

6.3.2. Performance Score – Novice vs Experienced Players

This section investigates whether player experience level affects the effectiveness of the three angklung training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The comparison was made between novice players and experienced players, using pre-test and post-test timing accuracy scores collected after each training method.

Participant Group Definition

1. **Novice Players**: Participants who had **little to no experience with angklung playing**, and had not previously been trained in cue-guided methods. This group combines:
   - **NIN (Non-Indonesian Novices)**: International participants with no cultural background in angklung.
   - **INA (Indonesian Novices)**: Local Indonesian participants who are culturally familiar with angklung but had limited playing experience.
2. **Experienced Players**: Participants from the **SMA (Indonesian High School) group**, who had previously received **formal angklung training and ensemble experience** under the guidance of a human conductor.

Hypotheses

H_0 (Null Hypothesis): There is no significant difference in angklung-playing skill improvement among the three training methods (NB, HB, and HBP) for novice and experienced players.

H_1 (Alternative Hypothesis): At least one training method (NB, HB, or HBP) leads to significantly different skill improvement compared to the others.

Friedman Test Results

Table 6.3: Friedman Test Results Performance Score – Player-Level

Player-Level	Chi-Square	p-value	Conclusion
Novice: 27/36	3.6415	0.1619	Not significant
Experienced: 9/36	1.5429	0.4624	Not significant

Interpretation
The p-values for both groups exceed the standard significance level of 0.05, indicating **no statistically significant differences** in performance improvement across the three training methods. Thus, the null hypothesis (H_0) is retained.
These findings suggest the following:

- **For novice players**, NB, HB, and HBP were equally effective in supporting timing accuracy and performance progression.
- **For experienced players**, none of the training methods demonstrated superior or inferior results, reinforcing that the Cue-Guided System maintains consistent learning potential regardless of prior training exposure.

This result supports the notion that the Cue-Guided Angklung Training System can accommodate players of varying skill levels, and that learners may begin with any of the three methods without negatively impacting their learning outcomes.

6.3.3. Performance Score – Indonesia vs Non-Indonesia

This section explores whether cultural background plays a role in how participants respond to the three training methods. The comparison was conducted between **Indonesian participants (INA + SMA)** and **Non-Indonesian participants (NIN)**, based on their performance scores across NB, HB, and HBP.

Participant Group Definition

1. **Indonesian Participants**: This group consists of two subgroups:
   - **INA (Indonesian Novices)**: Participants with cultural familiarity but limited angklung playing experience.
   - **SMA (Experienced Indonesian Players)**: Participants with formal angklung training and ensemble experience.
2. **Non-Indonesian Participants (NIN)**: International participants from various countries with **no prior exposure to angklung or Indonesian musical traditions**, representing a culturally unfamiliar group.

Hypotheses
H_0 (Null Hypothesis): There is no significant difference in angklung-playing skill improvement among the three training methods (NB, HB, and HBP) for Indonesian and Non-Indonesian participants.
H_1 (Alternative Hypothesis): At least one training method leads to significantly different skill improvement between the two cultural groups.

Friedman Test Results

Table 6.4: Friedman Test Results Performance Score – Nationality

Nationality	Chi-Square	p-value	Conclusion
Indonesian: 18/36	2.2817	0.3195	Not significant
Non-Indonesian: 18/36	0.3714	0.8305	Not significant

Interpretation
The Friedman Test shows **no statistically significant differences** in performance improvement among the three training methods for either group:

- Indonesian participants demonstrated similar performance outcomes using NB, HB, and HBP.
- Non-Indonesian participants also showed comparable improvements across all three methods, despite their lack of cultural familiarity with angklung or **cue-guided training**.

These findings suggest that the system:

- Supports **equal accessibility and effectiveness** across cultural backgrounds.
- Offers a **universal learning interface**, allowing players from diverse origins to follow and benefit from the training without prior exposure.

This highlights the potential for adopting the system in international education settings, especially where angklung is introduced as a cross-cultural or world music subject.

6.3.4. Performance Score – With vs Without Musical Background

This section evaluates whether participants' prior experience with music affects their response to the three angklung training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The comparison was made between those who **had previous musical training** and those who **did not**.

Participant Group Definition

1. **With Musical Background (Y):** Participants who reported prior experience in music learning or playing other musical instruments before participating in the angklung experiment.
2. **Without Musical Background (N):** Participants with no prior formal or informal training in music.

Hypotheses
H_0 (Null Hypothesis): There is no significant difference in angklung-playing skill improvement among the three training methods (NB, HB, and HBP) for participants with or without musical background.
H_1 (Alternative Hypothesis): At least one training method leads to significantly different skill improvement between the two groups.

Friedman Test Results

Table 6.5: Friedman Test Results Performance Score – Musical Background

Musical Background	Chi-Square	p-value	Conclusion
Yes: 30/36	1.5556	0.4594	Not significant
No: 6/36	2.3333	0.3114	Not significant

Interpretation
The analysis indicates that **no significant difference** was found between the training methods for either group:

- Participants **with prior musical experience** did not gain significantly more benefit from any specific training method.
- Similarly, those **without musical experience** performed equally well across all three methods.

These findings emphasize that:

- The Cue-Guided System provides a **level learning field** for both musically trained and untrained learners.
- Each method—NB, HB, and HBP—was designed to be intuitive and supportive even for those without background knowledge of rhythm, notation, or ensemble performance.

This supports the broader usability of the system in inclusive educational settings where students may begin with varied levels of musical exposure.

6.3.5. Performance Score – Answering RQ2a

RQ2a: How does player performance change when using a Cue-Guided System?

Based on the experimental results and statistical analyses using the Friedman Test, this study found **no significant difference in timing accuracy improvement across the three training methods**: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). This finding held true across various participant profiles:

1. **Novice vs Experienced Players**: Both groups showed comparable performance improvements across NB, HB, and HBP. No method significantly outperformed the others.
2. **Indonesian vs Non-Indonesian Participants**: Cultural background did not affect the effectiveness of the training methods. Participants unfamiliar with angklung performed similarly to those with cultural exposure.
3. **With vs Without Musical Background**: Prior musical experience had no significant impact on performance outcomes. Both musically trained and untrained learners benefited equally from the training system.

Interpretation and Implication
Although no training method showed statistical superiority, the overall trend indicates that **each method effectively supports performance improvement** in its own way. NB provides visual predictability, HB introduces structured conductor gestures, and HBP offers anticipatory cues to aid timing. The absence of significant differences suggests that:

1. **The Cue-Guided System provides stable learning outcomes** regardless of the method used.

2. **Learners can start with any training method**, and do not require a fixed learning sequence (e.g., from NB to HB to HBP).
3. **The system design is robust across diverse learner profiles**, making it suitable for broader implementation in multicultural and mixed-skill educational settings.

In summary, RQ2a is answered as follows:
The Cue-Guided System supports angklung-playing performance consistently across different methods and participant types, enabling flexible and inclusive training without dependence on prior skill, culture, or sequence.

6.4. Results for RQ2b: Usability and User Engagement

This section presents the results related to RQ2b, which asks:
RQ2b: How do players experience usability and user engagement when using a Cue-Guided System?

To answer this question, the study employed two validated instruments:

1. **System Usability Scale (SUS)**: Measures the overall usability and simplicity of interacting with the training system.
2. **User Experience Questionnaire – Short Version (UEQ-S)**: Assesses players' perceptions of the system in terms of **pragmatic quality** (efficiency, clarity) and **hedonic quality** (stimulation, enjoyment).

The goal is to determine whether specific groups perceived differences in usability or engagement across the three training methods, and whether those perceptions align with their performance scores. Each sub-section will present **Friedman Test results** and **interpretation** for each comparison.

6.4.1. SUS Score

The System Usability Scale (SUS) is a widely recognized tool for assessing the usability of a system, product, or service. Developed by John Brooke in 1986, SUS consists of a 10-item questionnaire designed to capture users' subjective perceptions of a system's usability. Each item is scored on a 5-point Likert scale ranging from 1 ("Strongly Disagree") to 5 ("Strongly Agree"). The SUS provides a quick, reliable, and standardized way to evaluate the usability of a system, with scores ranging from 0 to 100. A SUS score above 68 is generally considered above average, while scores below this threshold indicate room for improvement.
This experiment employed the SUS to evaluate the usability of the three training methods (Notebar, Hand-Sign Bot, Hand-Sign Bot with Preview) from the perspective of novice angklung players. Specifically, the SUS was used to:

1. Measure User Satisfaction: Determine how intuitive and user-friendly each method was for participants without prior experience.
2. Identify Usability Issues: Highlight areas where each method could be improved based on user feedback.
3. Compare Methods: Provide a standardized way to compare the usability of the three training methods, aiding in evaluating their effectiveness.

The SUS questionnaire consists of 10 statements alternating between positive (+) and negative (-) phrasing to avoid response bias. Each question evaluates a specific aspect of usability (see Table 6.6 and 6.7).

Table 6.6: SUS List of Questions[110], [111], [112]

No	Questions	Type
Q1	I think I would like to use this training method frequently. *(Saya pikir saya ingin menggunakan metode pelatihan ini sesering mungkin.)*	(+)
Q2	I thought this training method was easy to use. *(Saya merasa metode pelatihan ini mudah digunakan.)*	(+)
Q3	I think I would need the support of a technical person to be able to use this training method. *(Saya pikir saya membutuhkan bantuan seseorang yang memiliki pengetahuan teknis untuk bisa menggunakan metode pelatihan ini.)*	(-)
Q4	I would imagine that most people would learn to use this training method very quickly. *(Saya yakin kebanyakan orang akan bisa belajar menggunakan metode pelatihan ini dengan cepat.)*	(+)
Q5	I felt very confident using this training method. *(Saya merasa percaya diri saat menggunakan metode pelatihan ini.)*	(+)
Q6	I needed to learn a lot of things before I could get going with this training method. *(Saya perlu mempelajari banyak hal terlebih dahulu sebelum dapat menggunakan metode pelatihan ini dengan baik.)*	(-)
Q7	I thought there was too much inconsistency in this training method. *(Saya merasa metode pelatihan ini memiliki terlalu banyak ketidakkonsistenan.)*	(-)
Q8	I found this training method unnecessarily complex. *(Saya merasa metode pelatihan ini terlalu rumit.)*	(-)
Q9	I found this training method very cumbersome to use. *(Saya merasa metode pelatihan ini sangat membingungkan saat digunakan.)*	(-)
Q10	I found the various functions in this training method were well-integrated. *(Saya merasa berbagai fungsi dalam metode pelatihan ini terintegrasi dengan baik.)*	(+)

Table 6.7: Explanation of SUS Questions [110], [111], [112]

No	Explanation	Type
Q1	Measures the perceived usefulness and likelihood of continued usage.	(+)
Q2	Assesses the perceived simplicity of the method.	(+)
Q3	Evaluates the system's independence and ease of adoption.	(-)
Q4	Gauges perceived ease of learning.	(+)
Q5	Reflects user confidence in operating the system.	(+)

No	Explanation	Type
Q6	Identifies potential learning barriers.	(-)
Q7	Assesses consistency in system design and functionality.	(-)
Q8	Measures the perceived complexity and whether it hinders usability.	(-)
Q9	Identifies perceived frustrations during usage.	(-)
Q10	Evaluates how seamlessly the system's features work together.	(+)

SUS scores are calculated by assigning points to each question:

1. For positively worded questions (Q1, Q2, Q4, Q5, Q10): Subtract 1 from the score.
2. For negatively worded questions (Q3, Q6, Q7, Q8, Q9): Subtract the score from 5.
3. Sum the adjusted scores and multiply by 2.5 to obtain a final score out of 100.

The SUS score ranges from 0 to 100, but it is not a percentage. Instead, it is a composite score that reflects the usability of a system. The interpretation of the scores is divided into several categories (see Table 6.8).

Table 6.8: SUS Score Scale [110], [111], [112]

SUS Score	Category	Interpretation
0 – 50	Poor	The system is difficult to use and requires major improvements.
51 – 67	Fair (OK)	Usable but with evident flaws that need addressing.
68 – 84	Good	The system is user-friendly and provides positive experience.
85 – 100	Excellent	The system is highly intuitive and offers exceptional usability.

SUS participant's score can be found at **Appendix L.**

6.4.1.1. SUS Score – Novice vs Experienced Players

This section compares the usability perception of the three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—between novice and experienced players, based on their System Usability Scale (SUS) responses.

Participant Group Definition

- **Novice Players**: Participants from the **NIN** and **INA** groups, with no formal angklung training.
- **Experienced Players**: Participants from the **SMA** group, with prior angklung ensemble experience.

Hypotheses

H_0 (Null Hypothesis): There is no significant difference in SUS scores among the three training methods (NB, HB, and HBP) for novice or experienced players.

H_1 (Alternative Hypothesis): At least one training method (NB, HB, or HBP) shows a significantly different SUS score for novice or experienced players.

Friedman Test Result

Table 6.9: Friedman Test Results SUS Score – Player-Level

Player-Level	Chi-Square	p-value	Conclusion
Novice: 27/36	25.2762	0.0000	Significant
Experienced: 9/36	15.9429	0.0003	Significant

The Friedman test shows statistically significant differences in usability scores among NB, HB, and HBP for both player groups.

Wilcoxon Signed-Rank Test
Novice

Comparison	Z-Score	p-value	Conclusion
SUS_NB vs. SUS_HB	20.5	0.0000	Significant
SUS_NB vs. SUS_HBP	24.5	0.0000	Significant
SUS_HB vs. SUS_HBP	137.5	0.7207	Not Significant

Experienced

Comparison	Z-Score	p-value	Conclusion
SUS_NB vs. SUS_HB	0	0.0039	Significant
SUS_NB vs. SUS_HBP	0	0.0039	Significant
SUS_HB vs. SUS_HBP	1	0.0158	Significant

Interpretation

1. Both novice and experienced participants rated HB and HBP as significantly more usable than NB.
2. Among novice players, HB and HBP were perceived similarly in usability.
3. Among experienced players, HBP was rated significantly more usable than HB, likely due to the added benefit of anticipatory cues.

These results indicate a clear preference for handsign-based systems over the visual-based Notebar method, particularly among users with musical training.

6.4.1.2. SUS Score – Indonesian vs Non-Indonesian Participants

This section presents the usability comparison of the three angklung training methods across participants from different cultural backgrounds—Indonesian and Non-Indonesian—using System Usability Scale (SUS) scores.

Participant Group Definition

- **Indonesian Participants**: Participants from the **INA** and **SMA** groups, culturally familiar with angklung and hand-sign systems.
- **Non-Indonesian Participants**: Participants from the **NIN** group, with no prior cultural exposure to angklung.

Hypotheses
H_0 (Null Hypothesis): There is no significant difference in SUS scores among the three training methods for Indonesian or non-Indonesian participants.
H_1 (Alternative Hypothesis): At least one training method yields a significantly different SUS score for Indonesian or non-Indonesian participants.

Friedman Test Result

Table 6.10: Friedman Test Results SUS Score – Nationality

Nationality	Chi-Square	p-value	Conclusion
Indonesian: 18/36	28.0845	0.0000	Significant
Non-Indonesian: 18/36	12.7826	0.0017	Significant

Statistical results show significant differences in SUS scores across training methods for both cultural groups.

Wilcoxon Signed-Rank Test
Indonesian Participants

Comparison	Z-Score	p-value	Conclusion
SUS_NB vs. SUS_HB	0	0.0000	Significant
SUS_NB vs. SUS_HBP	0	0.0000	Significant
SUS_HB vs. SUS_HBP	52.5	0.2520	Not Significant

Non-Indonesian Participants

Comparison	Z-Score	p-value	Conclusion
SUS_NB vs. SUS_HB	17	0.0016	Significant
SUS_NB vs. SUS_HBP	22	0.0040	Significant
SUS_HB vs. SUS_HBP	55.5	0.7982	Not Significant

Interpretation
1. For both Indonesian and Non-Indonesian participants, HB and HBP were significantly more usable than NB.
2. No significant difference was found between HB and HBP in either group.
3. This suggests that participants from different cultural backgrounds perceive Cue-Guided Systems as more usable, regardless of prior exposure to angklung.

6.4.1.3. SUS Score – With vs Without Musical Background

This section compares the System Usability Scale (SUS) scores based on participants' prior experience with music. The objective is to evaluate whether musical background influences usability perception across the three training methods.

Participant Group Definition
- **With Musical Background**: Participants who had prior training or experience in music (e.g., instrument playing, formal classes).

- **Without Musical Background**: Participants with no structured music learning experience.

Hypotheses
H_0 (Null Hypothesis): There is no significant difference in SUS scores among the three training methods based on musical background.
H_1 (Alternative Hypothesis): At least one training method yields a significantly different SUS score between participants with and without musical background.

Friedman Test Result

Table 6.11: Friedman Test Results SUS Score – Musical Background

Musical Background	Chi-Square	p-value	Conclusion
Yes: 30/36	33.1453	0.0000	Significant
No: 6/36	6.517	0.0384	Significant

Both groups showed significant differences in usability perception across training methods.

Wilcoxon Signed-Rank Test
With Musical Background

Comparison	Z-Score	p-value	Conclusion
SUS_NB vs. SUS_HB	15.5	0.0000	Significant
SUS_NB vs. SUS_HBP	19.5	0.0000	Significant
SUS_HB vs. SUS_HBP	153.5	0.3921	Not Significant

Without Musical Background

Comparison	Z-Score	p-value	Conclusion
SUS_NB vs. SUS_HB	0	0.0312	Significant
SUS_NB vs. SUS_HBP	1	0.0625	Not Significant
SUS_HB vs. SUS_HBP	5	0.5002	Not Significant

Interpretation
1. Participants with musical background found both HB and HBP significantly more usable than NB.
2. For participants without musical background, only HB showed significantly higher usability than NB.
3. Across both groups, the difference between HB and HBP was not statistically significant, though musical learners showed stronger preference patterns overall.

6.4.1.4. Answering RQ2b Based on SUS Score

Research Question 2b (RQ2b):
How do players experience usability and user engagement when using a Cue-Guided System?

To address RQ2b in terms of usability, the System Usability Scale (SUS) results were analyzed using non-parametric Friedman Tests followed by Wilcoxon Signed-Rank Tests as post-hoc analysis. The analysis was grouped by player type (novice vs. experienced), cultural background (Indonesian vs. non-Indonesian), and musical background (with vs. without musical experience).

Key Findings

1. **Across All Groups**
   There were statistically significant differences in SUS scores among the three training methods (Notebar, Hand-Sign Bot, and Hand-Sign Bot with Preview), indicating that players perceived different levels of usability for each method.
2. **Novice Players**
   - HB and HBP were rated significantly higher than NB.
   - No significant difference between HB and HBP, suggesting that both hand-sign-based methods were similarly usable for novices. Although HBP was designed to offer anticipatory cues that support mental preparation, the lack of significant difference with HB may be attributed to the simplicity of the musical task and limited exposure time.
3. **Experienced Players**
   - Significant differences were found between all pairs (NB–HB, NB–HBP, HB–HBP).
   - HBP was perceived as slightly more usable than HB, with both outperforming NB.
4. **Indonesian and Non-Indonesian Participants**
   - Both groups rated HB and HBP higher than NB.
   - Among non-Indonesian participants, the difference between HB and HBP was not significant.
   - Indonesian participants did not show a preference between HB and HBP either, suggesting cultural familiarity did not strongly influence SUS outcomes between the two cue-guided methods.
5. **Participants with Musical Background**
   - Strong preference for HB and HBP over NB.
   - No significant difference between HB and HBP.
6. **Participants without Musical Background**
   - Significant preference for HB over NB.
   - No significant difference between NB and HBP or between HB and HBP.

Conclusion

SUS results confirm that **hand-sign training** methods (HB and HBP) are perceived as significantly more usable than the baseline Notebar system (NB) across different participant groups. While no single cue-guided method was universally superior, both HB and HBP offer enhanced usability experiences for self-guided angklung practice, fulfilling part of the study's objective to create a usable training system for novice learners. The intended usability enhancement from HBP's anticipatory preview (designed to support mental preparation) did not lead to statistically higher SUS ratings. This suggests that while anticipatory design may conceptually benefit timing readiness, its practical impact requires further validation under more complex or prolonged training conditions.

6.4.2 User Experience Evaluation (UEQ-S)

The UEQ-S is a validated tool designed to measure user experience across six key dimensions, providing insights into how users perceive the system in terms of usability, engagement, and overall satisfaction. This study utilized a 7-point scale for the UEQ-S, ranging from -3 to +3, where negative values indicate a negative perception, and positive values indicate a positive perception. The scale allows for a nuanced understanding of user feedback, capturing subtle differences in user experience.

Dimensions of UEQ-S

The UEQ-S measures the following six dimensions of user experience:

1. Attractiveness – General appeal of the system.
2. Perspicuity – Ease of learning and understanding.
3. Efficiency – Speed and performance.
4. Dependability – Control and predictability.
5. Stimulation – Engagement and enjoyment.
6. Novelty – Innovativeness and uniqueness.

UEQ-S Questions

The UEQ-S consists of eight questions, each representing a pair of contrasting adjectives. Participants were asked to rate their experience on a 7-point scale between the two extremes (see table 6.12). The questions are as follows:

Table 6.12: UEQ-S Questions [115], [116]

No	Left Side (Negative)	Right Side (Positive)
Q1	Menghalangi (Obstructive)	Mendukung (Supportive)
Q2	Rumit (Complicated)	Sederhana (Easy)
Q3	Tidak efisien (Inefficient)	Efisien (Efficient)
Q4	Membingungkan (Confusing)	Jelas (Clear)
Q5	Membosankan (Boring)	Mengasyikkan (Exciting)
Q6	Tidak menarik (Not interesting)	Menarik (Interesting)
Q7	Konvensional (Conventional)	Berdaya Cipta (Inventive)
Q8	Lazim (Usual)	Terdepan (Leading Edge)

The UEQ-S was administered to participants after they interacted with the system. Each question was designed to capture one or more of the six dimensions of user experience. For example:

1. Q1 and Q6 primarily measure Attractiveness.
2. Q2 and Q4 focus on Perspicuity.
3. Q3 evaluates Efficiency.
4. Q1 also contributes to Dependability.
5. Q5 assesses Stimulation.
6. Q7 and Q8 measure Novelty.

The use of a 7-point scale ensures that the data collected is granular enough to detect subtle variations in user perception. This approach allows for a comprehensive analysis of user experience, highlighting both strengths and areas for improvement in the system.

6.4.2.1. UEQ-S Score – Novice vs Experienced

This section explores the perceived user experience of the three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—from the perspective of novice and experienced angklung players. The analysis is based on the 8-item User Experience Questionnaire Short (UEQ-S), which captures perceptions across pragmatic (e.g., clarity, ease, supportiveness) and hedonic (e.g., excitement, inventiveness, modernity) dimensions. Each item is scored on a 7-point semantic differential scale. The comparison uses descriptive analysis of score patterns and thematic interpretation supported by visualizations.
The primary aim is to understand how player experience level influences their perception of usability and engagement across different training methods.

Visual Analysis

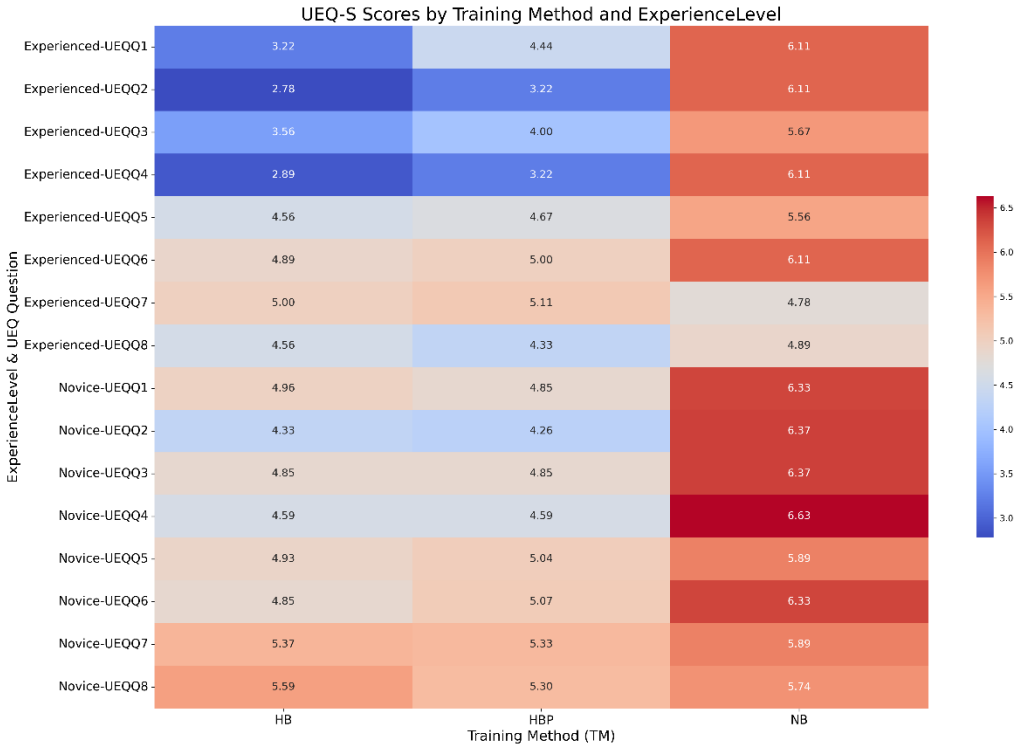


Figure 6.2: Heatmap UEQ-S - Player-Level

The heatmap shows average UEQ-S responses grouped by player experience level and training method:

Observation Highlights

1. **NB** consistently received the **highest average scores** across almost all UEQ-S items for both novice and experienced players.

2. **HB** was perceived **less favorably**, particularly in items Q2 (Complicated–Easy), Q3 (Inefficient–Efficient), and Q4 (Confusing–Clear), especially by experienced players.
3. **HBP** was often rated **moderately** between NB and HB, particularly for excitement and inventiveness.

Summary Table: UEQ-S Interpretation per Item

UEQ-S Question	Novice	Experienced
Q1: Obstructive – Supportive	NB most supportive, HB acceptable, HBP moderate	NB most supportive, HB least supportive
Q2: Complicated – Easy	NB easiest, HBP okay, HB more complex	NB easiest, HB very complicated
Q3: Inefficient – Efficient	NB most efficient, HBP better than HB	NB most efficient, HB lowest
Q4: Confusing – Clear	NB clearest, HB most confusing	NB clearest, HB very confusing
Q5: Boring – Exciting	NB & HBP more exciting, HB slightly less	NB most exciting, others neutral
Q6: Not Interesting – Interesting	NB & HBP interesting, HB lower	NB most interesting
Q7: Conventional – Inventive	HBP and HB seen as inventive	HB slightly more inventive
Q8: Usual – Leading Edge	NB and HBP rated as modern	NB most modern, HBP also accepted

Thematic Interpretation

1. **Support & Simplicity (Q1–Q4):**
   Both novice and experienced users overwhelmingly favored NB for being supportive, easy, and clear. This suggests that NB provides a more stable and predictable user interface, particularly helpful during the initial learning process.
2. **Engagement & Motivation (Q5–Q6):**
   HBP scored competitively with NB in excitement and interest among novices, indicating its potential to sustain player motivation. Experienced players, however, were more neutral—possibly due to a preference for streamlined interfaces.
3. **Creativity & Innovation (Q7–Q8):**
   HBP and HB were perceived as more inventive, especially among experienced players. This reflects their appreciation for the handsign-cue interaction style, even if it required more effort to learn.

Conclusion

In summary, **NB emerged as the most favored training method in terms of clarity, ease of use, and user support**, especially for novice players. While **HBP was appreciated for its inventive and engaging qualities**, **HB tended to receive the lowest scores**, particularly among experienced users, due to its relative complexity.

These results support the idea that experience level significantly influences user perceptions of usability and engagement. The Cue-Guided Systems (HB and HBP), while more complex, show potential value in long-term learning and creative engagement, particularly when preceded by NB.

6.4.2.2. UEQ-S Score – Indonesian vs Non-Indonesian

This section compares the perceived user experience of the three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—between Indonesian and Non-Indonesian participants. Using the UEQ-S questionnaire, this analysis seeks to identify cultural or contextual differences in how users interact with each system. The responses are evaluated descriptively using heatmaps and thematic interpretation to uncover patterns across the 8 usability and engagement dimensions.

This analysis provides insights into cross-cultural reception of digital angklung training methods, an important factor given angklung's cultural roots and the diversity of this study's participant base.

Visual Analysis

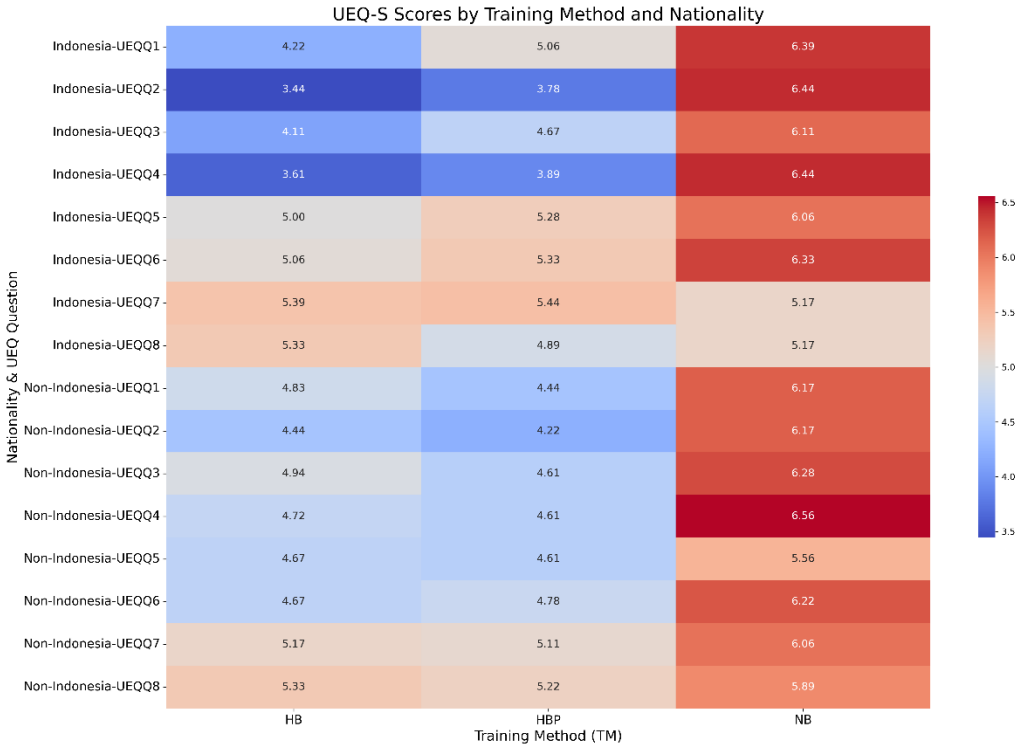


Figure 6.3: Heatmap UEQ-S - Nationality

The heatmap illustrates average UEQ-S scores across eight questions for both Indonesian and Non-Indonesian participants:

Observation Highlights

1. **Both groups consistently rated NB the highest**, especially in **clarity (Q4)** and **efficiency (Q3)**.
2. **HB** received mixed reactions, with **Indonesians perceiving it as more confusing** (Q4), while **Non-Indonesians rated it more moderately**.

3. **HBP** received moderate to positive responses in excitement (Q5), inventiveness (Q7), and modernity (Q8), especially from Non-Indonesians.

Summary Table: UEQ-S Interpretation per Item

UEQ-S Question	Indonesian	Non-Indonesian
Q1: Obstructive – Supportive	NB most supportive, HB obstructive	NB top, HB more accepted
Q2: Complicated – Easy	NB easiest, HB complex	NB easiest, HBP moderate
Q3: Inefficient – Efficient	NB most efficient, HB lowest	NB most efficient, HB acceptable
Q4: Confusing – Clear	NB clearest, HB confusing	NB clearest, HB less confusing
Q5: Boring – Exciting	NB most exciting, HBP moderate	HB & HBP more engaging
Q6: Not Interesting – Interesting	NB most interesting, HBP better than HB	HB & HBP more interesting than for Indonesians
Q7: Conventional – Inventive	HBP slightly more inventive	HB and HBP inventive
Q8: Usual – Leading Edge	NB most modern, HBP acceptable	HB and HBP seen as modern

Thematic Interpretation

1. **System Familiarity & Clarity (Q1–Q4):**
   Indonesian participants strongly favored NB for supportiveness, ease, and clarity, and showed greater difficulty with HB, possibly due to unfamiliarity with its gesture-based mechanics or different expectations regarding digital training tools.
2. **Engagement & Interest (Q5–Q6):**
   Non-Indonesians rated HB and HBP more favorably than Indonesians in terms of excitement and interest. This suggests that non-local users may perceive the cue-guided methods as novel and stimulating, whereas Indonesian users may view NB as more aligned with traditional instruction styles.
3. **Perceived Innovation (Q7–Q8):**
   Both groups recognized HB and HBP as inventive and modern. However, Indonesians still gave NB the edge in modernity—possibly reflecting their cultural affinity and greater familiarity with the angklung training content provided in NB.

Conclusion

NB remains the most accessible and favorably perceived training method across both groups. However, **Non-Indonesian participants showed greater appreciation for the interactive and novel nature of HB and HBP**, especially in terms of engagement. In contrast, **Indonesian participants preferred NB's clarity and structure**, likely due to closer alignment with their expectations or prior learning experiences with angklung.
These findings suggest that cultural familiarity plays a significant role in shaping user experience, especially when introducing non-traditional, technology-mediated music training tools.

6.4.2.3. UEQ-S Score – With vs Without Musical Background

This section examines how participants with and without prior musical experience perceived the usability and user experience of the three angklung training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—based on UEQ-S responses. As musical background can affect familiarity with timing, rhythm, and coordination, this analysis helps determine whether prior exposure to music influences engagement and usability perceptions.
The analysis uses descriptive interpretations and group-based comparisons across the eight UEQ-S dimensions.

Visual Analysis

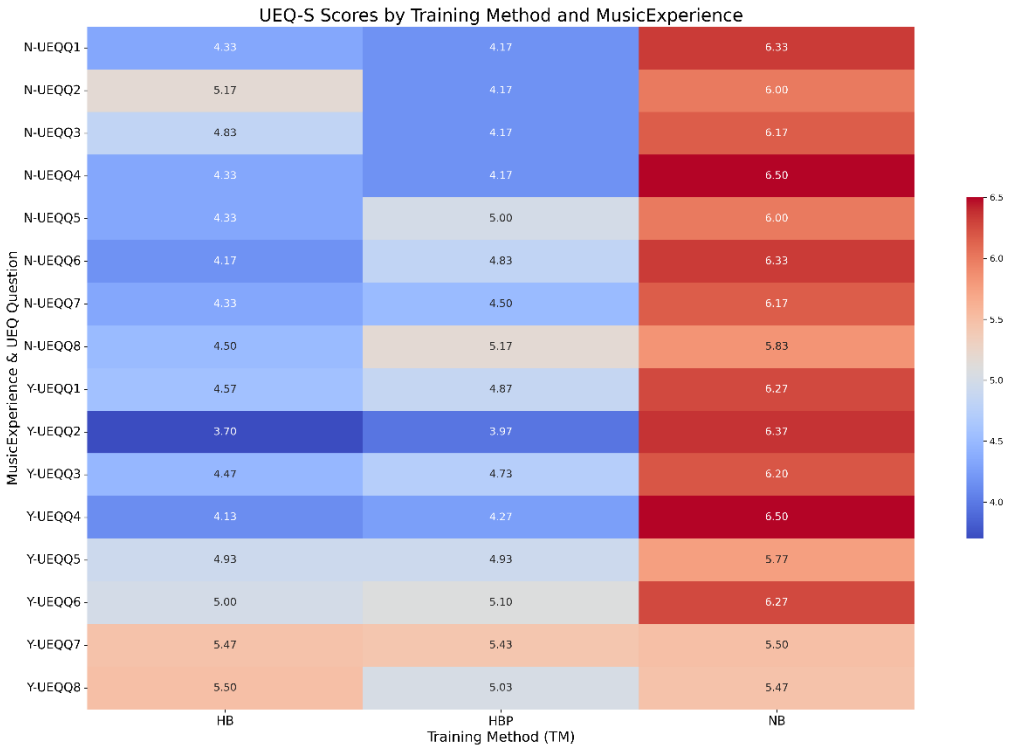


Figure 6.4: Heatmap UEQ-S - Music Background

The heatmap summarizes how participants evaluated each method across eight experience-related questions:

Observation Highlights

1. **NB** was favored across most pragmatic items (Q1–Q4) by **both groups**, indicating its clarity and ease of use.
2. **HB** received **lower scores**, especially among those **without music experience**, who rated it confusing, obstructive, and inefficient.
3. **HBP** scored well in **engagement-related items** (Q5–Q7), especially among participants with a musical background.

Summary Table: UEQ-S Interpretation per Item

UEQ-S Question	With Music Experience	Without Music Experience
Q1: Obstructive – Supportive	NB & HBP supportive, HB acceptable	NB supportive, HB obstructive
Q2: Complicated – Easy	NB & HBP easy, HB harder	NB easiest, HB & HBP very difficult
Q3: Inefficient – Efficient	NB & HBP efficient, HB moderate	NB efficient, HB & HBP not efficient
Q4: Confusing – Clear	NB & HBP clear, HB confusing	NB very clear, HB & HBP confusing
Q5: Boring – Exciting	HB & HBP engaging, NB still top	NB most exciting, others boring
Q6: Not Interesting – Interesting	NB & HBP interesting	NB most interesting, HB & HBP not appealing
Q7: Conventional – Inventive	HB & HBP inventive	NB seen as inventive, others less
Q8: Usual – Leading Edge	HB & HBP modern, NB solid	NB modern, others confusing

Thematic Interpretation

1. **Ease and Efficiency (Q1–Q4):**
   Participants **without music experience** strongly preferred NB for its clarity and ease, while finding HB and HBP too complex. Conversely, **participants with musical experience** were more open to HBP, rating it nearly as efficient and supportive as NB.
2. **Engagement and Motivation (Q5–Q6):**
   Music-experienced participants appreciated HB and HBP for their **engagement and inventiveness**, suggesting that they were comfortable with more interactive systems. In contrast, non-musicians gravitated to the simplicity and predictability of NB.
3. **Innovation and Perceived Modernity (Q7–Q8):**
   Participants with music backgrounds saw HB and HBP as modern and inventive. Interestingly, non-musicians still associated NB with modernity, perhaps because its intuitive, visual-based interface is similar to popular rhythm games.

Conclusion

User experience with angklung training methods varies significantly based on musical background. **Participants without prior musical experience clearly favored NB**, while **participants with music experience were more receptive to HBP**, and to some extent, HB. These results highlight the importance of **tailoring digital music training tools** to different learner profiles—providing simplicity and structure for novices, while allowing interactive engagement for more musically inclined learners.

6.4.2.4. Answering RQ2b Based on UEQ-S Score

Restatement of RQ2b

RQ2b: *How do players experience usability and user engagement when using a Cue-Guided System?*

This sub-question seeks to understand the perceived usability and emotional appeal of the training system, as experienced by diverse participant groups. While the SUS score

provides a standardized measure of usability, the UEQ-S expands the analysis by examining multiple user experience dimensions, including clarity, efficiency, excitement, and innovativeness.

Summary of Findings from UEQ-S

Across all participant groups, the **Notebar (NB)** method consistently received **higher scores** in pragmatic dimensions—such as *ease of use, clarity, efficiency, and supportiveness*. This indicates that NB was universally accessible and well-suited for novices.

However, in hedonic dimensions—such as *engagement, inventiveness, and modernity*—**Hand-Sign Bot with Preview (HBP)** emerged as a strong alternative, especially among participants with musical experience or non-Indonesian cultural backgrounds. **Hand-Sign Bot without Preview (HB)** tended to receive the lowest ratings overall, particularly in terms of clarity and ease, though it was still perceived as inventive by some participants.

Group-Specific Observations

1. **Novice Participants:** Strongly preferred NB for its clarity and ease. HB was perceived as confusing, while HBP was more engaging but still slightly difficult.
2. **Experienced Players:** Recognized NB's efficiency but were more open to HBP's inventive and dynamic interface.
3. **Indonesian Participants:** Rated NB highest across all items, reflecting cultural familiarity and perhaps preference for structured guidance.
4. **Non-Indonesian Participants:** Showed greater appreciation for HB and HBP, especially in engagement and innovation.
5. **With Musical Background:** Valued HBP for its interactivity and excitement; NB was still rated highly in usability.
6. **Without Musical Background:** Preferred NB almost exclusively; HB and HBP were seen as difficult and unclear.

Conclusion

The results from the UEQ-S confirm that **RQ2b can be answered positively**, with important nuances:

- **NB is the most universally usable and supportive system**, especially for novices.
- **HBP introduces more engagement and innovation**, and is preferred by musically trained users.
- **HB is seen as inventive but presents usability challenges**, especially among non-musicians and novices.

These insights demonstrate that different training methods offer distinct user experiences and may be strategically introduced based on learner profiles. A flexible, learner-centered approach to system deployment is essential for optimizing usability and engagement in digital angklung training.

6.4.3. Players Experience Usability and User Engagement - Answering RQ2b

Restatement of RQ2b

RQ2b: *How do players experience usability and user engagement when using a Cue-Guided System?*

This research question was addressed through two complementary user experience instruments: the **System Usability Scale (SUS)** and the **User Experience Questionnaire – Short (UEQ-S)**. These instruments were applied across different participant backgrounds, including experience level, nationality, and musical background, to evaluate how users interact with and perceive the Cue-Guided Angklung Training System.

Insights from SUS

The SUS results revealed the following patterns:

1. **NB consistently received the highest usability scores**, significantly outperforming HB and HBP across all participant groups.
2. **HBP showed moderate usability**, often ranking above HB but below NB.
3. **HB was perceived as the least usable**, with several groups finding its interface confusing or demanding.

These results indicate that **NB is the most accessible training method**, especially for users without prior musical training or experience in ensemble-based learning.

Insights from UEQ-S

The UEQ-S provided a richer picture of user engagement and emotional experience:

1. **NB was rated highest in supportiveness, clarity, and efficiency**, reinforcing its role as a novice-friendly interface.
2. **HBP was perceived as more engaging, inventive, and modern**, particularly by users with musical experience and non-Indonesian participants.
3. **HB was consistently rated lower in clarity and ease**, though some users still appreciated its innovative approach to hand-sign conducting.

While **NB led in pragmatic usability**, **HBP gained recognition for emotional and creative appeal**, making it a potential bridge between basic training and more expressive performance development.

Conclusion

The findings from SUS and UEQ-S together offer a comprehensive answer to RQ2b:

1. The Cue-Guided Angklung Training System is usable and engaging, but **player perception varies depending on the training method and individual background**.
2. **NB serves as the most accessible and usable entry point**, particularly for novice.
3. **HBP introduces meaningful engagement through anticipatory hand-signs**, which enhance user interaction, especially for musically experienced players.
4. **HB is seen as less intuitive but still inventive**, suggesting room for improvement in gesture clarity or instructional support.

In this study, "usable" in the SUS context refers to the pragmatic aspects of interaction—such as clarity, ease, and system efficiency—while "usable" in UEQ-S includes broader experiential factors like emotional appeal and innovation. Recognizing these distinct constructs prevents misinterpretation and reinforces that both tools serve complementary purposes in evaluating the system.

In sum, the Cue-Guided Angklung Training System supports diverse user experiences, but its effectiveness depends on proper alignment between method complexity and player readiness. These insights highlight the value of adaptable, multi-method training strategies for digital angklung education.

6.5. Participant Feedback on Training Methods: Supplementary Qualitative Analysis

This section presents an analysis of participant feedback regarding different training methods, including Human Conductor (HC), Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). The feedback was gathered from participants, reflecting their perceptions of usability, realism, and challenge of each method (see Appendix O).

This section presents a **supplementary analysis** based on open-ended participant feedback collected after the experimental sessions. While the primary evaluations in this study focused on performance scores (RQ2a), system usability (RQ2b), and expert evaluation (RQ2c), this qualitative exploration was conducted to gain additional insights into users' subjective experiences with each cue-guided training method.

Qualitative Data Analysis (QDA) is a method for systematically examining non-numerical data—such as textual responses—to identify patterns, themes, and meanings that emerge from participants' expressions (Braun & Clarke, 2006) [128]. This approach does not aim to generalize findings statistically but rather to enrich the understanding of how users interacted with the system and what aspects they found intuitive, difficult, enjoyable, or confusing. As Braun and Clarke emphasize:

"Thematic analysis is a method for identifying, analyzing, and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail" (Braun & Clarke, 2006, p. 79).

In this study, participant feedback was analyzed using a six-step QDA framework, adapted from thematic analysis methodology. The six stages consisted of:

1. **Data Familiarization** – immersing in the feedback data to gain an initial understanding.
2. **Initial Coding** – labeling recurring phrases and key expressions from participants.
3. **Thematic Analysis** – grouping codes into broader conceptual categories.
4. **Frequency Analysis** – identifying how often certain codes or themes appeared.
5. **Data Interpretation** – visualizing and explaining the relationships across themes and user groups.
6. **Conclusion & Recommendations** – summarizing insights and suggesting improvements to the training system.

While this analysis is not intended to formally address the research questions, it serves to provide interpretive value and inform future development by presenting grounded

feedback from actual users. The following sections describe each step of the analysis in turn.

6.5.1. Step 1: Data Familiarization

The first stage in the qualitative data analysis process involved immersing in the complete set of open-ended responses provided by participants across all three cue-guided training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). At this stage, the researcher systematically read through all responses multiple times to become familiar with the tone, language, and overall sentiment expressed by the users.

The purpose of this step was to gain an initial holistic understanding of the dataset and to identify early impressions, such as whether users found a method intuitive, confusing, enjoyable, or challenging. Observations included recurring descriptive terms like *"easy to follow," "realistic movement," "too fast,"* and *"helpful for timing."*

During familiarization, responses were reviewed with an open mind, without any predefined assumptions or categories. This stage helped the researcher prepare for the next step—initial coding—by identifying subtle nuances and emotionally charged expressions that may not immediately appear significant in quantitative evaluation tools such as SUS or UEQ-S.

This process also allowed the researcher to note early contrasts between participant groups, such as novice users commenting more frequently on timing difficulties or visual overload, while experienced users were more likely to highlight differences in gesture clarity and rhythm interpretation. In summary, data familiarization provided the interpretive groundwork necessary for deeper and more structured analysis in the following stages of the QDA process.

6.5.2. Step 2: Initial Coding

Following familiarization, the second step of the qualitative data analysis focused on generating initial codes. This stage involved systematically identifying and labeling significant features within each participant's comment. The aim was to segment the feedback into manageable units of meaning, which would later serve as the foundation for theme development.

Each comment was broken down into short phrases or statements that conveyed a distinct idea or emotional response. These segments were then assigned **descriptive codes**—concise labels that captured the essence of the content. For example:

- "I really like the colors, it makes it easy to follow" → *visual clarity, ease of use*
- "The hand signs were too fast for me" → *gesture speed, timing difficulty*
- "I enjoy playing with this system. It feels like a game." → *engagement, enjoyment*

To ensure consistency, a coding guide was created and iteratively refined as more data were reviewed. When applicable, certain codes were also annotated with **participant characteristics**, such as *novice*, *experienced*, or *with music background*, allowing for later comparison across categories.

Coding was performed inductively, meaning no predefined categories were imposed. Instead, the codes emerged from the data itself—reflecting the natural expressions and

recurring concerns of the users. This inductive approach allowed for unexpected findings to surface and maintained the exploratory spirit of the analysis.

By the end of this phase, a comprehensive list of codes was compiled, encompassing a range of experiential domains such as *usability*, *visual design*, *hand-sign recognition*, *timing perception*, and *learning motivation*. These codes were then grouped into larger categories during the subsequent thematic analysis phase.

6.5.3. Step 3: Thematic Analysis

In the third stage of the QDA process, the codes generated during initial coding were systematically examined and clustered into broader themes. These themes represent higher-order concepts that encapsulate patterns across multiple participant responses. The goal of this step was to move beyond individual expressions and identify underlying dimensions that characterized the user experience with each cue-guided training method. Through iterative review and comparison, the following three major themes were identified:

1. **Usability**
   This theme encompassed comments related to how intuitive, clear, or confusing the system was to operate. Participants frequently mentioned aspects such as ease of following cues, clarity of visual and hand-sign instructions, and perceived cognitive load.
   Example: "NB is easier to follow because I can see when to start and stop."
2. **Realism**
   This theme emerged around perceptions of the naturalness and authenticity of the hand-sign animations. Many participants compared the digital hand gestures to human conductors, noting whether the movements felt believable or robotic.
   Example: "HB looks closer to a real conductor, but sometimes the movement feels stiff."
3. **Challenge**
   The third theme captured participants' reflections on difficulty, particularly concerning timing, speed of cues, and cognitive coordination. Some users noted that the cues were "too fast" or "hard to keep up with," especially in HBP, which introduced anticipatory elements.
   Example: "I had trouble keeping up with the gestures. It moved too fast and made me anxious."

The thematic analysis provided a structured way to interpret users' subjective experiences, guiding the next stage—frequency analysis—to understand how prevalent each theme was and whether any patterns emerged across participant groups.

6.5.4. Step 4: Frequency Analysis

To quantify the prominence of the themes identified in the previous step, a frequency analysis was conducted across all participant comments. Each comment was coded according to whether it reflected elements of *Usability*, *Realism*, or *Challenge*. The analysis was applied to feedback from the three cue-guided training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—based on actual participant data from the final version of the dataset.

The following table summarizes the frequency of each theme by training method:

Table 6.13: Summarizes the frequency of each theme by training method

Method	Usability	Realism	Challenge
NB	16	1	0
HB	6	9	19
HBP	0	0	17

These findings highlight clear patterns in user perception:

- **NB (Notebar)** was most frequently associated with *usability* themes. Participants repeatedly mentioned how easy it was to follow, describing it as structured, predictable, and novice-friendly. Very few participants linked NB with realism or challenge, suggesting it was effective for clarity but lacked expressive or musical depth.
- **HB (Hand-Sign Bot without Preview)** received more balanced feedback across themes. Many users acknowledged the system's *realistic* gestures, comparing it favorably to a human conductor. However, a high number of *challenge-related* comments also emerged, particularly regarding gesture abruptness, timing rigidity, and the cognitive effort required to follow the movements.
- **HBP (Hand-Sign Bot with Preview)** was almost exclusively linked to the *challenge* theme. Despite its aim to support anticipation, participants expressed confusion and cognitive overload due to the dual-conductor structure and fast-paced instructions. No usability or realism themes were directly associated with HBP in the coded feedback.

To further explore how these patterns may vary across participant backgrounds, the next section interprets the thematic results by comparing responses from novice and experienced users, Indonesian and non-Indonesian participants, and those with or without prior music training.

6.5.5. Step 5: Data Interpretation

This step synthesizes the frequency data into interpretive insights by examining how different participant groups experienced each cue-guided training method. The aim is to contextualize how the themes of Usability, Realism, and Challenge varied not only across the methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—but also across participant backgrounds. While the previous step presented aggregate theme frequencies per method, this section highlights patterns observed within three key categories:

1. Skill Level: Novice vs Experienced
2. Cultural Background: Indonesian vs Non-Indonesian
3. Musical Background: With vs Without Music Experience

1. Skill Level: Novice vs Experienced

Method	Usability	Realism	Challenge	← Participant Group
NB	10	1	0	Novice
HB	4	5	14	Novice
HBP	0	0	15	Novice
NB	6	0	0	Experienced
HB	2	4	5	Experienced
HBP	0	0	2	Experienced

Interpretation:
Novice participants strongly associated NB with usability and expressed difficulty with HB and especially HBP, where challenge themes dominated. In contrast, experienced participants were more tolerant of the complexity in HB and HBP, and commented more frequently on realism, especially in HB. NB remained usable for both groups, but more appreciated by novices.

2. Cultural Background: Indonesian vs Non-Indonesian

Method	Usability	Realism	Challenge	← Participant Group
NB	7	0	0	Indonesian
HB	4	6	11	Indonesian
HBP	0	0	4	Indonesian
NB	9	1	0	Non-Indonesian
HB	2	3	8	Non-Indonesian
HBP	0	0	13	Non-Indonesian

Interpretation:
Indonesian participants appeared more comfortable with HB, recognizing its realism and reporting fewer challenges than non-Indonesian users. In contrast, non-Indonesians reported higher levels of confusion, particularly with HBP. NB was universally usable, with slightly stronger usability recognition among non-Indonesians, likely due to its clear visual structure.

3. Musical Background: With vs Without Music Experience

Method	Usability	Realism	Challenge	← Participant Group
NB	13	0	0	With Music
HB	5	9	17	With Music
HBP	0	0	13	With Music
NB	3	1	0	No Music
HB	1	0	2	No Music
HBP	0	0	4	No Music

Interpretation:
Participants with music experience appreciated the realism of HB more than those without. However, even musically trained users reported high challenge when using HB and HBP, indicating that realistic or complex cues still required adaptation. Those without music experience preferred NB, which they found easy to use and non-threatening, while rarely associating it with realism or challenge.

Overall Synthesis

1. NB was consistently described as clear and supportive, particularly for novices and non-musicians.
2. HB received the highest recognition for realism but also had a high cognitive cost, especially among non-Indonesians and novices.
3. HBP was associated almost exclusively with challenge, confirming its demanding nature and indicating the need for a more gradual introduction or simplified version for self-training contexts.

These insights reflect the diversity of user experiences and reinforce the value of tailoring cue-guided methods to specific learner profiles. The next step synthesizes these observations into recommendations for improving system usability and engagement.

6.5.6. Step 6: Conclusion and Recommendations

This final stage summarizes the key findings from the thematic and frequency-based analysis and proposes targeted improvements to the cue-guided training system. The qualitative insights, derived from coded participant comments, revealed nuanced differences in how users with varying backgrounds perceived each training method in terms of usability, realism, and challenge.

Summary of Findings

1. **Notebar (NB)** was the most widely praised for its **usability**, especially by novice users, non-musicians, and non-Indonesian participants. It was perceived as clear, structured, and supportive—but **also lacked expressive depth and realism**.
2. **Hand-Sign Bot without Preview (HB)** received strong feedback in terms of realism, particularly among experienced and musically trained users. However, it also generated a **high number of challenge-related** comments, indicating issues with gesture fluidity, rigidity, and timing.
3. **Hand-Sign Bot with Preview (HBP)** was consistently linked to **challenges across all user groups**. Although some participants valued the anticipatory cue structure, many reported difficulty processing the dual-conductor system and described the method as overwhelming or unnatural.

These findings suggest that different user profiles require different types of cue support, and no single method is universally effective for all learners.

Recommendations for System Improvement

1. **Progressive Method Transition:** Introduce a gradual pathway from NB to HB and eventually to HBP, allowing users to build rhythm awareness and visual-motor coordination before encountering anticipatory cues.
2. **User Profiling for Personalization:** Incorporate optional user profiling (e.g., self-declared musical background or familiarity with angklung) to suggest a starting method and adjust cue complexity accordingly.
3. **Gesture Refinement for HB:** Improve gesture design in HB to enhance fluidity and reduce abrupt transitions. Smoother motion would improve followability and reduce timing-related confusion.
4. **Cognitive Load Reduction in HBP:** Simplify the HBP interface by optimizing the timing and spatial separation of main and sub-conductor cues. Consider limiting HBP to intermediate or advanced training modules.
5. **Multilingual/Cultural Guidance for Hand-Sign Cues:** For non-Indonesian users, include brief visual or textual explanations of hand-sign meaning, particularly for those unfamiliar with angklung conducting conventions.
6. **Visual Accessibility Enhancements for NB:** Address specific usability barriers such as color-blind accessibility or excessive visual similarity, ensuring the NB interface supports diverse perceptual needs.

These participant-based insights not only validate the observed system limitations but also directly inform the development priorities outlined in the next chapter. The challenges and preferences expressed here form a critical foundation for defining future improvements in cue-guided angklung training, both in terms of usability and cultural-musical alignment.

6.6. Expert Evaluation of HB and HBP

To assess the effectiveness of Hand-Sign Bot without Preview (HB) and Hand-Sign Bot with Preview (HBP) as training tools for novice angklung players, expert evaluations were conducted. Four angklung instructors (two senior and two junior), each with varying levels of teaching experience ranging from two to fifty-four years, provided insights into the advantages, limitations, and areas for improvement of HB and HBP compared to traditional Human Conductor (HC)-led training. Their assessments aimed to determine how well HB and HBP replicate real-world conductor-led angklung training and their potential impact on angklung education (see Appendix A).

6.6.1. Framework Analysis (FA) Methodology

To systematically analyze expert evaluations, Framework Analysis (FA) was applied. FA is a structured method for analyzing qualitative data, particularly useful when evaluating pre-defined research questions and identifying thematic patterns in interview data. The FA process in this study consisted of the following steps:

1. **Familiarization:** Experts' feedback was transcribed, and initial observations were made regarding recurring themes.

2. **Identifying a Thematic Framework: Four** key themes emerged based on expert input:
    a. Gesture clarity and accuracy – How well HB and HBP replicate the hand-sign gestures used in traditional conductor-led angklung training.
    b. Effectiveness for novice training – The ability of HB and HBP to serve as substitutes or enhancements for human conductor-led instruction.
    c. Realism and resemblance to a human conductor – The degree to which HB and HBP replicate the natural movements, expressiveness, and flexibility of a human conductor.
    d. Limitations and areas for future improvement – Identifying potential refinements to improve HB and HBP's usability, efficiency, and adaptability.
3. **Indexing and Coding:** Each expert response was categorized under the relevant themes, ensuring that findings were systematically mapped to each research question.
4. **Charting:** Data were organized into a structured matrix to compare insights across experts, allowing for a clearer visualization of patterns and relationships between themes.
5. **Mapping and Interpretation:** Thematic insights were analyzed to derive actionable conclusions and recommendations for HB and HBP refinement, aligning with RQ2c.

Summary of FA Stages in This Study

1. **Familiarization:** We invited four angklung experts with diverse teaching backgrounds, ranging from two to fifty-four years of experience. The experts provided insights on HB and HBP in comparison to HC, focusing on their advantages, limitations, and areas for improvement. Their responses were transcribed and reviewed to identify recurring themes.
2. **Identifying a Thematic Framework:** Based on the initial analysis of expert feedback, four main themes emerged:
    a. Gesture clarity and accuracy – How well HB and HBP replicate the hand-sign gestures used in traditional conductor-led angklung training.
    b. Effectiveness for novice training – The ability of HB and HBP to serve as substitutes or enhancements for human conductor-led instruction.
    c. Realism and resemblance to a human conductor – The degree to which HB and HBP replicate the natural movements, expressiveness, and flexibility of a human conductor.
    d. Limitations and areas for future improvement – Identifying potential refinements to improve HB and HBP's usability, efficiency, and adaptability.
3. **Indexing and Coding:** Each expert's response was categorized according to the thematic framework. Specific comments and observations were mapped under the four predefined themes, allowing structured comparison. This step ensured consistency in analyzing qualitative feedback from different experts.
4. **Charting:** Data were organized into structured tables and matrices, summarizing expert responses across key themes. This allowed for direct comparisons between expert opinions, highlighting similarities and contradictions in their perspectives. Example: Experts agreed that HB is useful for structured training but lacks expressiveness and fluidity.

5. **Mapping and Interpretation:** The findings were analyzed to derive practical recommendations for HB and HBP improvements. Insights were linked to RQ2c to validate whether HB and HBP can replicate HC training.

6.6.2. Summary of Expert Insights

Using the FA approach, the following key insights were identified:

1. Gesture Clarity and Accuracy

Experts generally found HB to be an effective tool for simulating hand-sign gestures, providing clear and structured visual cues for novice players. The predefined movements of HB were particularly useful for novices who are still learning to follow a conductor. However, some experts noted that:

Findings	Expert Quotes	Implication for HB/HBP
HB's gestures are structured but appear rigid	"HB is structured, but lacks fluidity."	Improve movement transitions
HBP's anticipatory cues aid synchronization but can be overwhelming	"HBP helps timing but is complex for novices."	Allow adjustable anticipatory delay
HB and HBP need better alignment with real HC behavior	"Some gestures don't fully match conductor nuances."	Optimize gesture transitions based on HC standards

Description:

1. HB's gestures, while accurate, appeared somewhat rigid and mechanical, lacking the natural fluidity of a human conductor's movements. They suggested refining HB's motion smoothness to make it feel more expressive and dynamic.
2. HBP's anticipatory cues were regarded as beneficial for improving synchronization, as they allow players to prepare for upcoming notes. However, some experts noted that the additional sub-conductor movements could be overwhelming, especially for less-experienced players.
3. Alignment with real conductor behavior needed further optimization, particularly in HBP's anticipatory gestures, which could be better adjusted to match human conductor nuances.

2. Effectiveness for Novice Training

When evaluating HB and HBP in the context of novice training, experts highlighted several key advantages:

Findings	Expert Quotes	Implication for HB/HBP
HB helps novices understand conductor cues	"HB is a good alternative when HC is unavailable."	Standardize gestures for structured training
HBP is more suited for intermediate learners	"HBP requires prior experience in conductor-following."	Position HBP as an advanced training tool
NB is easiest for novices but lacks realism	"NB is easy but lacks expressive depth."	Combine HB/HBP with interactive rhythm exercises

Description:

1. HB was highly rated for its ability to help novices understand conductor cues, providing a reliable substitute for an HC when one is unavailable. Its structured, predefined gestures offer a consistent learning experience that helps players develop a fundamental understanding of angklung conductor signs.
2. HBP was seen as a more advanced tool, ideal for players who have already developed basic conductor-following skills but need to refine their timing and coordination.
3. NB was considered the easiest tool for absolute novices, as it provides a direct mapping of notes to actions. However, experts emphasized that HB and HBP offer a more realistic training experience, particularly as students' progress.
4. Experts recommended integrating rhythm-based exercises into HB and HBP training, as this would enhance their effectiveness in preparing students for real ensemble performances.

3. Realism and Resemblance to a Human Conductor

Experts acknowledged that HB effectively simulates a handsign conductor, making it a valuable training aid. However, they also pointed out key differences between HB/HBP and a real human conductor:

Findings	Expert Quotes	Implication for HB/HBP
HB lacks expressiveness and emotional depth	"HC conveys emotion, HB does not."	Explore AI-based gesture adaptation
HBP's anticipatory cues improve realism	"HBP is a step closer to real conductor guidance."	Optimize HBP cue timing to human responsiveness
HB and HBP could help standardize handsign training	"A structured digital system would help unify conductor education."	Develop standardized training modules

Description:

1. HB lacks the emotional depth, flexibility, and expressive variation of a human conductor, which could limit players' ability to interpret dynamic changes in music.
2. HBP's anticipatory cues were regarded as a significant improvement over HB, as they help mimic the guidance provided by an experienced conductor. However, the rigid timing of HBP's anticipatory cues sometimes made it difficult for players to adapt naturally.
3. One expert suggested that HB and HBP could standardize handsign teaching across different angklung education programs, ensuring consistency in training that is often lacking in traditional HC-led instruction.

4. Limitations and Areas for Improvement

Despite their advantages, HB and HBP still have areas that require refinement. Experts identified the following limitations:

Findings	Expert Quotes	Implication for HB/HBP
HC provides real-time adaptability that HB/HBP lack	"HB and HBP are pre-defined, not dynamic."	Explore real-time adaptability in future iterations
HBP's anticipatory cues need customizable delay settings	"Fixed timing doesn't fit all songs."	Implement adjustable HBP settings
HB's movement fluidity needs improvement	"HB looks too robotic."	Enhance transition smoothness for HB

Description:

1. HC provides real-time adaptability and expressiveness, which HB and HBP currently lack. Unlike a human conductor, HB and HBP operate on pre-defined cues that do not dynamically adjust based on the players' performance.
2. HBP's anticipatory delay should be customizable, allowing players to adjust its timing based on different song tempos and playing styles.
3. HB's hand movements need more fluid transitions, rather than abrupt shifts between gestures, to better simulate human conductor motions.
4. NB, while effective for novices, could benefit from interactive tutorials to improve engagement and provide a more step-by-step learning experience.

6.6.3. Comparison of Training Methods in Learning according to Angklung expert

Refer to Table 6.14 below to conclude the Comparison of Training Methods in Learning according to the Angklung expert, based on the advantages, disadvantages, and recommendations for each training method.

Table 6.14: Comparison of Training Methods in Learning according to Angklung expert

TM	Advantages	Disadvantages	Recommendations
HC	- Effective for small to medium groups. - Provides human interaction and expressive musicality. - Suitable for ensemble training.	- Limited in managing large groups. - Lacks individualized feedback. - Requires clear sightlines for synchronization.	- Utilize assistants or section leaders for large groups. - Combine with other methods to provide individualized feedback.
NB	- Highly useful for novices. - Provides clear structural guidance. - Easy to understand and follow.	- Lacks interaction and musical depth. - Can feel mechanical and rigid.	- Incorporate rhythmic and interactive elements. - Include a step-by-step tutorial to enhance engagement.
HB	- Effectively simulates hand-sign movements. - Useful for self-practice. - Potential for standardizing angklung education.	- Movements appear rigid. - Lacks emotional depth and flexibility.	- Improve movement fluidity. - Add speed variations and smoother transitions.
HBP	- Provides anticipatory cues for advanced training.	- High complexity, requiring greater player adaptation.	- Adjust anticipatory delay settings.

- Enhances synchronization and timing accuracy.	- Requires dual focus on multiple cues.	- Add dynamic variations for better adaptability. - Improve user interface for accessibility.

6.6.4. Conclusion and Recommendations

Based on key evaluation criteria, we conclude:

1. **Gesture Clarity and Accuracy:** HB successfully replicates hand-sign gestures, making it an effective instructional tool. HBP's anticipatory cues further enhance synchronization but require refinement to improve alignment with real conductor behavior. While functional, HB's movement remains rigid compared to a human conductor, necessitating improved motion fluidity.
2. **Effectiveness for Novice Training:** HB serves as a practical substitute for HC, particularly in structured training environments where a human conductor may not always be available. HBP offers an advanced training approach, aiding players in refining their timing and coordination. However, both tools could be enhanced by integrating rhythm-based exercises to reinforce timing accuracy.
3. **Realism and Resemblance to a Human Conductor:** Although HB and HBP provide structured and consistent training, they lack the expressiveness and adaptability inherent to a human conductor. HBP presents a more dynamic approach through anticipatory cues, which simulate the natural guidance of an HC. Experts suggest that HB and HBP have the potential to standardize handsign teaching across angklung training programs.
4. **Limitations and Areas for Future Improvement:** While HB and HBP enhance structured angklung training, they currently lack real-time adaptability. Experts recommend introducing customizable tempo settings and refining motion fluidity for HB. HBP's anticipatory delay should be adjustable to accommodate varying song tempos. Additionally, NB, as a novice-friendly tool, could be improved with interactive tutorials for better engagement.

HB and HBP demonstrate strong potential as structured angklung training tools, offering clarity, consistency, and scalability. **HB is an effective tool for early-stage training**, helping students learn to follow conductor gestures. **HBP is preferred for more advanced learners,** as it improves anticipation and coordination but may require an adaptation period. However, improvements in motion fluidity, expressive dynamics, and adaptability are necessary to bridge the gap between digital training methods and the nuanced leadership of a human conductor.

6.6.5. Experts' Perspective – Answering (RQ2c)

Restatement of RQ2c

RQ2c: *What are experts' perspectives on the challenges and advantages of handsign-based approaches as angklung training methods?*

To address this research question, expert evaluations were collected from angklung instructors and cultural practitioners with professional backgrounds in ensemble performance and educational training. These experts provided qualitative feedback after

observing and interacting with the HB (Hand-Sign Bot) and HBP (Hand-Sign Bot with Preview) systems.

Summary of Key Expert Insights

Theme	Expert Observation
Gesture Clarity and Accuracy	Experts confirmed that HB successfully replicates hand-sign gestures used in traditional angklung instruction. This accuracy makes HB effective in guiding note execution.
Effectiveness for Novice Training	Experts regarded HB as a reliable instructional aid, especially useful in situations where a human conductor is unavailable. It provides consistency and structure for early-stage learning.
Realism and Human Resemblance	Experts acknowledged the value of HB and HBP for training purposes but noted their lack of expressive nuance and non-verbal dynamics typical of a human conductor (HC).
Predictive Support in HBP	The anticipatory guidance in HBP was perceived as a helpful innovation, allowing learners to prepare for note transitions. However, some experts raised concerns about potential visual overload.
Areas for Future Improvement	Experts suggested enhancing interactivity, particularly in NB, with tutorials or prompts. They also emphasized the need for adaptive responses to player behavior, which current versions of HB and HBP do not provide.

Conclusion
Experts viewed the Cue-Guided System as a promising tool for angklung training. Both HB and HBP were recognized for their structured and consistent cue delivery, making them suitable for novice instruction. However, they also highlighted several challenges, including limited expressiveness and absence of real-time adaptability.
In conclusion, the handsign-based approach, as implemented in HB and HBP, offers substantial pedagogical value, particularly in environments where access to skilled human conductors is limited. These findings directly answer RQ2c and reinforce the importance of continued refinement of digital training systems for traditional music education.

6.7. Answering RQ2

This section provides a synthesized response to **RQ2**—*"How do players and experts perceive the angklung-playing experience using a Cue-Guided System?"*—based on the combination of performance data (RQ2a), usability and engagement scores (RQ2b), and expert interviews (RQ2c).

Overview of Findings
The cue-guided angklung training system introduced in this study comprises three core training methods: Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP). Each method offers distinct instructional strategies, with NB focusing on visual cues and HB/HBP simulating human conductor hand-signs. The evaluation of this system yielded the following key insights:

Player Performance and Skill Development (RQ2a)
Based on the results of the **Friedman test**, no statistically significant differences were found in performance improvements among the three training methods. Both novice and experienced participants showed skill gains across NB, HB, and HBP, suggesting that each method effectively supports timing and note accuracy during individual practice. This finding supports the idea that **a variety of cue-based systems can facilitate basic angklung training**, even in the absence of ensemble settings.

Usability and Engagement (RQ2b)
SUS Scores:

1. Novice players rated **NB** significantly higher in terms of usability and ease of use.
2. HB and HBP were perceived as more complex, especially by participants without a musical background, though experienced players adapted more effectively to all methods.
3. HBP was not rated significantly higher than HB, indicating similar levels of perceived usability.

UEQ-S Scores:

1. NB was consistently rated as the **most supportive, efficient, and clear**, particularly by novice users.
2. HB was perceived as **less supportive and more confusing**, especially by those with limited angklung experience.
3. HBP was seen as **inventive and interesting**, bridging aspects of both NB (anticipation) and HB (conductor-like gesture).
4. Participant background (experience level, nationality, musical training) played a notable role in shaping perceptions of system engagement and clarity.

Overall, **NB stood out as the most novice-friendly system**, while HBP showed potential as a more advanced tool for players ready to transition toward ensemble-like practice.

Expert Perceptions (RQ2c)
Experts viewed **HB and HBP as promising innovations** that closely mimic the core principles of traditional angklung conducting. Specific observations include:

- **HB effectively replicates hand-sign instructions**, allowing for structured, repeatable training sessions.
- **HBP adds value by incorporating anticipatory gestures**, though experts acknowledged that processing two conductors may overwhelm some learners.
- Experts affirmed that these systems are beneficial for training in contexts where human conductors are unavailable.
- Nonetheless, they noted that **HB and HBP lack expressive nuance**, which limits their role in teaching musical phrasing and dynamics. Suggestions for future development include **enhancing gesture expressiveness and integrating contextual instructions.**

Conclusion

In summary, players and experts perceive the cue-guided angklung system as a viable alternative for individual practice and early-stage training. While **NB offers clarity and ease**, **HB and HBP introduce players to ensemble-relevant skills**, such as gesture-following and anticipatory timing. The system's flexibility to accommodate different user types—novice, experienced, Indonesian, international, with or without music background—enhances its value in diverse educational contexts.

Thus, the findings provide strong support for the Cue-Guided System's applicability in angklung training, while also highlighting areas for future enhancement to increase its pedagogical effectiveness and realism.

Chapter 7 Discussion and Conclusion

7.1. Summary of Research Contributions

This dissertation presents a cue-guided digital training system for individual angklung learners, designed to support structured practice through both visual and gestural cue-based methods. The research introduces three training methods—Notebar (NB), Hand-Sign Bot without Preview (HB), and Hand-Sign Bot with Preview (HBP)—and evaluates their impact on novice and experienced players through a combination of experimental testing, usability and engagement assessments, and expert interviews.
The main contributions of this study can be summarized as follows:

1. **Development of a Conductor-Guided Individual Training System:**
   This research successfully designed and implemented a digital angklung training system that simulates the presence of a conductor using two distinct approaches:
   a. *Visual-cue approach* (NB), based on color-coded note indicators.
   b. *Handsign-cue approach* (HB and HBP), replicating traditional hand-signs from Saung Angklung Udjo.
2. **Introduction of Dual-Conductor Model (HBP):**
   The Hand-Sign Bot with Preview (HBP) introduces a novel concept of anticipatory hand-sign cues using a second virtual conductor. This model helps players prepare for upcoming notes, bridging the gap between static visual cues and real-time conducting gestures.
3. **Structured Evaluation Across Multiple Dimensions:**
   The system was evaluated through a rigorous multi-phase methodology:
   a. **Performance measurement** using pre- and post-tests.
   b. **Usability and user experience assessments** using SUS and UEQ-S across diverse participant backgrounds.
   c. **Expert validation** using Framework Analysis to gather professional feedback on the strengths and limitations of HB and HBP.
4. **Support for Independent Learning in Traditional Music Training:**
   By enabling individual angklung practice without the presence of a human conductor or ensemble, this system offers a new model for self-paced, culturally grounded music education. It extends the reach of angklung training into non-formal and cross-cultural settings.
5. **Positioning Within General Instrumental Training Research:**
   This study contributes to broader digital music education by offering a unique handsign-based conductor model that differs from conventional notation-based or rhythm-based digital tools. It represents the first implementation of digitally simulated angklung conducting using culturally authentic gestural cues.
6. **Contribution to Information Science and Human-Computer Interaction (HCI):**
   From an Information Science and HCI standpoint, this study addresses the technical challenge of conveying musical structure without symbolic notation. The system translates conductor-based timing into structured visual sequences

that maintain low cognitive load while supporting cue-following, rhythmic timing, and note anticipation. A key design focus was developing an interface that supports timing guidance and anticipation for players who do not read music, using purely visual and gestural cues. This low-barrier cue delivery method reflects a user-centered HCI approach tailored to the angklung learning context. It demonstrates how ensemble-relevant skills can be trained through self-guided interaction, using only visual and gestural prompts, without requiring real-time recognition or feedback.

These contributions collectively advance the field of angklung pedagogy and provide new directions for integrating traditional music practices with digital learning technologies. The alignment between interface design and ensemble-style timing behavior supports a novel interaction model in digital music learning, offering a pathway for culturally responsive and accessible instructional tools.

7.2. Answering Research Questions and Objectives

This section revisits the research objectives (RO) and research questions (RQ) to clarify how each has been addressed through the system development, experimental testing, and evaluation activities conducted in this study.

Research Objective (RO):
To develop and evaluate a cue-guided angklung training system using visual-cue and handsign-cue approaches for novice players, focusing on individual learning and performance assessment based on player experience, usability, engagement, and expert evaluation.

RQ1: How can a cue-guided training system be developed to support angklung learning for novice players?
Answered in Chapter 4.
This study developed a three-method training system:

1. NB (Notebar) provides visual cues through color-coded bars to support timing.
2. HB (Hand-Sign Bot) simulates hand-signs from a human conductor for gesture-based guidance.
3. HBP (Hand-Sign Bot with Preview) introduces anticipatory hand-sign cues via a secondary conductor to enhance prediction and preparation.

All methods were integrated into a self-training system, enabling players to practice individually without ensemble or instructor presence.

RQ2: How do players and experts perceive the angklung-playing experience using a cue-guided system?
Answered in Chapter 6.
RQ2 was answered by evaluating three subcomponents:

a. **RQ2a: How does player performance change when using a Cue-Guided System?**
   Performance scores from pre- and post-tests showed that all three training methods support individual skill development, with no method showing

statistically superior performance across participant categories. This suggests each method is equally capable of improving angklung-playing accuracy.

b. **RQ2b: How do players experience usability and user engagement when using a Cue-Guided System?**
   SUS and UEQ-S evaluations revealed that player perceptions vary depending on experience, nationality, and musical background. NB was generally favored for usability and ease, while HBP was preferred for innovation and engagement. HB was considered helpful, but more complex to interpret for some groups.
c. **RQ2c: What are experts' perspectives on the challenges and advantages of handsign-based approaches as angklung training methods?**
   Experts validated HB and HBP as culturally authentic and useful tools for structured practice. They noted HB's clarity in gesture replication and HBP's innovative predictive design, while also suggesting improvements in expressiveness and cognitive load for novice users.

Through these findings, the study successfully fulfills its research objective, confirming that cue-guided digital systems—both visual and gestural—can support independent angklung training while respecting traditional instructional methods.

7.3. Implications for Angklung Training and Music Education

The findings of this study offer meaningful contributions to both angklung pedagogy and the broader field of music education, particularly in the context of digital and culturally responsive instructional design.

For Angklung Education:

1. **Bridging Traditional Methods and Modern Technology.**
   The system demonstrates that digital tools—when designed to reflect traditional conductor practices—can effectively complement or even substitute the presence of a human conductor in early-stage angklung learning. The handsign-cue methods (HB and HBP), in particular, preserve the pedagogical essence of angklung instruction rooted in Saung Angklung Udjo's practices.
2. **Enabling Independent Practice.**
   Angklung is traditionally group-based, yet this research proves that meaningful individual practice is possible. Through the use of NB, HB, and HBP, learners can engage in self-training that builds foundational skills such as timing, anticipation, and coordination before joining an ensemble.
3. **Support for Inclusive and Remote Learning.**
   The system paves the way for angklung training beyond formal or geographically limited settings. It can be adopted by schools with limited access to angklung instructors or by diaspora communities aiming to maintain cultural ties through music.

For Music Education at Large:

1. **Expanding Models of Digital Instrumental Training.**

Most digital music systems are either notation-based or rhythm-game inspired. This study introduces a gesture-based training model that is not only interactive but also rooted in cultural tradition, offering a novel approach within the spectrum of digital music pedagogy.

2. **Culturally Responsive Technology Design.**
   By aligning the system with traditional Indonesian conducting gestures, this study reinforces the importance of designing learning tools that respect and reflect cultural authenticity. It provides a model for how local traditions can be meaningfully embedded in global educational technology.
3. **Designing for Diverse Learners.**
   The system was tested with participants from various nationalities, skill levels, and musical backgrounds. The results suggest that customizable or multimodal training tools (e.g., combining NB, HB, and HBP) are essential to meet the needs of diverse learners in music education.

The system developed in this study promises to make angklung practice more accessible, structured, and culturally grounded. It holds promise not only for preserving a traditional musical form but also for modernizing and expanding its pedagogy through carefully designed digital innovation.

7.4. Limitations of the Study

While this study provides valuable insights into the development and evaluation of a cue-guided angklung training system, several limitations should be acknowledged:

1. **Focus on Individual Training Only**
   The system was designed exclusively for **self-training (Phase 1)**, emphasizing individual learning without ensemble coordination. Although angklung is inherently performed in groups, this research intentionally limited its scope to individual practice, aiming to assess how digital cue-based methods can support independent skill acquisition. Therefore, findings cannot yet be generalized to real-time group rehearsal or live ensemble contexts.
2. **Sample Size and Participant Diversity**
   The experimental studies were conducted in two phases with a relatively small sample size.
   a. The **JAIST experiment** in Japan involved **18 novice, non-Indonesian participants**, all without prior experience in angklung or conductor-led training.
   b. The **Indonesia experiment** included **18 participants—9 novices and 9 experienced high school players**—offering a valuable comparison between skill levels.
   While this design provides useful contrast, broader generalization would benefit from a larger and more demographically varied participant pool.
3. **Absence of Real-Time Interaction or Adaptivity**
   The training system provides pre-scripted conductor cues (visual or handsign), but it does not adapt to player behavior in real time. This may limit responsiveness to individual learning pace, errors, or engagement.
4. **Controlled Evaluation Contexts Only**

All training and testing were conducted in structured or lab-like environments. Real-world deployment in classrooms, cultural centers, or remote communities has not yet been validated, which may affect ecological validity.

5. **Lack of Expressive Musical Cues**
   While HB and HBP replicate structural gestures for timing and anticipation, they do not yet simulate expressive qualities such as emotional dynamics, flexible tempo, or gesture nuance that human conductors naturally convey.
6. **Dependence on Visual Interpretation**
   Notebar (NB) requires accurate color perception, making it less accessible for color-blind users. Meanwhile, Hand-Sign Bot with Preview (HBP), with its dual-conductor display, may be cognitively demanding for some learners, especially novices unfamiliar with multi-channel visual inputs.

These limitations define the current scope of the study and simultaneously suggest opportunities for future development. In particular, the transition from **Phase 1: Self-Training** to **Phase 2: Group-Training** and **Phase 3: Remote-Training** offers a promising roadmap for expanding the applicability of cue-guided angklung training systems.

7.5. Future Research Directions

Building on the contributions and limitations of this study, several directions are proposed to extend and refine the cue-guided angklung training system.

1. Advancing to Group and Remote Training (Phases 2 and 3)
This study represents the first phase—Self-Training—of a broader angklung training model. Subsequent phases include:

Phase 2: Group Training
This phase will enable multiple players to rehearse together in real-time ensemble settings using HB or HBP. Research will need to address group-level synchronization, conductor-following behavior, and collective performance evaluation.

Phase 3: Remote-Conductor Training
This phase will support geographically distributed angklung learners using a digital conducting system and the introduction of PlayerBot, a virtual angklung player that mimics ensemble behavior using recorded data. This opens access for diaspora communities and remote education settings.

2. Real-Time Feedback and Interaction
Future systems could integrate real-time interaction features, such as tempo tracking or note detection, enabling the system to respond dynamically to the player's accuracy. This enhancement would increase engagement and support more adaptive learning trajectories. In contrast to classical music settings where conductors dynamically adjust tempo, phrasing, and expression in real time based on ensemble responses, the proposed system currently operates on pre-programmed sequences. NB, HB, and HBP are designed for structured learning, particularly suited for novice players. Future work may explore dynamic cue adaptation based on real-time user input, thereby simulating expressive flexibility found in live ensemble settings and enriching HCI value.

3. Adaptive Learning Based on Player Profiles
The study revealed differing responses to training methods based on player experience, nationality, and musical background. In future implementations, an adaptive interface could recommend or adjust the training path (NB → HB → HBP) using early performance metrics such as reaction timing, cue-following accuracy, or error rate. This approach supports a personalized training trajectory, aligning with modern adaptive learning systems in educational technology and reinforcing learner engagement.

4. Custom Handsign and Integration of Expert Hand-Sign Systems
The current HB and HBP systems are based on a limited standard of eight hand-sign gestures. However, future development will explore collaboration with experts such as **Frederik Jonathan A.,** who has developed an extended library of over **60 hand signs** for angklung. Instructors may also be allowed to **define or modify hand-sign gestures** based on their teaching style, offering deeper flexibility and personalization.

5. Conductor Avatar Customization for Educators
The system architecture supports modular 3D models for conductors. Educators will be allowed to replace the conductor avatar with a custom 3D object, offering cultural or stylistic adaptation. This feature promotes localization and cultural responsiveness, but access will be restricted to instructors to prevent distraction among learners.

6. Visual Enhancements for Cross-Method Consistency
To ensure a smooth transition from Notebar to handsign-based methods, visual enhancements will be applied across all training modes:

a. Notebar (NB): Add hand-sign symbols at the beginning of each colored bar, connecting each note to a visual gestural representation.
b. HB and HBP: Apply the same color schemes and label cues used in NB to the conductor's hand—e.g., if "Do" is blue, the avatar's hand is also blue and labeled "Do". This consistency will enhance pitch-gesture association, especially important for novice learners without prior music training.

These adjustments respond directly to reviewer feedback and aim to improve learners' ability to internalize pitch-gesture associations across training formats.

7. Image Recognition for Dynamic Conductor Input
Future systems may integrate **image recognition technology** to record or live-capture gestures from real human conductors. Instead of relying solely on pre-rendered animations, instructors could perform hand signs naturally, and the system would translate them into real-time visual guidance. This would bridge the gap between digital and human-led instruction, and explore hybrid human-computer interaction models for traditional ensemble settings.

8. Expressive Cue Encoding and Strength-Based Control
Although this system currently focuses only on timing cues, expressive elements such as shaking intensity or dynamic emphasis (e.g., forte/piano) could be encoded visually.

a. In Notebar, this may include bar thickness or waveform cues.

b. In HB/HBP, hand gestures could be enhanced through motion amplitude, facial expression, or avatar posture.

This direction will extend the expressive training capacity of the system while maintaining cognitive simplicity for novice users.

These future directions highlight the continued commitment to developing a cue-guided angklung training ecosystem that is flexible, adaptive, and culturally responsive—ultimately empowering learners, educators, and communities to preserve and innovate traditional music through thoughtful technological design.

7.6. Conclusion

This dissertation presented the design, development, and evaluation of a cue-guided angklung training system aimed at supporting novice players through structured, independent practice. Recognizing the challenges faced by learners—such as limited access to human conductors, difficulty anticipating musical cues, and low confidence in ensemble contexts—the study proposed three distinct training methods: **Notebar (NB)**, **Hand-Sign Bot without Preview (HB)**, and **Hand-Sign Bot with Preview (HBP)**. These methods represented two instructional paradigms: **visual-cue** (NB) and **handsign-cue** (HB and HBP), both inspired by traditional angklung pedagogy yet implemented through digital interfaces.

The system was developed with a focus on **self-training**, forming the first phase of a larger angklung training model. Through controlled experiments and multi-perspective evaluations, the study investigated the effectiveness of each method in improving performance, usability, and user engagement. Quantitative findings revealed no statistically significant differences in performance scores across training methods, suggesting that all three approaches are similarly effective for skill acquisition. However, **usability evaluations using SUS** indicated a clear preference for NB, especially among novice users, while **user engagement scores from UEQ-S** demonstrated the potential of HBP to offer a more inventive and dynamic experience.

Expert evaluations further supported the feasibility of using HB and HBP in structured training environments, acknowledging their clarity and instructional value while also identifying limitations in expressiveness and adaptivity compared to human conductors. These insights guided the formulation of future research directions that include extending the system into **group and remote training**, incorporating **custom handsign systems**, and improving **visual consistency** across training methods.

In summary, this research contributes a novel, culturally grounded, and systematically evaluated approach to digital angklung training. It advances the integration of traditional performance practices with modern educational technology, providing a foundation for future innovations in music learning and heritage preservation. By enabling independent learning while simulating ensemble coordination, the Cue-Guided System not only addresses current pedagogical gaps but also lays the groundwork for scalable, inclusive, and adaptive angklung education.

Publications

Journal Papers
B. Hardiyana and S. Hasegawa, “Design of Angklung Music Scoring System Based on Remote Training,” J. Adv. Res. Appl. Sci. Eng. Technol., vol. 31, no. 1, pp. 355–364, 2023, doi: 10.37934/araset.31.1.355364.

International Conferences (Proceedings)
B. Hardiyana and S. Hasegawa, “Angklung Music Training with a Scoring system based on Online and Onsite Group,” Asean Workshop on Information Science and Technology (AWIST) 2023., pp. 28. 2023.
B. Hardiyana, A. Mukharil Bachtiar, K. Sugita, D. Effendi, B. Noviansyah, P. Siritanawan, W. Gu, K. Ota and S. Hasegawa, “Assessing the Effectiveness of Notebar, ConductorBot, and Sub-ConductorBot Methods in Training Novice Angklung Players,” International Conference on Informatics, Engineering, Science and Technology (INCITEST) 2024, Status: **In Press**

Presentations at Academic Conferences (Oral)
B. Hardiyana, W. Gu and S. Hasegawa, “Design of Self-Training Angklung Music Scoring System for Normal and Deaf Students”, The 17th International Conference on Knowledge, Information and Creativity Support Systems (KICSS) 2022.
B. Hardiyana and S. Hasegawa, “Angklung Music Training with a Scoring system based on Online and Onsite Group,” Asean Workshop on Information Science and Technology (AWIST) 2023., pp. 28. 2023.

Awards
The Best Presenter, B. Hardiyana, A. Mukharil Bachtiar, K. Sugita, D. Effendi, B. Noviansyah, P. Siritanawan, W. Gu, K. Ota and S. Hasegawa, “Assessing the Effectiveness of Notebar, ConductorBot, and Sub-ConductorBot Methods in Training Novice Angklung Players,” International Conference on Informatics, Engineering, Science and Technology (INCITEST) 2024.

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APPENDIX

Appendix A: Full Expert Interview Responses

Question	Muhammad Naufal Hafizah Setiawan	Frederik Jonathan A.	Eddy Permadi	Mutiara Dwi Salma
How long have you been teaching angklung?	5 years (2 years informal teaching, 3 years formal teaching).	28 years (since 1996).	54 years (since 1970, initially as Mr. Daeng's student).	2 years (2 years informal, 2 years formal teaching).
What are the differences in teaching angklung at novice, intermediate, and advanced levels?	For novice students, I typically use the handsign method as it is simpler and does not require note memorization. For higher-level students, I transition to the sheet music method, which is more suitable for complex pieces requiring accurate note execution and memorization.	The handsign method is great for novices but has limitations, as it only covers one octave (8 notes). I developed 60 additional handsign gestures to cover missing notes and allow for more advanced, dynamic performances.	Novices should focus on rhythm and synchronization first, while advanced students must learn how to express emotion and dynamics in music to enhance their performance quality.	I start with easy songs using the handsign method before transitioning to sheet music for more complex pieces. Competitions are also a great motivation for students.
What are the main challenges in teaching angklung, and how do you overcome them?	Many novices struggle with matching their timing to the conductor. The solution is repetitive training using handsign before playing in an ensemble.	Many students over-rely on conductor cues without truly understanding the musical structure. I teach internal timing awareness so they don't just depend on handsign gestures.	The biggest challenge is getting students to understand the emotion behind the music, as angklung is not just about hitting the right notes but about musical expression.	Keeping students engaged is difficult. I use familiar and fun songs first to build their confidence before moving on to more difficult pieces.
What techniques do you use to keep students engaged and motivated in learning angklung?	I keep students engaged by starting with fun, simple songs before moving to structured training. I also use handsign games and rhythm exercises to make learning interactive.	I introduce creative handsign gestures and give students small challenges or group competitions to keep them motivated.	Performances are key. When students know they will be performing, they are naturally more engaged and motivated to practice.	Competitions! I encourage my students to join angklung competitions, which significantly boosts their motivation to practice.
How many people are effectively managed when playing with an HC?	An experienced HC can manage a group of up to 50 players, but beyond that, it becomes difficult to maintain synchronization without additional cues or section leaders.	For simple songs, a single HC can manage around 60-80 players. For more complex songs, smaller groups (around 30 players per HC) are more effective.	A well-trained angklung orchestra can have up to 100 players under one HC, but it requires a high level of discipline and prior rehearsals.	For novices, a group of 20-30 is manageable, but for larger groups, the HC needs assistants or sectional leaders.

Question	Muhammad Naufal Hafizah Setiawan	Frederik Jonathan A.	Eddy Permadi	Mutiara Dwi Salma
In your opinion, what are the limitations of the HC method?	Managing large groups is challenging, especially for fast or complex pieces. Players with weak timing awareness struggle without additional visual guides.	HC relies on clear sightlines—if a player cannot see the HC, synchronization becomes difficult. This limitation affects large performances.	HC lacks the ability to give individualized guidance, making it difficult for novices to catch up in a large ensemble setting.	HC is limited in its ability to provide immediate feedback to individual players, making it less effective for novices who require constant guidance.
What are your thoughts about my Proposed Training Method (NB, HB, HBP)?	Hand-Sign Bot without Preview (HB) is highly beneficial for novice players, though its movements are fast. It successfully simulates a handsign conductor, making it an excellent training tool.	Hand-Sign Bot could standardize my 60 handsign gestures, making it easier for students to learn at home. This tool has great potential for national angklung education programs.	Although HB lacks the emotional depth of a human conductor, it performs handsign movements well following standard rules. It is a good alternative when an HC is unavailable.	Notebar (NB) is useful for absolute novices, while HB can serve as a temporary instructor for those learning to follow a conductor.
Do you have any suggestions for each Proposed Training Method?	NB is effective for absolute novices but could integrate more rhythm-based exercises. HB should refine its movement smoothness, making it more natural. HBP may include varied anticipatory cues to better match tempo changes.	NB is great for self-learning but could integrate a more interactive tutorial. HB should enhance its realism in hand movement. HBP should allow for dynamic variations in its anticipatory cues.	NB is a helpful introduction for novices but could benefit from adjustable tempo settings. HB would be more effective if it incorporated more fluid transitions in gestures. HBP could improve its timing cues based on real conductor behavior.	NB is excellent for initial exposure to angklung but could include a step-by-step guide. HB could improve by offering multiple speed settings for movement. HBP might be enhanced by allowing users to adjust the anticipatory delay.

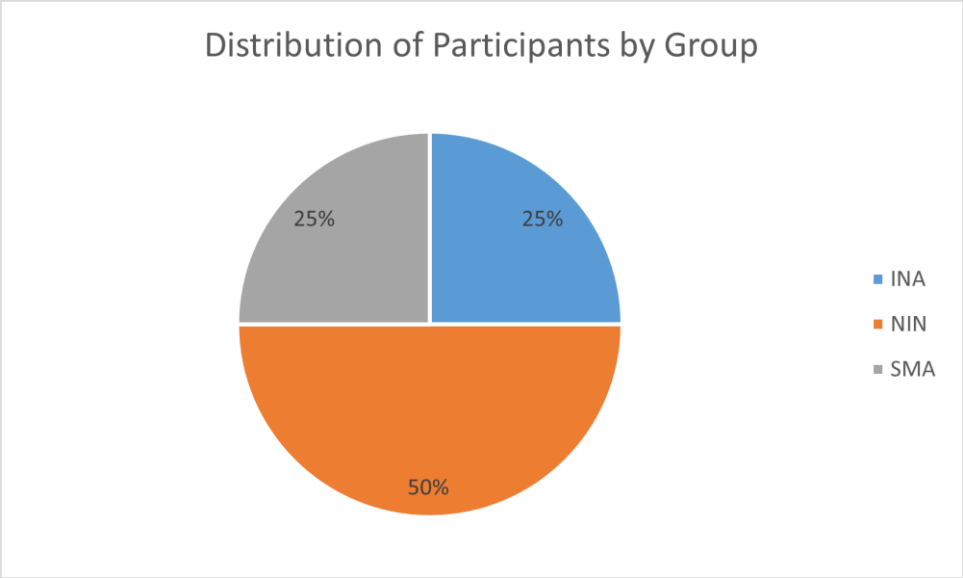
Appendix B: List of Participant

P Code	Nationality	Player Level	Gender	Age
INA-P01	Indonesia	Novice	M	21-25
INA-P02	Indonesia	Novice	M	21-25
INA-P03	Indonesia	Novice	M	21-25
INA-P04	Indonesia	Novice	F	21-25
INA-P05	Indonesia	Novice	F	21-25
INA-P06	Indonesia	Novice	F	21-25
INA-P07	Indonesia	Novice	F	21-25
INA-P08	Indonesia	Novice	F	21-25
INA-P09	Indonesia	Novice	M	21-25
NIN-P01	China	Novice	M	26-30
NIN-P02	China	Novice	M	26-30
NIN-P03	China	Novice	M	26-30
NIN-P04	China	Novice	M	26-30
NIN-P05	China	Novice	M	26-30
NIN-P06	India	Novice	M	26-30
NIN-P07	India	Novice	F	26-30
NIN-P08	Japan	Novice	M	26-30
NIN-P09	China	Novice	F	26-30
NIN-P10	Japan	Novice	M	26-30
NIN-P11	Pakistan	Novice	M	26-30
NIN-P12	South Korea	Novice	M	26-30
NIN-P13	India	Novice	F	26-30
NIN-P14	India	Novice	M	26-30
NIN-P15	China	Novice	F	26-30
NIN-P16	India	Novice	F	26-30
NIN-P17	China	Novice	M	26-30
NIN-P18	Vietnam	Novice	M	26-30
SMA-P01	Indonesia	Experienced	F	16-20
SMA-P02	Indonesia	Experienced	F	16-20
SMA-P03	Indonesia	Experienced	F	16-20
SMA-P04	Indonesia	Experienced	F	16-20
SMA-P05	Indonesia	Experienced	F	16-20
SMA-P06	Indonesia	Experienced	F	16-20
SMA-P07	Indonesia	Experienced	F	16-20
SMA-P08	Indonesia	Experienced	F	16-20
SMA-P09	Indonesia	Experienced	F	16-20

Appendix C: Participant Demographics

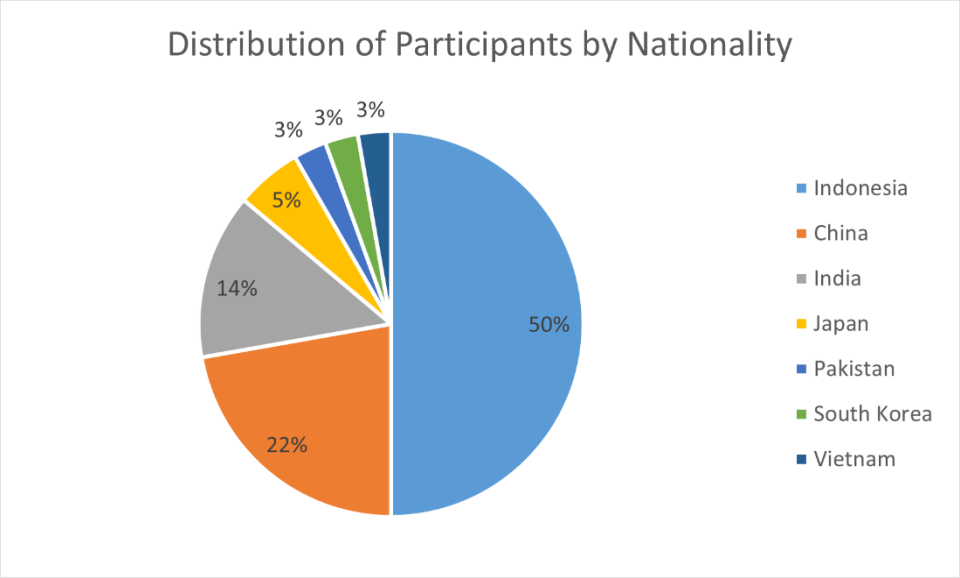
1. Distribution of Participants by Group

Group	Number of Participants	Percentage
INA	9	25%
NIN	18	50%
SMA	9	25%



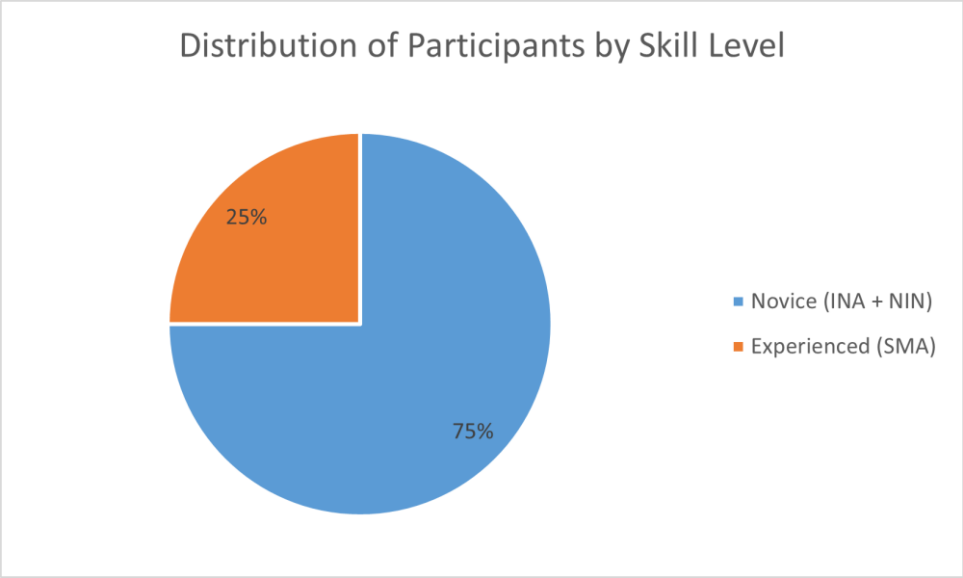
2. Distribution of Participants by Nationality

Nationality	Number of Participants	Percentage
Indonesia	18	50%
China	8	22.20%
India	5	13.90%
Japan	2	5.60%
Pakistan	1	2.80%
South Korea	1	2.80%
Vietnam	1	2.80%



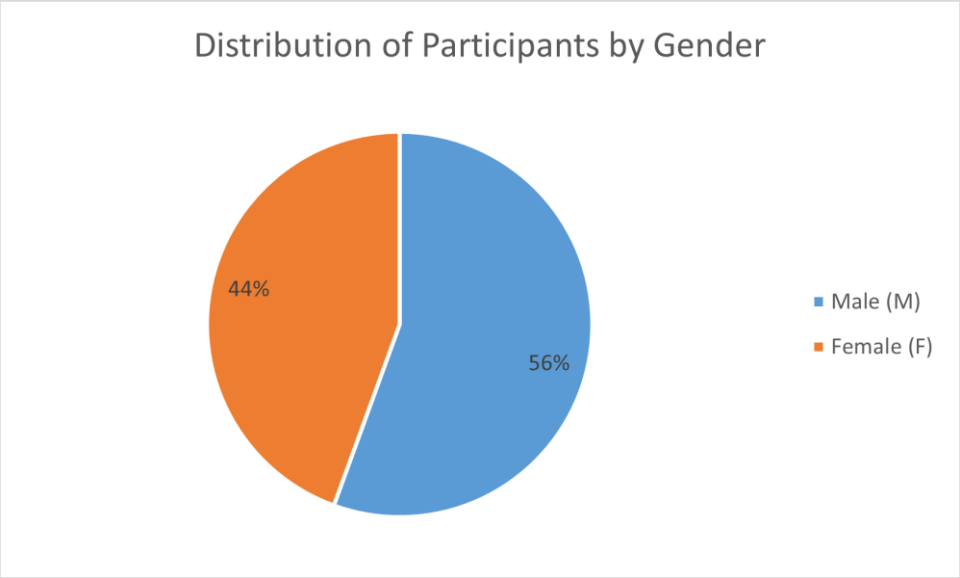
3. Distribution of Participants by Skill Level

Skill Level	Number of Participants	Percentage
Novice (INA + NIN)	27	75%
Experienced (SMA)	9	25%



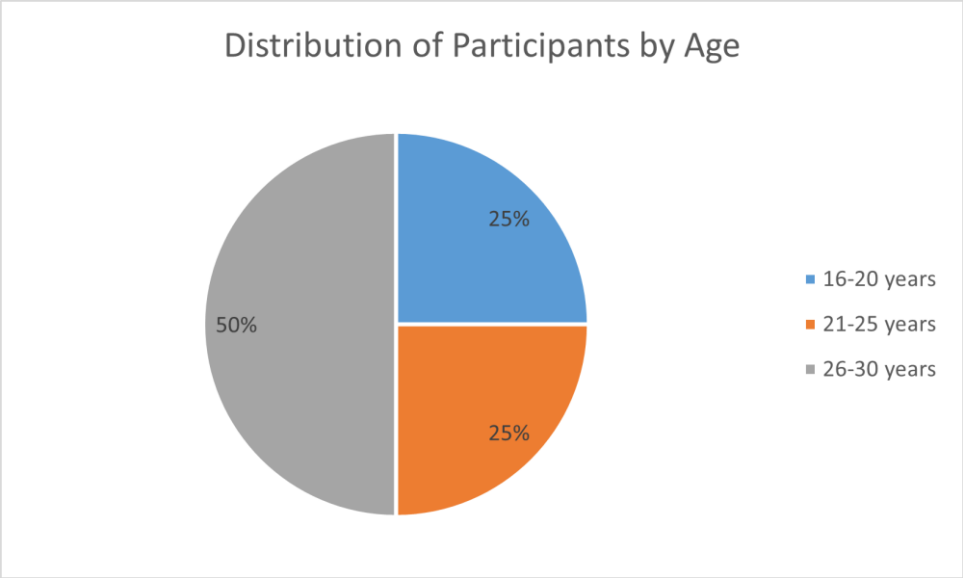
4. Distribution of Participants by Gender

Gender	Number of Participants	Percentage
Male (M)	20	55.60%
Female (F)	16	44.40%



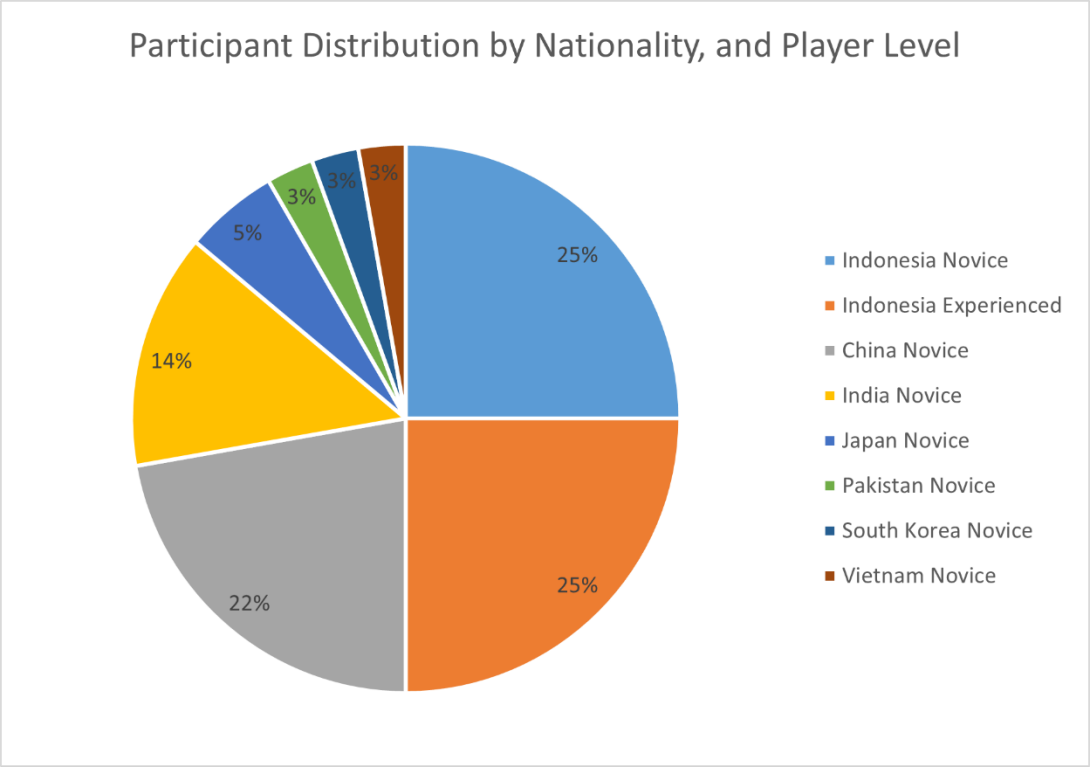
5. Distribution of Participants by Age

Age Group	Number of Participants	Percentage
16-20 years	9	25%
21-25 years	9	25%
26-30 years	18	50%

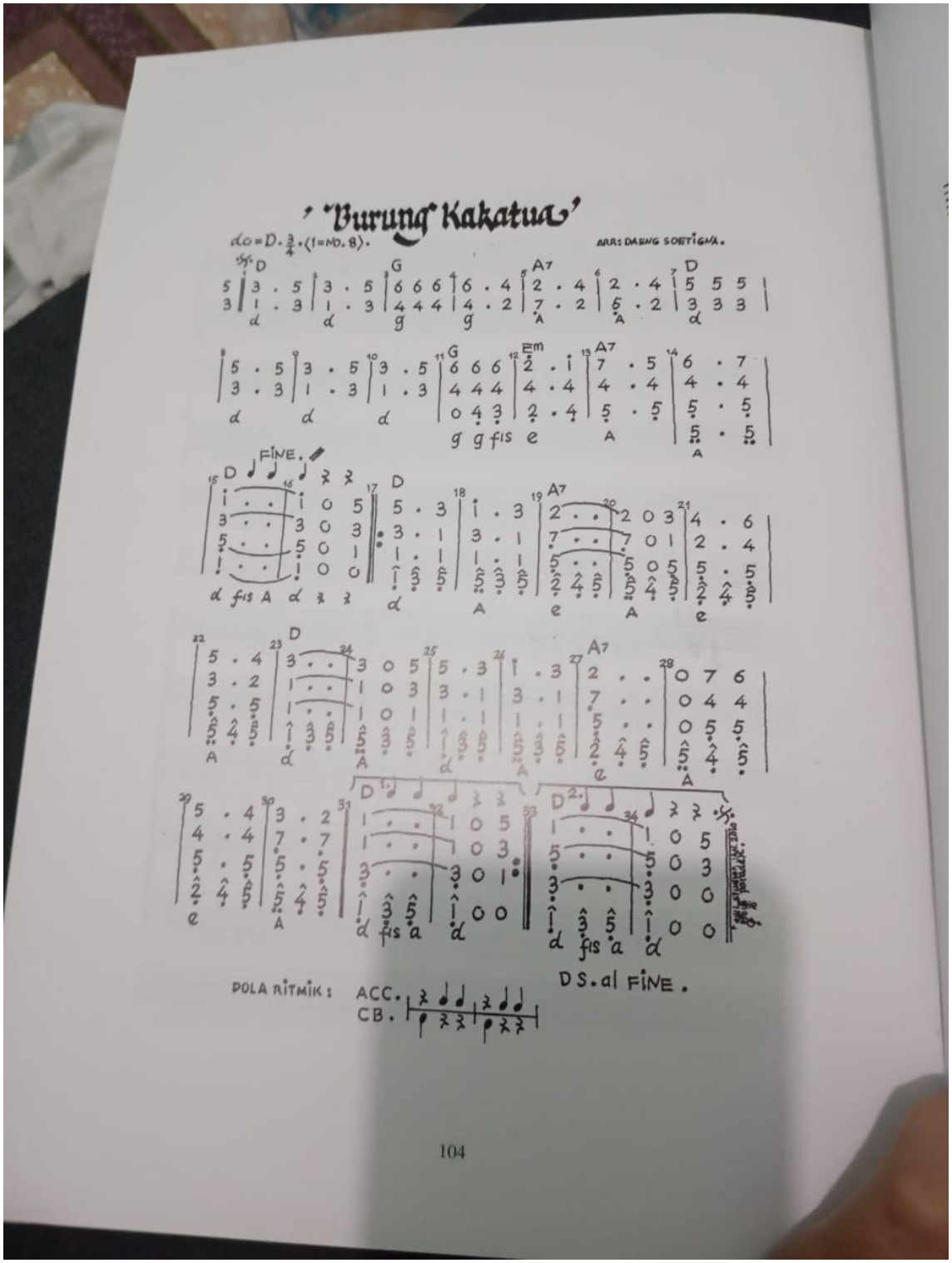


6. Participant Distribution by Nationality, and Player Level

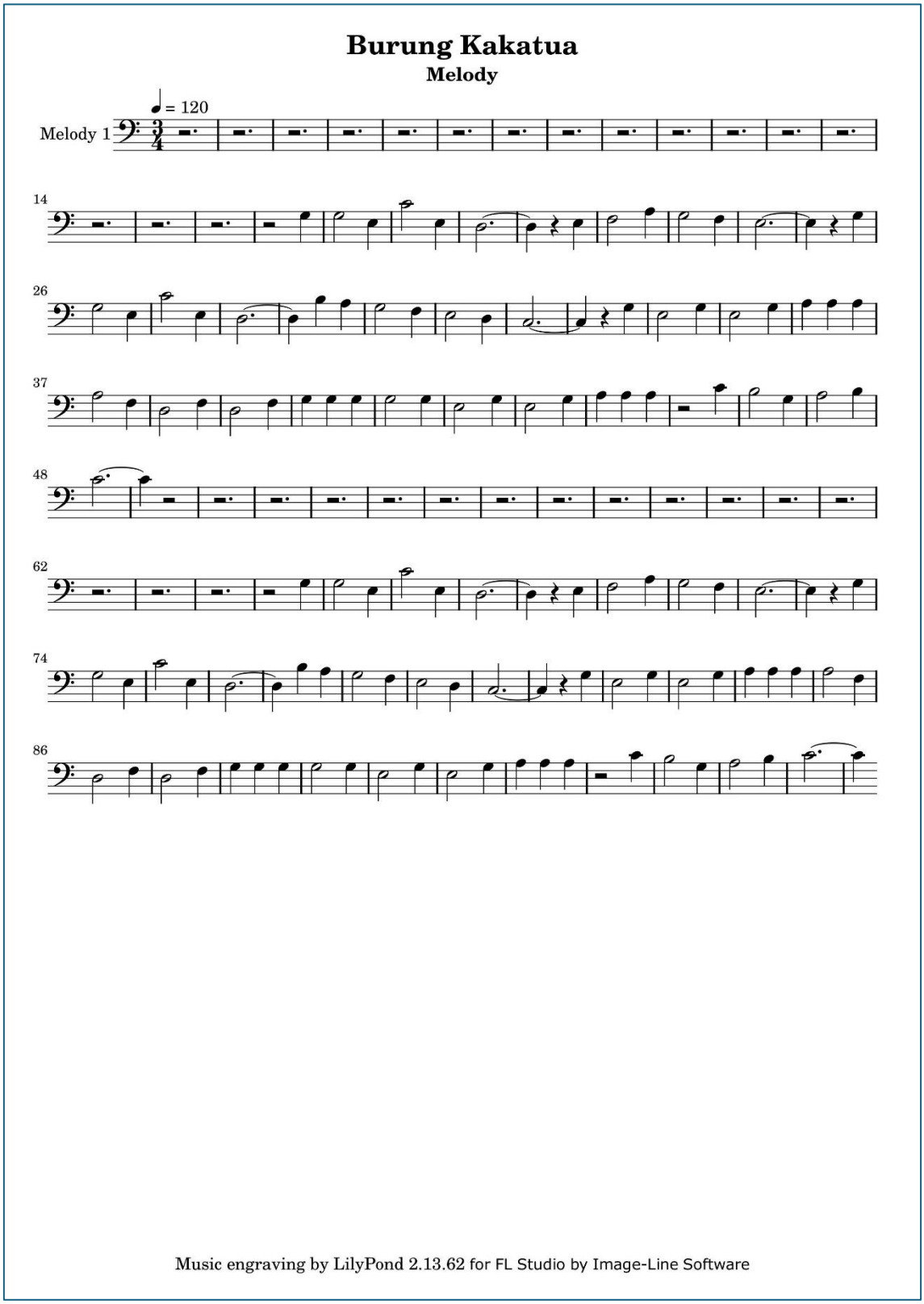
Nationality	Player Level	Count
Indonesia	Novice	9
Indonesia	Experienced	9
China	Novice	8
India	Novice	5
Japan	Novice	2
Pakistan	Novice	1
South Korea	Novice	1
Vietnam	Novice	1



Appendix D. Burung Kakak Tua original arrangement by Pak Daeng Soetigna

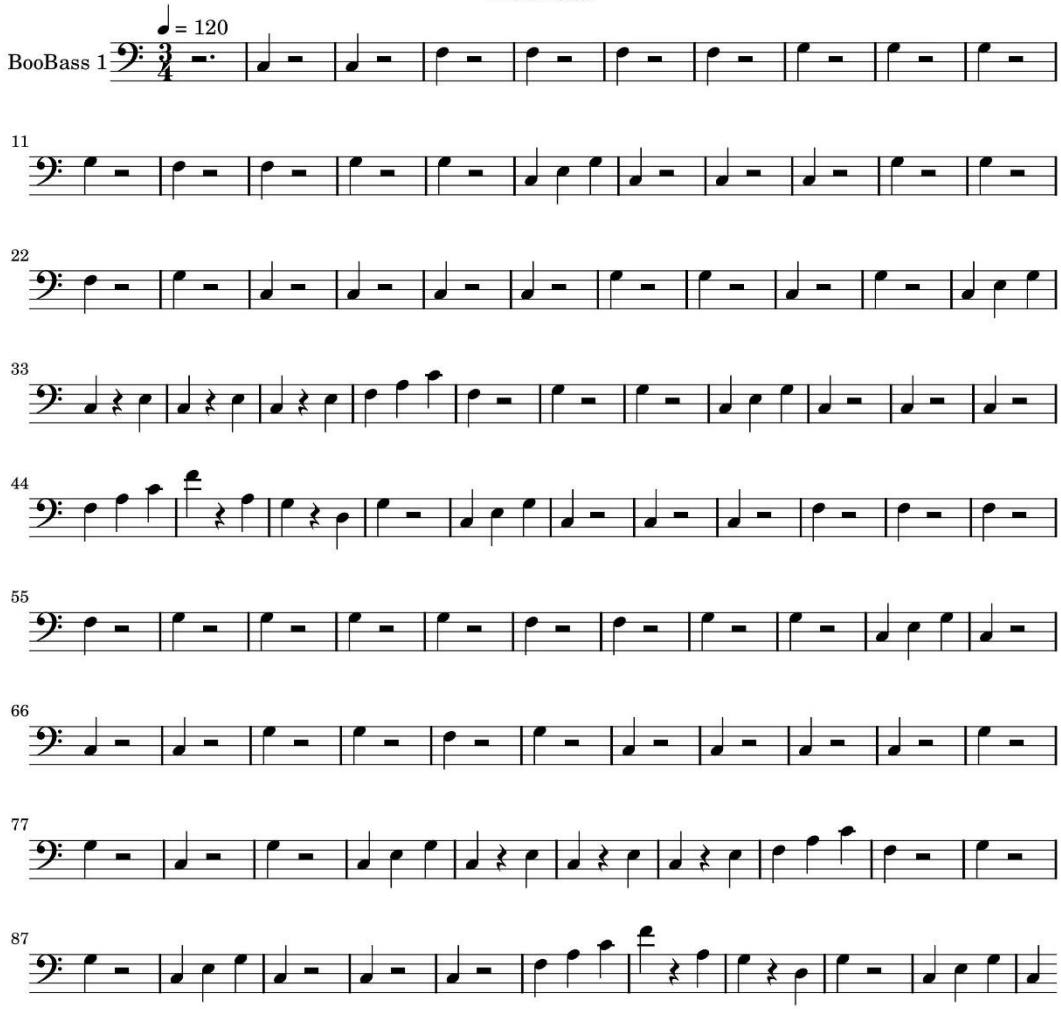


Appendix E. Burung Kakak Tua arrangement novice angklung-player friendly



Burung Kakatua

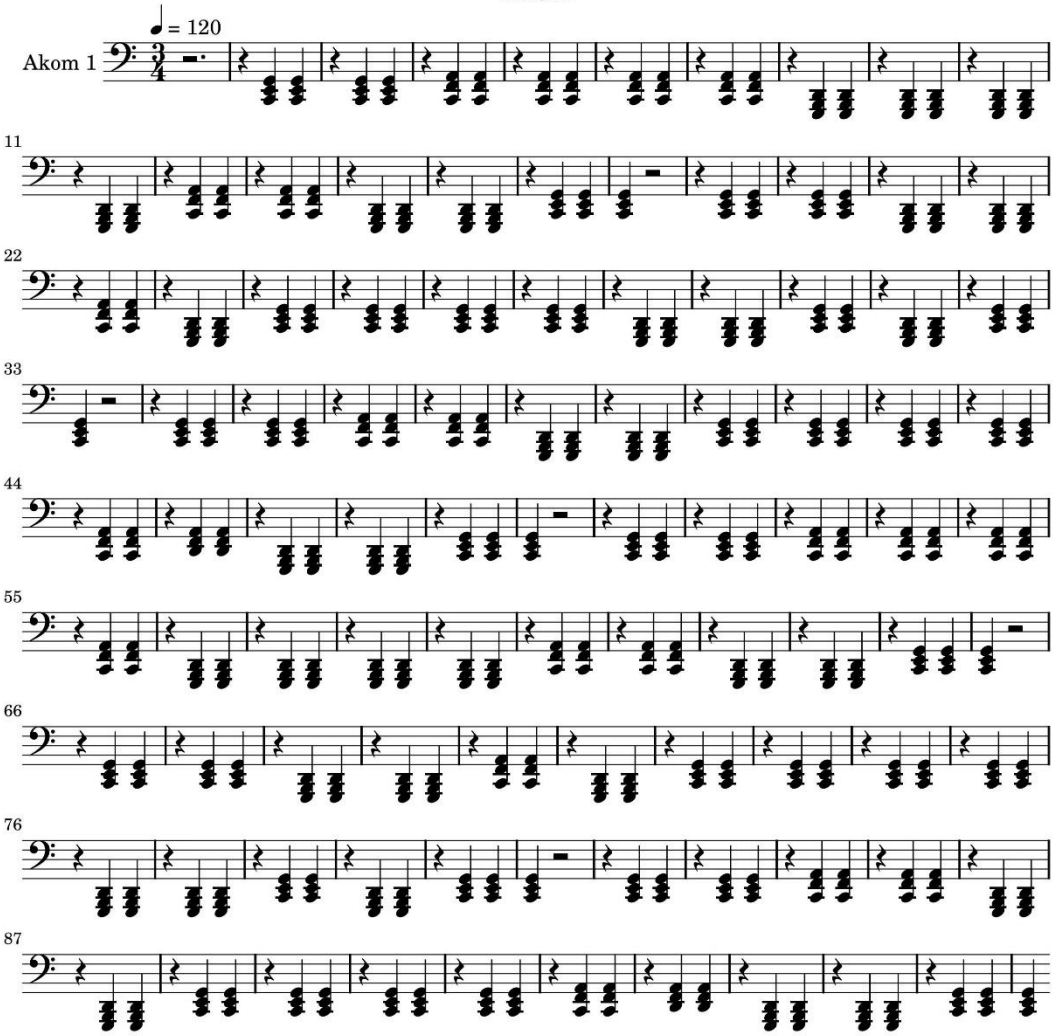
BooBass



Music engraving by LilyPond 2.13.62 for FL Studio by Image-Line Software

Burung Kakatua

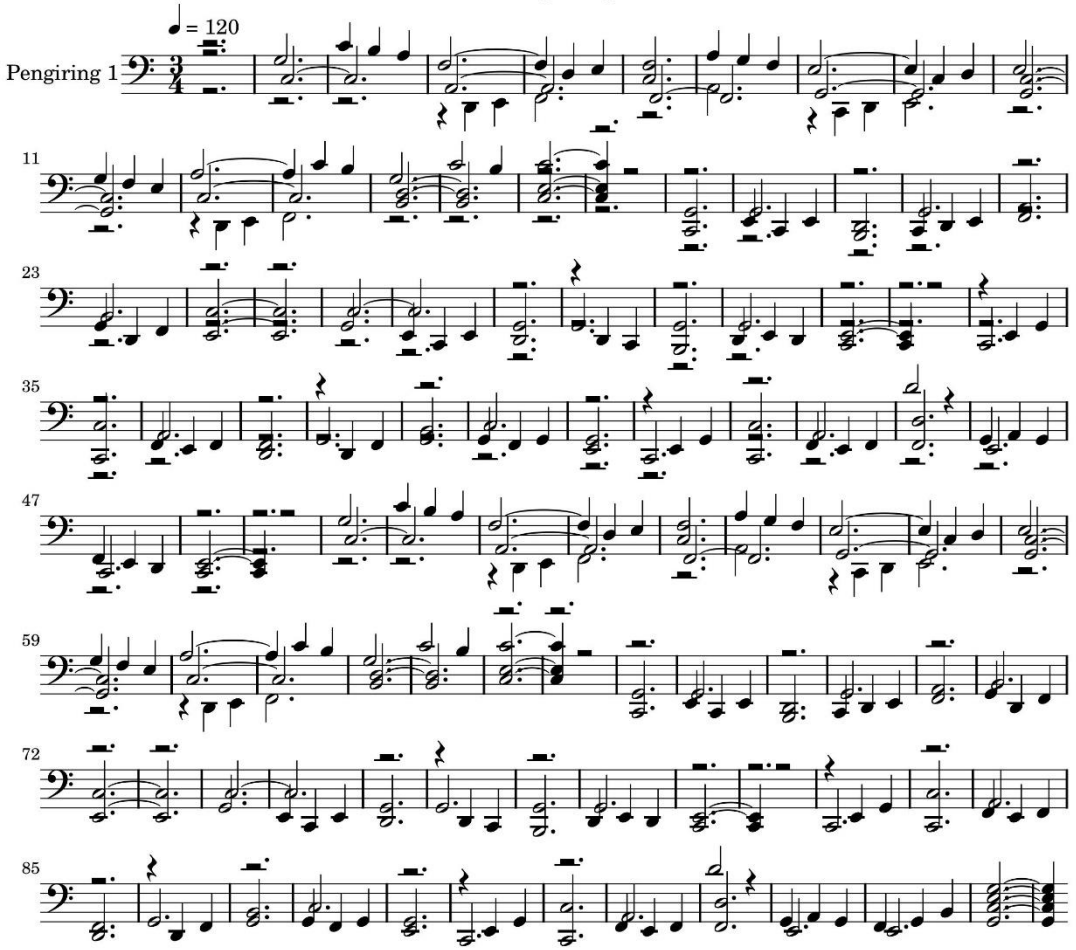
Akom



Music engraving by LilyPond 2.13.62 for FL Studio by Image-Line Software

Burung Kakatua

Pengiring



Music engraving by LilyPond 2.13.62 for FL Studio by Image-Line Software

Appendix F. Consent Form for Participant

Consent Form

Japan Advanced Institute of Science and Technology
Affiliation: Center for Innovative Distance Education and Research
Research Supervisor: Professor Shinobu Hasegawa

I received a detailed explanation from presenter Bella Hardiyana on "Notebar and ConductorBot method to replace human conductors for novice angklung players". The explanation took place in Room _____ of JAIST, accompanied by instructional materials. I have understood the experiment's purpose, methodology, personal information protection measures, and safety management considerations. I willingly consent to provide the requested personal information, data, and any related information for the experiment.

Items explained and understood.
(Please indicate with a check mark (✓) on the left side of the items you have understood in the consent form, and indicate with a cross mark (×) on the left side of the items you have not understood.)

1 Outline of the experimental plan:
( ) ・Purpose and significance of the experiment
( ) ・Information and data to be provided

2 Personal Information Protection:
( ) ・Collection of personal information is necessary in accordance with the purpose and experimental plan.
( ) ・Methods for anonymizing the provided data, etc.
( ) ・Proper storage and management of data

3 Intrusion and security management:
( ) ・Expected discomfort, burden, etc.

4 Informed consent:
( ) ・Participation in the experimental plan is voluntary.
( ) ・There will be no adverse consequences if you won't join this experiment.
( ) ・There will be no adverse consequences if the consent is withdrawn.
( ) ・If consent is withdrawn, any provided data or materials will be discarded.
( ) ・There will be no adverse consequences if you withdraw your consent.
( ) ・Provided data will be discarded upon withdrawal of consent.
( ) ・Collected data will not be shared with others without the individual's consent.
( ) ・Plans for presenting the experimental results include conference presentations and publication of papers.
( ) ・Payment (or non-payment) of compensation for participating in the research plan.

Year Month Day

Name (Signature) _____

Contact (Email Address) _____

同 意 書

北陸先端科学技術大学院大学
所属： 遠隔教育研究イノベーションセンター
研究責任者名： 長谷川 忍 殿

私は，「初心者のアンクルン奏者のための人間指揮者を代替するノートバーおよびコンダクターボット方法」の研究・実験の実施について，説明者 Bella Hardiyana より，＿＿＿＿＿＿において説明書を用いて説明を受け，実験の目的，方法，個人情報保護，安全管理での配慮などについて十分理解しましたので，実験に参加し，求められた私個人に係る情報，データ等を提供することに同意いたします．

説明を受けて理解した項目
（理解できた項目の左に○、理解できなかった項目の左に×を記載ください。）

1 実験計画の概要に関する事項
（ ）・実験の目的，意義
（ ）・提供する情報，データ等

2 個人情報保護の方法に関する事項
（ ）・個人情報の収集が実験目的，実験計画に照らして必要であること
（ ）・提供を受けたデータ等処理の匿名化の方法
（ ）・データの保管・管理について適切になされること

3 侵襲および安全管理に関する事項
（ ）・予想される苦痛、負担等

4 インフォームド・コンセントに関する事項
（ ）・実験計画への参加は任意であると
（ ）・実験計画に参加に同意しないことにより不利益な対応を受けないこと
（ ）・研究計画に参加に同意した後でも，外部発表前であれば文書により同意を撤回することができること
（ ）・本人から請求があれば，当該データを開示すること
（ ）・同意を撤回しても，そのことにより何ら不利益を蒙らないこと
（ ）・同意を撤回した場合，提供されたデータ等は廃棄されること
（ ）・収集したデータ等は，本人の同意を得ることなく他者に渡さないこと
（ ）・実験成果の発表の方法について，学会発表，論文発表の予定
（ ）・研究計画参加に対して謝礼を支払うこと（または支払わないこと）

年 月 日

氏 名（自署）＿＿＿＿＿＿＿＿＿＿

連絡先(メールアドレス)＿＿＿＿＿＿＿＿＿＿

Appendix G. Pre-Experiment Questionnaire

1 - Pre-Experiment Questionnaire

Experiment Date (Day, Date)	,
Instance	UNIKOM / SMA15
Group ID	A / B / C
Participant ID (P-No)	P-
Sign / TTD	
Full Name	
Student Number	
Email Address	
Age (yo)	
Gender	M / F
Grade (Kelas / Tingkat)	

1. Apakah anda tahu angklung *(Do you know what is angklung)?* *Y / N*
2. Apakah anda tahu cara memainkan angklung *(Do you know how to play angklung)?* *Y / N*
3. Apakah anda pernah bermain angklung *(Do you have experience with angklung)?* *Y / N*
4. Apakah anda pernah bermain alat musik selain angklung (*Do you have experience with other musical instruments? (such as guitar, piano, harmonica, etc.))*

Jika Iya *(If Yes)*

Jika Tidak, apakah anda tahu Melodi Solfège *(If no, do you know Solfège syllables (Do-Re-Mi-Fa-So-La-Si)?)*

Y / N

1

Appendix H. SUS and UEQ Questionnaire

2 - SUS and UEQ Questionnaires

Instance	UNIKOM / SMA15
Group ID	A / B / C
Participant ID (P-No)	P-
PM Number	PM-1 / PM-2 / PM-3
Training Method	NB / CB / SC
Note	Re / Fa / Do'
Sign / TTD	

System Usability Scale (SUS)

Terima kasih telah mencoba metode pelatihan ini. Kami ingin mengetahui pendapat Anda mengenai kemudahan penggunaan dan pengalaman keseluruhan selama menggunakan metode ini. Mohon untuk mengisi kuesioner berikut dengan memberikan penilaian terhadap tiap pernyataan yang sesuai dengan pengalaman Anda. Jawaban Anda akan membantu kami dalam mengevaluasi dan meningkatkan metode pelatihan ini.

Thank you for trying out this training method. We would like to know your thoughts on the ease of use and overall experience during the training. Please fill out the following questionnaire by rating each statement according to your experience. Your responses will help us evaluate and improve this training method.

1 Sangat Tidak Setuju ~ 5 Sangat Setuju *(1 Strongly Disagree ~ 5 Strongly Agree)*

1. Saya pikir saya ingin menggunakan metode pelatihan ini sesering mungkin. *(I think I would like to use this training method frequently.)*	1 2 3 4 5
2. Saya merasa metode pelatihan ini mudah digunakan. *(I thought this training method was easy to use.)*	1 2 3 4 5
3. Saya pikir saya membutuhkan bantuan seseorang yang memiliki pengetahuan teknis untuk bisa menggunakan metode pelatihan ini. *(I think I would need the support of a technical person to be able to use this training method.)*	1 2 3 4 5
4. Saya yakin kebanyakan orang akan bisa belajar menggunakan metode pelatihan ini dengan cepat. *(I would imagine that most people would learn to use this training method very quickly.)*	1 2 3 4 5
5. Saya merasa percaya diri saat menggunakan metode pelatihan ini. *(I felt very confident using this training method.)*	1 2 3 4 5

1

6.	Saya perlu mempelajari banyak hal terlebih dahulu sebelum dapat menggunakan metode pelatihan ini dengan baik. *(I needed to learn a lot of things before I could get going with this training method.)*	1 2 3 4 5
7.	Saya merasa metode pelatihan ini memiliki terlalu banyak ketidakkonsistenan. *(I thought there was too much inconsistency in this training method.)*	1 2 3 4 5
8.	Saya merasa metode pelatihan ini terlalu rumit. *(I found this training method unnecessarily complex.)*	1 2 3 4 5
9.	Saya merasa metode pelatihan ini sangat membingungkan saat digunakan. *(I found this training method very cumbersome to use.)*	1 2 3 4 5
10.	Saya merasa berbagai fungsi dalam metode pelatihan ini terintegrasi dengan baik. *(I found the various functions in this training method were well-integrated.)*	1 2 3 4 5

The User Experience Questionnaire (UEQ)

Terima kasih atas partisipasi Anda dalam penelitian ini. Untuk lebih memahami pengalaman Anda, kami mengundang Anda untuk mengisi kuesioner berikut. Kuesioner ini mencakup beberapa aspek seperti kegunaan, daya tarik, dan kenyamanan saat menggunakan metode pelatihan. Mohon untuk memberikan penilaian yang sesuai dengan persepsi dan pengalaman Anda. Masukan Anda sangat berharga bagi kami!

(Thank you for participating in this study. To gain further insight into your experience, we invite you to complete the following questionnaire. This questionnaire covers aspects such as usability, attractiveness, and comfort in using the training method. Please rate each item based on your perception and experience. Your input is very valuable to us!)

1	Menghalangi *(Obstructive)*	1 2 3 4 5 6 7	Mendukung *(Supportive)*
2	Rumit *(Complicated)*	1 2 3 4 5 6 7	Sederhana *(Easy)*
3	Tidak efisien *(Inefficient)*	1 2 3 4 5 6 7	Efisien *(Efficient)*
4	Membingungkan *(Confusing)*	1 2 3 4 5 6 7	Jelas *(Clear)*
5	Membosankan *(Boring)*	1 2 3 4 5 6 7	Mengasyikkan *(Exciting)*
6	Tidak menarik *(Not interesting)*	1 2 3 4 5 6 7	Menarik *(Interesting)*
7	Konvensional *(Conventional)*	1 2 3 4 5 6 7	Berdaya Cipta *(Inventive)*
8	Lazim *(Usual)*	1 2 3 4 5 6 7	Terdepan *(Leading Edge)*

Appendix I. Questionnaire to Improve the Training Method

3 - Questionnaire to Improve the Proposed Method

Instance	UNIKOM / SMA15
Group ID	A / B / C
Participant ID (P-No)	P-
Sign / TTD	

1. Apakah anda mempunyai saran untuk meningkatkan NB method *(Do you have any suggestions for improving the NB method)?*

2. Apakah anda mempunyai saran untuk meningkatkan CB method *(Do you have any suggestions for improving the CB method)?*

3. Apakah anda mempunyai saran untuk meningkatkan SC method *(Do you have any suggestions for improving the SC method)?*

4. Apakah anda mempunyai saran agar eksperimen selanjutnya menjadi lebih baik *(Do you have any other comments or suggestions regarding the experiment or the methods used)?*

1

Appendix J. Participant Comments

P Code	HC (Human Conductor)	NB	HB	HBP	Feeling
NIN-P01	Can follow melody and rhythm	Too easy	Don't like it	Really don't like it	NB easy but lacks angklung feel. HB & HBP closer to real angklung.
NIN-P02	Don't know how to stop	Easy but disconnects from real humans	Easy to follow but unpredictable	Sub-conductor disturbs rhythm	NB feels like a game. HB & HBP harder but more angklung-like.
NIN-P03	Experience with conductor but not hand-signs	Easy to follow	Unnatural, fast	Hard to focus on two robots	NB structured but lacks interaction. HB & HBP require angklung-style focus.
NIN-P04	Hard to follow, too fast	Easy to follow	Unnatural pre-motion	1s preview helps, but multiple notes cause issues	NB makes playing clear but lacks musical depth. HB & HBP require real-time adaptation.
NIN-P05	Uncertain stopping points	Simpler, but lacks enjoyment	Sudden, unnatural	Same issue as HB	NB lacks enjoyment, like a game. HB & HBP feel more angklung-like but need improvement.
NIN-P06	Confused by different heights but easy to follow	Feels like a game, easy focus	Too fast	Difficult	NB structured but artificial. HB & HBP challenging but realistic.
NIN-P07	Interesting	More suitable	Difficult to follow	Harder than HB but useful if adapted	NB easy but mechanical. HB & HBP simulate angklung's unpredictability.
NIN-P08	Difficult to predict hand-sign timing	Easiest	Abrupt, but no ambiguity	Too much information causes confusion	NB helps timing but lacks realism. HB & HBP overload with information but feel natural.
NIN-P09	Human rhythm is good	Clear playing time	Lacks rhythm	HBP doesn't match music, confusing	NB has clear timing but no rhythm. HB & HBP closer to real conductor experience.
NIN-P10	Hand movements predictable	Color focus makes it easy	Abrupt and fast, difficult	Easier with HBP but overwhelming	NB efficient but lacks musical feel. HB & HBP require more angklung-style reaction.
NIN-P11	Depends on tempo	Okay if game view changes	Good, but robots too perfect	Useless since 1s is too short	NB adaptable but detached. HB & HBP add realism but harder to follow.
NIN-P12	Humans can't perfectly show signs	Good for knowing note range	Not smooth	Hard to focus	NB provides clarity but lacks artistry. HB & HBP demand angklung-like focus.
NIN-P13	Takes time but improves	Most fun, but lacks real interaction	Sub-conductor distracting	Accurate but ineffective for me	NB fun but unnatural. HB & HBP accurate but disruptive.
NIN-P14	Time-consuming for novices	Good for knowing duration	Rigid	Fast movements distracting	NB easy but robotic. HB & HBP add real angklung dynamics.
NIN-P15	Difficult but catches flow	Like a video game	No distractions, easier than HBP	Harder than HC	NB feels like a video game. HB & HBP require real angklung engagement.
NIN-P16	Gives confidence	Easier, but no mistake feedback	Always consistent	Sign drop makes HBP hard	NB structured but mechanical. HB & HBP develop confidence in real angklung playing.
NIN-P17	Difficult at first	Clear and color is easy to distinguish	Most difficult	Too fast, hard to focus	NB very clear but lacks human rhythm. HB & HBP harder but necessary for angklung.
NIN-P18	Not as easy as expected	Most suitable	Abrupt, difficult	Hard to focus on both robots	NB best guidance but artificial. HB & HBP require full angklung adaptation.
INA-P01	Time-consuming	No angklung feel	Rigid, difficult	Better if accustomed	NB lacks playing feel. HB & HBP more realistic but harder.
INA-P02	Predictable	Color-blind issue	Difficult but clearer	Better adapted to HC	NB lacks interaction. HB & HBP better transition to real HC.

P Code	HC (Human Conductor)	NB	HB	HBP	Feeling
INA-P03	More engaging	Know when to start/stop	Rigid but clear	More preparation, better than HB	NB structured but detached. HB & HBP give real playing experience.
INA-P04	Predictable	Easier	Not too hard but unnatural	More difficult due to focus shifting	NB makes practice easy but mechanical. HB & HBP more natural.
INA-P05	Adaptable	More fun	Too fast, hard to distinguish	1s delay too long	NB feels like a game. HB & HBP have better control.
INA-P06	Consistent	Simple and easy	Difficult, not smooth	1s delay is good	NB efficient but artificial. HB & HBP closer to human feel.
INA-P07	Feeling connected	More enjoyable	Better focus, human-like	Confusing	NB lacks angklung feel. HB & HBP better for focus and timing.
INA-P08	More fun	More focus, better duration control	Shocking movements	Distracting	NB engaging but synthetic. HB & HBP challenge real coordination.
INA-P09	More structured	Best focus	Harder level	Helpful	NB clear but lacks musical artistry. HB & HBP feel more immersive.
SMA-P01	Very simple to follow	Clear but color similarity issues	Seems slow but actually fast, feels unnatural	Easier than HB but still requires extra focus	NB lacks angklung feel, feels like a game. HB & HBP simulate real angklung.
SMA-P02	Easy and intuitive	Simpler but lacks response like real angklung	Fast and structured, but robotic	More predictable than HB, but needs extra effort	NB lacks traditional angklung sensation. HB & HBP feel more musical.
SMA-P03	Not challenging, very familiar	Basic and game-like	Feels different from human conductor	Better than HB, but still mechanical	NB fun but not immersive. HB & HBP have real angklung movement.
SMA-P04	Easy to anticipate	Too basic, lacks complexity	Not smooth, lacks human conductor feel	Somewhat easier than HB but still inefficient	NB feels more like a tool than playing. HB & HBP provide a closer angklung experience.
SMA-P05	Predictable and smooth	Very simple, good for novices but not immersive	Disjointed and stiff movements	More effective than HB, but needs improvement	NB too structured, HB & HBP replicate real angklung better.
SMA-P06	More natural than HB	Lacks challenge, predictable	Abrupt movements make it hard to follow	HBP adds better timing but split focus makes it tricky	NB lacks angklung flow. HB & HBP help feel like playing real angklung.
SMA-P07	Feels comfortable and smooth	Too easy, like a simplified version	Too robotic, lacks expressive motion	HBP is harder but helps in anticipation	NB makes it too systematic. HB & HBP provide a closer angklung-like experience.
SMA-P08	Good transition from HC	Super easy, almost no effort needed	Fast, stiff, difficult to predict next movement	Challenging but rewarding once adapted	NB is overly simplified. HB & HBP have a more organic angklung rhythm.
SMA-P09	Feels flawless, no hesitation	Straightforward, easy but lacks depth	Hard to align with next note, timing issue	Most difficult due to focus splitting	NB feels like a rhythm game, HB & HBP capture real angklung timing.

Appendix K. Participants Performance Score

P Code	PM	TM	Note	T1	T2	D
INA-P01	PM-1	NB	Re	81	86	6
INA-P01	PM-2	HB	Fa	75	94	19
INA-P01	PM-3	HBP	Do'	88	83	-4
INA-P02	PM-1	NB	Fa	75	94	19
INA-P02	PM-2	HB	Do'	100	100	0
INA-P02	PM-3	HBP	Re	86	83	-3
INA-P03	PM-1	NB	Do'	71	88	17
INA-P03	PM-2	HB	Re	75	81	6
INA-P03	PM-3	HBP	Fa	83	92	8
INA-P04	PM-1	HB	Re	75	67	-8
INA-P04	PM-2	HBP	Fa	83	78	-6
INA-P04	PM-3	NB	Do'	79	79	0
INA-P05	PM-1	HB	Fa	75	69	-6
INA-P05	PM-2	HBP	Do'	88	96	8
INA-P05	PM-3	NB	Re	72	86	14
INA-P06	PM-1	HB	Do'	67	96	29
INA-P06	PM-2	HBP	Re	94	83	-11
INA-P06	PM-3	NB	Fa	72	81	8
INA-P07	PM-1	HBP	Re	53	58	6
INA-P07	PM-2	NB	Fa	61	72	11
INA-P07	PM-3	HB	Do'	88	92	4
INA-P08	PM-1	HBP	Fa	50	67	17
INA-P08	PM-2	NB	Do'	88	88	0
INA-P08	PM-3	HB	Re	86	69	-17
INA-P09	PM-1	HBP	Do'	71	83	13
INA-P09	PM-2	NB	Re	36	75	39
INA-P09	PM-3	HB	Fa	58	78	19
NIN-P01	PM-1	NB	Re	81	81	0
NIN-P01	PM-2	HB	Fa	94	94	0
NIN-P01	PM-3	HBP	Do'	83	96	13
NIN-P02	PM-1	NB	Re	39	67	28
NIN-P02	PM-2	HB	Fa	78	86	8
NIN-P02	PM-3	HBP	Do'	79	92	13
NIN-P03	PM-1	NB	Fa	75	97	22
NIN-P03	PM-2	HB	Do'	88	83	-4
NIN-P03	PM-3	HBP	Re	69	75	6
NIN-P04	PM-1	NB	Fa	72	94	22
NIN-P04	PM-2	HB	Do'	100	100	0
NIN-P04	PM-3	HBP	Re	78	94	17

P Code	PM	TM	Note	T1	T2	D
NIN-P05	PM-1	NB	Do'	92	83	-8
NIN-P05	PM-2	HB	Re	69	67	-3
NIN-P05	PM-3	HBP	Fa	58	86	28
NIN-P06	PM-1	NB	Do'	75	79	4
NIN-P06	PM-2	HB	Re	56	94	39
NIN-P06	PM-3	HBP	Fa	97	92	-6
NIN-P07	PM-1	HB	Re	42	53	11
NIN-P07	PM-2	HBP	Fa	67	97	31
NIN-P07	PM-3	NB	Do'	46	83	38
NIN-P08	PM-1	HB	Re	56	75	19
NIN-P08	PM-2	HBP	Fa	78	92	14
NIN-P08	PM-3	NB	Do'	79	63	-17
NIN-P09	PM-1	HB	Fa	61	83	22
NIN-P09	PM-2	HBP	Do'	79	71	-8
NIN-P09	PM-3	NB	Re	64	78	14
NIN-P10	PM-1	HB	Fa	89	92	3
NIN-P10	PM-2	HBP	Do'	100	100	0
NIN-P10	PM-3	NB	Re	86	92	6
NIN-P11	PM-1	HB	Do'	63	58	-4
NIN-P11	PM-2	HBP	Re	58	58	0
NIN-P11	PM-3	NB	Fa	58	81	22
NIN-P12	PM-1	HB	Do'	83	96	13
NIN-P12	PM-2	HBP	Re	83	94	11
NIN-P12	PM-3	NB	Fa	92	97	6
NIN-P13	PM-1	HBP	Re	83	72	-11
NIN-P13	PM-2	NB	Fa	92	81	-11
NIN-P13	PM-3	HB	Do'	96	96	0
NIN-P14	PM-1	HBP	Re	50	67	17
NIN-P14	PM-2	NB	Fa	31	42	11
NIN-P14	PM-3	HB	Do'	83	79	-4
NIN-P15	PM-1	HBP	Fa	92	94	3
NIN-P15	PM-2	NB	Do'	88	100	13
NIN-P15	PM-3	HB	Re	61	81	19
NIN-P16	PM-1	HBP	Fa	94	94	0
NIN-P16	PM-2	NB	Do'	79	88	8
NIN-P16	PM-3	HB	Re	61	83	22
NIN-P17	PM-1	HBP	Do'	71	96	25
NIN-P17	PM-2	NB	Re	69	72	3
NIN-P17	PM-3	HB	Fa	78	100	22
NIN-P18	PM-1	HBP	Do'	92	96	4
NIN-P18	PM-2	NB	Re	56	69	14

P Code	PM	TM	Note	T1	T2	D
NIN-P18	PM-3	HB	Fa	86	89	3
SMA-P01	PM-1	NB	Re	75	94	19
SMA-P01	PM-2	HB	Fa	67	94	28
SMA-P01	PM-3	HBP	Do'	92	96	4
SMA-P02	PM-1	NB	Fa	89	89	0
SMA-P02	PM-2	HB	Do'	100	63	-38
SMA-P02	PM-3	HBP	Re	92	100	8
SMA-P03	PM-1	NB	Do'	88	75	-13
SMA-P03	PM-2	HB	Re	75	83	8
SMA-P03	PM-3	HBP	Fa	69	75	6
SMA-P04	PM-1	HB	Re	64	83	19
SMA-P04	PM-2	HBP	Fa	83	75	-8
SMA-P04	PM-3	NB	Do'	100	100	0
SMA-P05	PM-1	HB	Fa	53	72	19
SMA-P05	PM-2	HBP	Do'	100	100	0
SMA-P05	PM-3	NB	Re	89	89	0
SMA-P06	PM-1	HB	Do'	58	88	29
SMA-P06	PM-2	HBP	Re	86	72	-14
SMA-P06	PM-3	NB	Fa	81	75	-6
SMA-P07	PM-1	HBP	Re	61	92	31
SMA-P07	PM-2	NB	Fa	56	72	17
SMA-P07	PM-3	HB	Do'	100	100	0
SMA-P08	PM-1	HBP	Fa	75	67	-8
SMA-P08	PM-2	NB	Do'	100	100	0
SMA-P08	PM-3	HB	Re	61	86	25
SMA-P09	PM-1	HBP	Do'	88	88	0
SMA-P09	PM-2	NB	Re	100	94	-6
SMA-P09	PM-3	HB	Fa	78	69	-8

Appendix L. SUS participant's score

P Code	TM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUM	SUS Score
INA-P01	HB	2	1	3	2	2	3	0	1	1	2	17	42.5
INA-P01	NB	3	4	2	4	4	3	4	4	4	4	36	90
INA-P01	HBP	3	3	2	3	3	3	1	2	2	3	25	62.5
INA-P02	HB	3	1	1	2	0	3	4	2	1	3	20	50
INA-P02	NB	4	3	3	3	4	4	3	4	4	3	35	87.5
INA-P02	HBP	2	0	0	1	3	1	2	1	0	0	10	25
INA-P03	HB	1	2	3	1	1	1	3	1	1	3	17	42.5
INA-P03	NB	3	4	3	3	4	3	3	4	3	3	33	82.5
INA-P03	HBP	3	2	1	2	2	1	3	1	2	3	20	50
INA-P04	HB	4	2	2	3	3	2	2	2	3	1	24	60
INA-P04	NB	4	4	3	4	4	3	3	3	4	4	36	90
INA-P04	HBP	2	2	1	2	1	2	2	2	1	2	17	42.5
INA-P05	HB	3	2	1	3	3	2	3	3	3	3	26	65
INA-P05	NB	4	4	3	4	4	2	4	4	4	0	33	82.5
INA-P05	HBP	2	1	1	2	2	2	4	2	2	3	21	52.5
INA-P06	HB	3	2	3	2	2	2	3	3	3	2	25	62.5
INA-P06	NB	3	3	2	3	3	2	3	3	3	3	28	70
INA-P06	HBP	2	2	3	2	2	2	3	2	2	2	22	55
INA-P07	HB	1	1	1	1	1	1	2	1	2	2	13	32.5
INA-P07	NB	3	4	2	4	4	3	4	4	4	3	35	87.5
INA-P07	HBP	2	1	1	1	2	1	2	3	2	3	18	45
INA-P08	HB	2	2	3	2	2	3	4	2	1	4	25	62.5
INA-P08	NB	4	4	3	4	4	3	4	4	4	4	38	95
INA-P08	HBP	3	3	0	2	2	1	3	2	3	3	22	55
INA-P09	HB	2	1	3	1	2	4	3	2	2	3	23	57.5
INA-P09	NB	4	4	3	4	4	4	4	4	4	3	38	95
INA-P09	HBP	4	3	0	4	3	3	4	4	3	3	31	77.5
NIN-P01	HB	1	1	3	2	2	3	3	3	1	2	21	52.5
NIN-P01	NB	3	3	3	3	3	4	3	4	3	3	32	80
NIN-P01	HBP	3	2	1	2	2	3	3	2	2	4	24	60
NIN-P02	HB	0	1	1	0	1	0	1	1	0	1	6	15
NIN-P02	NB	4	4	0	3	3	4	4	4	4	4	34	85
NIN-P02	HBP	0	0	1	0	0	1	4	0	0	0	6	15
NIN-P03	HB	1	0	4	0	0	0	1	0	0	2	8	20
NIN-P03	NB	4	4	1	2	2	0	3	3	3	2	24	60
NIN-P03	HBP	1	0	2	1	1	0	1	0	0	2	8	20
NIN-P04	HB	2	2	1	2	2	2	2	3	2	2	20	50
NIN-P04	NB	3	4	3	3	3	4	4	4	3	2	33	82.5
NIN-P04	HBP	3	2	2	2	3	2	1	2	2	3	22	55
NIN-P05	HB	2	2	1	2	2	3	0	1	0	4	17	42.5
NIN-P05	NB	4	4	4	4	4	3	4	4	4	4	39	97.5
NIN-P05	HBP	1	0	4	0	0	0	0	0	0	0	5	12.5
NIN-P06	HB	4	3	4	4	4	4	4	4	0	4	35	87.5
NIN-P06	NB	4	4	4	4	4	4	4	4	4	3	39	97.5
NIN-P06	HBP	4	4	4	4	4	4	4	4	4	4	40	100
NIN-P07	HB	4	4	3	3	4	4	4	4	4	4	38	95

P Code	TM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUM	SUS Score
NIN-P07	NB	4	4	0	4	4	0	4	4	4	4	32	80
NIN-P07	HBP	4	4	3	4	4	3	4	4	4	4	38	95
NIN-P08	HB	3	3	3	4	4	2	3	3	3	2	30	75
NIN-P08	NB	3	4	3	3	4	4	4	4	4	3	36	90
NIN-P08	HBP	2	2	3	3	2	3	2	1	1	2	21	52.5
NIN-P09	HB	1	3	2	3	3	3	1	4	2	1	23	57.5
NIN-P09	NB	3	3	1	3	1	1	3	3	3	3	24	60
NIN-P09	HBP	0	1	3	3	1	3	1	1	1	3	17	42.5
NIN-P10	HB	3	1	1	4	3	4	4	4	4	4	32	80
NIN-P10	NB	4	4	4	4	4	4	4	4	4	4	40	100
NIN-P10	HBP	4	4	3	4	4	4	4	4	4	4	39	97.5
NIN-P11	HB	2	3	3	4	4	3	4	4	3	3	33	82.5
NIN-P11	NB	3	4	3	4	4	3	4	3	3	3	34	85
NIN-P11	HBP	2	3	3	4	4	4	3	3	3	3	32	80
NIN-P12	HB	1	3	3	1	4	4	3	4	4	3	30	75
NIN-P12	NB	4	4	0	4	4	4	4	4	4	0	32	80
NIN-P12	HBP	4	4	3	3	4	3	3	4	4	3	35	87.5
NIN-P13	HB	3	4	1	3	3	3	3	4	1	3	28	70
NIN-P13	NB	4	4	4	4	4	4	4	4	4	4	40	100
NIN-P13	HBP	3	3	4	3	3	3	4	3	4	2	32	80
NIN-P14	HB	4	3	3	3	4	4	4	4	4	3	36	90
NIN-P14	NB	2	3	3	2	1	1	3	3	4	2	24	60
NIN-P14	HBP	2	3	2	3	4	4	4	4	4	4	34	85
NIN-P15	HB	1	2	2	1	2	2	1	2	2	2	17	42.5
NIN-P15	NB	4	4	3	4	4	4	4	4	4	4	39	97.5
NIN-P15	HBP	2	2	3	1	2	3	3	1	1	3	21	52.5
NIN-P16	HB	3	3	1	3	3	3	4	4	4	4	32	80
NIN-P16	NB	4	4	4	4	4	4	4	4	4	4	40	100
NIN-P16	HBP	1	1	1	0	1	3	0	1	1	2	11	27.5
NIN-P17	HB	2	2	1	2	2	3	1	3	2	1	19	47.5
NIN-P17	NB	4	4	4	3	4	4	4	4	4	3	38	95
NIN-P17	HBP	3	3	4	4	3	4	3	4	4	3	35	87.5
NIN-P18	HB	3	3	4	3	2	4	4	4	4	2	33	82.5
NIN-P18	NB	4	4	4	4	4	4	4	4	4	4	40	100
NIN-P18	HBP	2	2	1	1	1	0	1	2	1	4	15	37.5
SMA-P01	HB	0	0	1	0	0	1	0	0	0	2	4	10
SMA-P01	NB	2	2	1	4	2	3	3	3	2	2	24	60
SMA-P01	HBP	1	1	1	1	0	3	1	0	0	2	10	25
SMA-P02	HB	1	0	3	1	2	1	2	3	1	2	16	40
SMA-P02	NB	2	3	1	3	3	1	3	1	4	3	24	60
SMA-P02	HBP	2	2	1	2	2	1	2	2	2	3	19	47.5
SMA-P03	HB	0	3	2	2	2	2	2	3	3	2	21	52.5
SMA-P03	NB	2	3	3	4	3	2	4	4	4	4	33	82.5
SMA-P03	HBP	2	3	1	2	3	3	3	3	1	3	24	60
SMA-P04	HB	1	1	0	1	2	0	2	1	1	2	11	27.5
SMA-P04	NB	3	4	2	4	3	2	3	4	4	4	33	82.5
SMA-P04	HBP	2	2	0	1	2	0	2	2	2	4	17	42.5
SMA-P05	HB	1	1	1	1	1	0	2	1	1	1	10	25

P Code	TM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUM	SUS Score
SMA-P05	NB	4	3	3	4	3	2	3	3	3	3	31	77.5
SMA-P05	HBP	1	2	0	1	1	1	3	1	1	2	13	32.5
SMA-P06	HB	2	1	0	1	1	0	2	1	1	2	11	27.5
SMA-P06	NB	3	3	2	3	3	1	3	2	2	4	26	65
SMA-P06	HBP	2	1	0	1	1	0	2	3	3	2	15	37.5
SMA-P07	HB	3	1	2	0	1	1	1	1	1	2	13	32.5
SMA-P07	NB	2	3	1	1	3	3	2	2	3	3	23	57.5
SMA-P07	HBP	2	1	0	1	2	0	1	2	2	2	13	32.5
SMA-P08	HB	2	1	1	3	2	0	2	1	1	2	15	37.5
SMA-P08	NB	3	4	4	4	4	4	3	4	4	3	37	92.5
SMA-P08	HBP	1	2	0	0	1	0	3	1	2	3	13	32.5
SMA-P09	HB	1	3	0	1	0	0	2	0	0	2	9	22.5
SMA-P09	NB	4	4	2	4	4	2	3	4	4	3	34	85
SMA-P09	HBP	1	0	0	2	1	0	2	1	2	3	12	30

Appendix M. UEQ-S participant's score

P Code	TM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
INA-P01	HB	5	4	4	4	5	5	5	6
INA-P01	NB	6	7	6	7	7	7	6	6
INA-P01	HBP	6	5	5	4	6	6	7	7
INA-P02	HB	6	3	4	2	4	3	7	7
INA-P02	NB	7	7	6	7	5	4	4	3
INA-P02	HBP	7	1	7	3	6	4	7	7
INA-P03	HB	6	3	4	3	6	4	5	5
INA-P03	NB	7	7	7	7	6	7	6	6
INA-P03	HBP	6	5	6	4	5	5	4	4
INA-P04	HB	5	6	5	5	6	7	6	5
INA-P04	NB	7	7	7	7	7	7	7	7
INA-P04	HBP	5	4	4	4	5	6	5	4
INA-P05	HB	5	4	6	7	6	6	6	7
INA-P05	NB	7	7	7	7	7	7	6	6
INA-P05	HBP	5	4	4	4	5	6	6	6
INA-P06	HB	4	5	4	4	5	5	4	5
INA-P06	NB	5	5	5	5	6	6	4	3
INA-P06	HBP	4	3	4	4	5	4	4	4
INA-P07	HB	5	4	5	4	5	5	7	7
INA-P07	NB	7	7	7	7	7	7	7	7
INA-P07	HBP	6	5	5	5	7	6	6	6
INA-P08	HB	6	4	5	6	7	7	7	7
INA-P08	NB	7	7	7	7	7	7	5	6
INA-P08	HBP	6	6	7	7	7	7	7	5
INA-P09	HB	5	4	5	4	5	5	5	6
INA-P09	NB	7	7	7	7	7	7	5	5
INA-P09	HBP	6	6	6	6	7	7	6	6
NIN-P01	HB	4	5	4	5	4	3	6	6
NIN-P01	NB	6	6	6	6	5	6	6	6
NIN-P01	HBP	5	5	6	6	5	5	7	6
NIN-P02	HB	2	2	2	1	5	2	3	5
NIN-P02	NB	6	7	6	6	5	6	6	6
NIN-P02	HBP	1	1	1	1	6	1	2	5
NIN-P03	HB	2	1	2	1	1	2	3	4
NIN-P03	NB	5	4	5	7	5	5	4	4
NIN-P03	HBP	1	1	1	1	1	2	4	2
NIN-P04	HB	4	5	5	5	4	4	5	5
NIN-P04	NB	5	6	6	6	4	6	5	4
NIN-P04	HBP	5	5	5	4	5	5	6	6
NIN-P05	HB	1	2	1	1	2	2	2	3

P Code	TM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
NIN-P05	NB	7	7	7	7	7	7	7	7
NIN-P05	HBP	1	1	2	1	1	1	1	2
NIN-P06	HB	7	6	7	7	6	7	7	7
NIN-P06	NB	7	7	7	7	6	7	7	7
NIN-P06	HBP	7	7	7	7	7	7	7	7
NIN-P07	HB	7	1	6	7	7	6	7	6
NIN-P07	NB	7	7	7	7	7	7	7	7
NIN-P07	HBP	7	6	7	7	7	7	7	6
NIN-P08	HB	5	5	6	5	4	5	4	3
NIN-P08	NB	6	6	6	6	5	6	6	6
NIN-P08	HBP	5	3	4	4	4	5	4	4
NIN-P09	HB	3	6	5	2	3	3	3	3
NIN-P09	NB	6	3	5	6	6	6	5	5
NIN-P09	HBP	3	4	3	2	3	3	5	5
NIN-P10	HB	7	4	7	7	7	7	7	7
NIN-P10	NB	5	7	7	7	3	4	5	6
NIN-P10	HBP	7	6	7	6	7	7	7	7
NIN-P11	HB	6	7	6	7	5	5	6	5
NIN-P11	NB	6	6	6	7	7	6	6	5
NIN-P11	HBP	5	7	6	7	6	6	5	5
NIN-P12	HB	7	5	6	6	7	7	6	6
NIN-P12	NB	7	7	7	7	6	7	7	7
NIN-P12	HBP	6	5	6	6	6	6	5	6
NIN-P13	HB	5	3	5	3	6	5	7	7
NIN-P13	NB	7	7	7	7	7	7	7	7
NIN-P13	HBP	7	5	5	6	6	6	7	7
NIN-P14	HB	7	6	7	6	7	6	6	6
NIN-P14	NB	5	3	4	5	5	5	4	5
NIN-P14	HBP	6	6	6	7	6	7	5	6
NIN-P15	HB	3	5	3	4	3	3	3	4
NIN-P15	NB	7	7	7	7	7	7	7	6
NIN-P15	HBP	4	3	4	4	4	7	4	5
NIN-P16	HB	6	6	6	6	6	6	7	7
NIN-P16	NB	7	7	7	7	7	7	7	6
NIN-P16	HBP	3	2	3	2	4	3	4	5
NIN-P17	HB	6	6	6	6	2	6	6	6
NIN-P17	NB	6	7	6	6	2	6	6	6
NIN-P17	HBP	4	6	6	7	2	6	5	5
NIN-P18	HB	5	5	5	6	5	5	5	6
NIN-P18	NB	6	7	7	7	6	7	7	6
NIN-P18	HBP	3	3	4	5	3	2	7	5
SMA-P01	HB	1	1	2	1	3	3	4	3

P Code	TM	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
SMA-P01	NB	4	3	4	5	4	6	4	4
SMA-P01	HBP	2	1	1	1	3	3	4	3
SMA-P02	HB	2	2	3	3	4	4	4	3
SMA-P02	NB	6	7	6	6	4	5	5	6
SMA-P02	HBP	4	3	3	4	4	4	5	4
SMA-P03	HB	5	3	4	3	4	4	5	4
SMA-P03	NB	7	7	7	7	6	6	5	4
SMA-P03	HBP	5	5	6	5	4	4	4	3
SMA-P04	HB	3	3	4	3	6	6	7	7
SMA-P04	NB	7	6	6	7	7	7	4	6
SMA-P04	HBP	5	3	4	3	7	7	7	6
SMA-P05	HB	5	3	4	3	5	6	4	3
SMA-P05	NB	7	7	6	6	6	7	2	2
SMA-P05	HBP	6	3	5	3	5	6	5	5
SMA-P06	HB	4	3	4	3	4	4	5	5
SMA-P06	NB	6	6	4	5	6	6	5	5
SMA-P06	HBP	4	3	4	3	4	5	4	5
SMA-P07	HB	2	2	2	3	4	6	7	5
SMA-P07	NB	4	5	4	5	3	4	6	4
SMA-P07	HBP	3	4	2	3	5	4	7	4
SMA-P08	HB	3	4	5	4	6	7	4	5
SMA-P08	NB	7	7	7	7	7	7	6	7
SMA-P08	HBP	5	4	6	3	6	7	5	5
SMA-P09	HB	4	4	4	3	5	4	5	6
SMA-P09	NB	7	7	7	7	7	7	6	6
SMA-P09	HBP	6	3	5	4	4	5	5	4

Appendix N. UEQ-S Summary

P Code	Q1_mean	Q1_std	Q2_mean	Q2_std	Q3_mean	Q3_std	Q4_mean	Q4_std	Q5_mean	Q5_std	Q6_mean	Q6_std	Q7_mean	Q7_std	Q8_mean	Q8_std
INA-P01	5.67	0.58	5.33	1.53	5.00	1.00	5.00	1.73	6.00	1.00	6.00	1.00	6.00	1.00	6.33	0.58
INA-P02	6.67	0.58	3.67	3.06	5.67	1.53	4.00	2.65	5.00	1.00	3.67	0.58	6.00	1.73	5.67	2.31
INA-P03	6.33	0.58	5.00	2.00	5.67	1.53	4.67	2.08	5.67	0.58	5.33	1.53	5.00	1.00	5.00	1.00
INA-P04	5.67	1.15	5.67	1.53	5.33	1.53	5.33	1.53	6.00	1.00	6.67	0.58	6.00	1.00	5.33	1.53
INA-P05	5.67	1.15	5.00	1.73	5.67	1.53	6.00	1.73	6.00	1.00	6.33	0.58	6.00	0.00	6.33	0.58
INA-P06	4.33	0.58	4.33	1.15	4.33	0.58	4.33	0.58	5.33	0.58	5.00	1.00	4.00	0.00	4.00	1.00
INA-P07	6.00	1.00	5.33	1.53	5.67	1.15	5.33	1.53	6.33	1.15	6.00	1.00	6.67	0.58	6.67	0.58
INA-P08	6.33	0.58	5.67	1.53	6.33	1.15	6.67	0.58	7.00	0.00	7.00	0.00	6.33	1.15	6.00	1.00
INA-P09	6.00	1.00	5.67	1.53	6.00	1.00	5.67	1.53	6.33	1.15	6.33	1.15	5.33	0.58	5.67	0.58
NIN-P01	5.00	1.00	5.33	0.58	5.33	1.15	5.67	0.58	4.67	0.58	4.67	1.53	6.33	0.58	6.00	0.00
NIN-P02	3.00	2.65	3.33	3.21	3.00	2.65	2.67	2.89	5.33	0.58	3.00	2.65	3.67	2.08	5.33	0.58
NIN-P03	2.67	2.08	2.00	1.73	2.67	2.08	3.00	3.46	2.33	2.31	3.00	1.73	3.67	0.58	3.33	1.15
NIN-P04	4.67	0.58	5.33	0.58	5.33	0.58	5.00	1.00	4.33	0.58	5.00	1.00	5.33	0.58	5.00	1.00
NIN-P05	3.00	3.46	3.33	3.21	3.33	3.21	3.00	3.46	3.33	3.21	3.33	3.21	3.33	3.21	4.00	2.65
NIN-P06	7.00	0.00	6.67	0.58	7.00	0.00	7.00	0.00	6.33	0.58	7.00	0.00	7.00	0.00	7.00	0.00
NIN-P07	7.00	0.00	4.67	3.21	6.67	0.58	7.00	0.00	7.00	0.00	6.67	0.58	7.00	0.00	6.33	0.58
NIN-P08	5.33	0.58	4.67	1.53	5.33	1.15	5.00	1.00	4.33	0.58	5.33	0.58	4.67	1.15	4.33	1.53
NIN-P09	4.00	1.73	4.33	1.53	4.33	1.15	3.33	2.31	4.00	1.73	4.00	1.73	4.33	1.15	4.33	1.15
NIN-P10	6.33	1.15	5.67	1.53	7.00	0.00	6.67	0.58	5.67	2.31	6.00	1.73	6.33	1.15	6.67	0.58
NIN-P11	5.67	0.58	6.67	0.58	6.00	0.00	7.00	0.00	6.00	1.00	5.67	0.58	5.67	0.58	5.00	0.00
NIN-P12	6.67	0.58	5.67	1.15	6.33	0.58	6.33	0.58	6.33	0.58	6.67	0.58	6.00	1.00	6.33	0.58
NIN-P13	6.33	1.15	5.00	2.00	5.67	1.15	5.33	2.08	6.33	0.58	6.00	1.00	7.00	0.00	7.00	0.00
NIN-P14	6.00	1.00	5.00	1.73	5.67	1.53	6.00	1.00	6.00	1.00	6.00	1.00	5.00	1.00	5.67	0.58
NIN-P15	4.67	2.08	5.00	2.00	4.67	2.08	5.00	1.73	4.67	2.08	5.67	2.31	4.67	2.08	5.00	1.00
NIN-P16	5.33	2.08	5.00	2.65	5.33	2.08	5.00	2.65	5.67	1.53	5.33	2.08	6.00	1.73	6.00	1.00

P Code	Q1_mean	Q1_std	Q2_mean	Q2_std	Q3_mean	Q3_std	Q4_mean	Q4_std	Q5_mean	Q5_std	Q6_mean	Q6_std	Q7_mean	Q7_std	Q8_mean	Q8_std
NIN-P17	5.33	1.15	6.33	0.58	6.00	0.00	6.33	0.58	2.00	0.00	6.00	0.00	5.67	0.58	5.67	0.58
NIN-P18	4.67	1.53	5.00	2.00	5.33	1.53	6.00	1.00	4.67	1.53	4.67	2.52	6.33	1.15	5.67	0.58
SMA-P01	2.33	1.53	1.67	1.15	2.33	1.53	2.33	2.31	3.33	0.58	4.00	1.73	4.00	0.00	3.33	0.58
SMA-P02	4.00	2.00	4.00	2.65	4.00	1.73	4.33	1.53	4.00	0.00	4.33	0.58	4.67	0.58	4.33	1.53
SMA-P03	5.67	1.15	5.00	2.00	5.67	1.53	5.00	2.00	4.67	1.15	4.67	1.15	4.67	0.58	3.67	0.58
SMA-P04	5.00	2.00	4.00	1.73	4.67	1.15	4.33	2.31	6.67	0.58	6.67	0.58	6.00	1.73	6.33	0.58
SMA-P05	6.00	1.00	4.33	2.31	5.00	1.00	4.00	1.73	5.33	0.58	6.33	0.58	3.67	1.53	3.33	1.53
SMA-P06	4.67	1.15	4.00	1.73	4.00	0.00	3.67	1.15	4.67	1.15	5.00	1.00	4.67	0.58	5.00	0.00
SMA-P07	3.00	1.00	3.67	1.53	2.67	1.15	3.67	1.15	4.00	1.00	4.67	1.15	6.67	0.58	4.33	0.58
SMA-P08	5.00	2.00	5.00	1.73	6.00	1.00	4.67	2.08	6.33	0.58	7.00	0.00	5.00	1.00	5.67	1.15
SMA-P09	5.67	1.53	4.67	2.08	5.33	1.53	4.67	2.08	5.33	1.53	5.33	1.53	5.33	0.58	5.33	1.15

Appendix O. Participant Comments

P Code	HC (Human Conductor)	NB (Notebar Color)	HB (Conductor Without Sub)	HBP (Conductor With Sub)	Feeling
NIN-P01	Can follow melody and rhythm	Too easy	Don't like it	Really don't like it	NB easy but lacks angklung feel. HB & HBP closer to real angklung.
NIN-P02	Don't know how to stop	Easy but disconnects from real humans	Easy to follow but unpredictable	Sub-conductor disturbs rhythm	NB feels like a game. HB & HBP harder but more angklung-like.
NIN-P03	Experience with conductor but not hand-signs	Easy to follow	Unnatural, fast	Hard to focus on two robots	NB structured but lacks interaction. HB & HBP require angklung-style focus.
NIN-P04	Hard to follow, too fast	Easy to follow	Unnatural pre-motion	1s preview helps, but multiple notes cause issues	NB makes playing clear but lacks musical depth. HB & HBP require real-time adaptation.
NIN-P05	Uncertain stopping points	Simpler, but lacks enjoyment	Sudden, unnatural	Same issue as HB	NB lacks enjoyment, like a game. HB & HBP feel more angklung-like but need improvement.
NIN-P06	Confused by different heights but easy to follow	Feels like a game, easy focus	Too fast	Difficult	NB structured but artificial. HB & HBP challenging but realistic.
NIN-P07	Interesting	More suitable	Difficult to follow	Harder than HB but useful if adapted	NB easy but mechanical. HB & HBP simulate angklung's unpredictability.
NIN-P08	Difficult to predict hand-sign timing	Easiest	Abrupt, but no ambiguity	Too much information causes confusion	NB helps timing but lacks realism. HB & HBP overload with information but feel natural.
NIN-P09	Human rhythm is good	Clear playing time	Lacks rhythm	HBP doesn't match music, confusing	NB has clear timing but no rhythm. HB & HBP closer to real conductor experience.
NIN-P10	Hand movements predictable	Color focus makes it easy	Abrupt and fast, difficult	Easier with HBP but overwhelming	NB efficient but lacks musical feel. HB & HBP require more angklung-style reaction.
NIN-P11	Depends on tempo	Okay if game view changes	Good, but robots too perfect	Useless since 1s is too short	NB adaptable but detached. HB & HBP add realism but harder to follow.
NIN-P12	Humans can't perfectly show signs	Good for knowing note range	Not smooth	Hard to focus	NB provides clarity but lacks artistry. HB & HBP demand angklung-like focus.
NIN-P13	Takes time but improves	Most fun, but lacks real interaction	Sub-conductor distracting	Accurate but ineffective for me	NB fun but unnatural. HB & HBP accurate but disruptive.
NIN-P14	Time-consuming for novices	Good for knowing duration	Rigid	Fast movements distracting	NB easy but robotic. HB & HBP add real angklung dynamics.
NIN-P15	Difficult but catches flow	Like a video game	No distractions, easier than HBP	Harder than HC	NB feels like a video game. HB & HBP require real angklung engagement.
NIN-P16	Gives confidence	Easier, but no mistake feedback	Always consistent	Sign drop makes HBP hard	NB structured but mechanical. HB & HBP develop confidence in real angklung playing.
NIN-P17	Difficult at first	Clear and color is easy to distinguish	Most difficult	Too fast, hard to focus	NB very clear but lacks human rhythm. HB & HBP harder but necessary for angklung.
NIN-P18	Not as easy as expected	Most suitable	Abrupt, difficult	Hard to focus on both robots	NB best guidance but artificial. HB & HBP require full angklung adaptation.
INA-P01	Time-consuming	No angklung feel	Rigid, difficult	Better if accustomed	NB lacks playing feel. HB & HBP more realistic but harder.
INA-P02	Predictable	Color-blind issue	Difficult but clearer	Better adapted to HC	NB lacks interaction. HB & HBP better transition to real HC.

INA-P03	More engaging	Know when to start/stop	Rigid but clear	More preparation, better than HB	NB structured but detached. HB & HBP give real playing experience.
INA-P04	Predictable	Easier	Not too hard but unnatural	More difficult due to focus shifting	NB makes practice easy but mechanical. HB & HBP more natural.
INA-P05	Adaptable	More fun	Too fast, hard to distinguish	1s delay too long	NB feels like a game. HB & HBP have better control.
INA-P06	Consistent	Simple and easy	Difficult, not smooth	1s delay is good	NB efficient but artificial. HB & HBP closer to human feel.
INA-P07	Feeling connected	More enjoyable	Better focus, human-like	Confusing	NB lacks angklung feel. HB & HBP better for focus and timing.
INA-P08	More fun	More focus, better duration control	Shocking movements	Distracting	NB engaging but synthetic. HB & HBP challenge real coordination.
INA-P09	More structured	Best focus	Harder level	Helpful	NB clear but lacks musical artistry. HB & HBP feel more immersive.
SMA-P01	Very simple to follow	Clear but color similarity issues	Seems slow but actually fast, feels unnatural	Easier than HB but still requires extra focus	NB lacks angklung feel, feels like a game. HB & HBP simulate real angklung.
SMA-P02	Easy and intuitive	Simpler but lacks response like real angklung	Fast and structured, but robotic	More predictable than HB, but needs extra effort	NB lacks traditional angklung sensation. HB & HBP feel more musical.
SMA-P03	Not challenging, very familiar	Basic and game-like	Feels different from human conductor	Better than HB, but still mechanical	NB fun but not immersive. HB & HBP have real angklung movement.
SMA-P04	Easy to anticipate	Too basic, lacks complexity	Not smooth, lacks human conductor feel	Somewhat easier than HB but still inefficient	NB feels more like a tool than playing. HB & HBP provide a closer angklung experience.
SMA-P05	Predictable and smooth	Very simple, good for novices but not immersive	Disjointed and stiff movements	More effective than HB, but needs improvement	NB too structured, HB & HBP replicate real angklung better.
SMA-P06	More natural than HB	Lacks challenge, predictable	Abrupt movements make it hard to follow	HBP adds better timing but split focus makes it tricky	NB lacks angklung flow. HB & HBP help feel like playing real angklung.
SMA-P07	Feels comfortable and smooth	Too easy, like a simplified version	Too robotic, lacks expressive motion	HBP is harder but helps in anticipation	NB makes it too systematic. HB & HBP provide a closer angklung-like experience.
SMA-P08	Good transition from HC	Super easy, almost no effort needed	Fast, stiff, difficult to predict next movement	Challenging but rewarding once adapted	NB is overly simplified. HB & HBP have a more organic angklung rhythm.
SMA-P09	Feels flawless, no hesitation	Straightforward, easy but lacks depth	Hard to align with next note, timing issue	Most difficult due to focus splitting	NB feels like a rhythm game, HB & HBP capture real angklung timing.