

Development of a Pitch System for the Traditional Musical Instrument “Bambu Entel” of the Talaud Islands in Sambuara Village

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ARTICLE INFO	ABSTRACT
Received: April 29, 2026	Bambu Entel is a traditional bamboo musical instrument originating from the Talaud Islands, North Sulawesi, Indonesia, whose distinctive construction and sound reflect the cultural knowledge of the Talaud community. However, its limited pitch availability may constrain its integration into broader musical arrangements and contemporary performance contexts. This study aimed to develop a new B-flat (B $\flat$) pitch for Bambu Entel while maintaining its traditional construction principles, acoustic characteristics, and cultural identity. The study employed a Research and Development (R&D) approach using the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation. The research was conducted in Sambuara Village, Talaud Islands Regency, in June 2025, involving Bambu Entel craftsmen, players, and traditional music and instrument experts. Data were collected through observation, interviews, expert validation, and product testing and were analyzed descriptively. The findings indicate that Bambu Entel production involves integrated knowledge of bamboo selection, harvesting conditions, material treatment, shaded drying, structural dimensions, and empirical tuning. The B $\flat$ pitch was successfully developed through gradual modification of the bamboo node opening, followed by repeated auditory evaluation and adjustment by experienced craftsmen. The process demonstrated that traditional empirical knowledge can effectively support tonal innovation without requiring fundamental changes to the instrument's construction or cultural characteristics. The resulting development expands the tonal functionality of Bambu Entel and creates opportunities for its use in broader musical arrangements, education, and contemporary performances. The study concludes that culturally grounded acoustic innovation can contribute to both the musical revitalization and sustainable preservation of Bambu Entel as Talaud cultural heritage.
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1. Introduction

Music is a form of human expression organized through elements such as melody, harmony, rhythm, timbre, and pitch. Beyond its aesthetic function, music serves as a medium through which individuals and communities communicate emotions, experiences, values, and cultural meanings. Musical experience engages complex cognitive and affective processes, involving perception, memory, expectation, and emotional responses to sound (Pando-Naude et al., 2021; Koelsch et al., 2021). Music is also fundamentally a social activity because musical participation involves interaction, coordination, reciprocity, and social cohesion among performers and listeners (Schiavio et al., 2022). Thus, music cannot be understood solely as an arrangement of sounds; it is simultaneously an artistic, cognitive, social, and cultural practice.

Traditional music represents an important form of cultural expression because musical practices are closely connected to the history, values, knowledge, and identity of particular communities. Musical instruments embody both tangible and intangible dimensions of cultural heritage because their construction, materials, playing techniques, repertoire, and performance contexts constitute knowledge transmitted within communities (Howard, 2022). Consequently, preserving traditional musical instruments requires attention not only to their physical survival but also to the musical knowledge and cultural practices associated with them. However, the sustainability of traditional music has become increasingly challenging because of modernization, technological development, changing cultural preferences, and declining intergenerational transmission. Recent ethnomusicological research demonstrates that traditional musical heritage can be threatened by social transformation, migration, technological change, and shifts in cultural practices (Matiure, 2023). Preservation therefore needs to incorporate documentation, education, community participation, and appropriate forms of innovation. In Indonesia, Susanto and Indrawan (2024) demonstrated the importance of developing a written notation-based learning system for Dambus as a strategy for documentation and transmission, indicating that innovation can support cultural preservation when it remains connected to the identity and characteristics of the original musical tradition.

Bamboo is particularly important in the development of traditional musical instruments because its physical and acoustic properties make it suitable for producing a wide variety of sounds. Its natural hollow structure, fiber arrangement, density, and mechanical properties influence vibration, resonance, and timbral characteristics. Deng et al. (2023) demonstrated that the multiscale structure of bamboo contributes significantly to its acoustic vibration performance, with fiber structures affecting vibration efficiency and parenchyma cells contributing to timbral characteristics. Consequently, the production of bamboo musical instruments involves not only cultural knowledge but also material and acoustic considerations. Research on bamboo instruments has further shown that the dimensions and structural characteristics of bamboo tubes influence fundamental frequency and resonance characteristics (Hamdan et al., 2022). The relationship between bamboo construction and pitch is particularly important when a traditional instrument is developed or modified to produce a new tonal system. Hamdan et al. (2022), in their study of the bamboo *angklung*, demonstrated that the fundamental frequency of bamboo tubes can be identified through frequency-spectrum analysis and that differences in tube dimensions influence the resulting pitch. These findings indicate that the development of a specific pitch requires systematic consideration of physical dimensions, resonance, and acoustic frequency rather than relying solely on empirical adjustment.

Recent studies in Indonesia further demonstrate the potential for innovation in bamboo-based musical traditions. Research on *Bambu Tunta* in the Sangihe Islands documented bamboo as the primary material of a traditional musical ensemble and identified distinctive musical structures and playing techniques, demonstrating the continuing relationship

between bamboo instruments and local cultural identity. Similarly, Setiawan et al. (2025) demonstrated that transforming a traditional object into a bamboo musical instrument through organological experimentation and acoustic measurement can generate new timbral possibilities while simultaneously revitalizing local cultural values. These studies indicate that innovation does not necessarily contradict cultural preservation; rather, carefully designed innovations can create opportunities for traditional instruments to remain musically functional and culturally relevant in changing social environments. The preservation of traditional instruments is also increasingly connected with documentation and digital technology. Recent work on Minahasan bamboo instruments has explored their digitization and virtualization through culturally informed digital musical instruments, demonstrating that technological approaches can provide new possibilities for representing and disseminating traditional bamboo sounds (Najoan et al., 2026). Such developments reinforce the idea that preservation should not be understood as keeping traditional instruments unchanged, but as maintaining their cultural identity while enabling them to participate meaningfully in contemporary musical environments.

One traditional bamboo instrument that deserves further scholarly attention is *Bambu Entel*, a musical instrument originating from the Talaud Islands of North Sulawesi, Indonesia. *Bambu Entel* is constructed from bamboo cut according to particular dimensions and is played by striking or stamping the instrument against the ground to produce its characteristic sound. It is associated with cultural activities of the Talaud community, including artistic performances, traditional dances, and customary activities. Its existence reflects local knowledge concerning the selection and utilization of natural materials as well as the community's musical creativity. However, compared with other Indonesian bamboo instruments such as *angklung* and *Bambu Tunta*, *Bambu Entel* has received limited scholarly attention, particularly regarding its acoustic characteristics and the possibility of developing its tonal system.

One important musical limitation of *Bambu Entel* is its restricted pitch availability. Although its existing tonal configuration provides a distinctive sonic identity, it may limit the instrument's ability to participate in a wider range of melodic structures and musical arrangements. This limitation becomes particularly relevant when traditional instruments are expected to interact with contemporary musical practices. Nevertheless, modifying the pitch system of a traditional instrument must be undertaken carefully because excessive modification may alter its characteristic sound and potentially weaken its cultural identity. The challenge is therefore to develop the instrument's musical capacity while maintaining its distinctive physical, acoustic, and cultural characteristics.

This issue reveals an important research gap. Previous studies have investigated the acoustic properties of bamboo instruments, including the relationship between tube dimensions, resonance, and pitch (Hamdan et al., 2022), while other studies have examined the structural and cultural dimensions of bamboo musical traditions and the possibilities of organological innovation (Matiure, 2023; Setiawan et al., 2025). Recent Indonesian studies have also addressed the preservation and development of traditional instruments through documentation, education, and technological innovation (Susanto & Indrawan, 2024; Najoan et al., 2026). However, limited research has specifically addressed the systematic development of a new pitch within a traditional Talaud bamboo instrument while considering its musical and cultural identity. In particular, the development of the B-flat (B $\flat$) pitch in *Bambu Entel* has not been adequately documented or investigated through an empirical acoustic and organological approach.

Therefore, the development of a new pitch system for *Bambu Entel* is important not only from a musical perspective but also as an effort to strengthen the sustainability of local cultural heritage. The development of the B $\flat$ pitch may expand the instrument's melodic possibilities,

increase its compatibility with other musical instruments, and create opportunities for its continued use in contemporary musical contexts without eliminating its traditional identity. Such an approach is consistent with recent perspectives on cultural heritage preservation, which emphasize the importance of combining continuity with creative adaptation rather than treating tradition as a static cultural form (Howard, 2022; Mاتيure, 2023).

Based on this background, this study aims to develop a new pitch, namely B-flat (B $\flat$), for the traditional Bambu Entel musical instrument in Sambuara Village, Talaud Islands Regency, North Sulawesi, Indonesia. The study specifically focuses on the development of the instrument's tonal characteristics while considering its construction, acoustic properties, and cultural significance. The resulting development is expected to contribute to the documentation, revitalization, and sustainability of Bambu Entel as an important component of the musical and cultural heritage of the Talaud Islands.

2. Method

This study employed a Research and Development (R&D) method to develop and test the feasibility of a new Bes (B-flat) tuning system for the traditional Bambu Entel musical instrument. The R&D approach was selected because it facilitates systematic product development through needs identification, design, development, validation, and testing (Sugiyono, 2019). The development aimed to introduce a tuning innovation while maintaining the musical and cultural characteristics of Bambu Entel from the Talaud Islands.

The study was conducted in Sambuara Village, Talaud Islands Regency, in June 2025. The location was purposively selected because Bambu Entel craftsmen and players remain actively involved in preserving and using the instrument. Informants included craftsmen, players, and experts in traditional music and musical instrument construction, selected based on their direct experience with Bambu Entel. A qualitative approach was used during the initial stage to identify the context, product characteristics, user experiences, and development needs (Busetto et al., 2020).

The research instruments consisted of an interview guide and validation questionnaire. Interviews were conducted with craftsmen and players to obtain information about the construction, sound characteristics, existing tuning system, and requirements for developing the Bes (B-flat) tuning system. The questionnaire was administered to traditional music experts, instrument experts/craftsmen, and players to assess product feasibility and user responses. Data were collected through interviews, expert validation, and product testing. The validation results were used to identify weaknesses and guide product revisions before implementation (Sugiyono, 2019).

The development procedure followed the ADDIE model, comprising Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009).

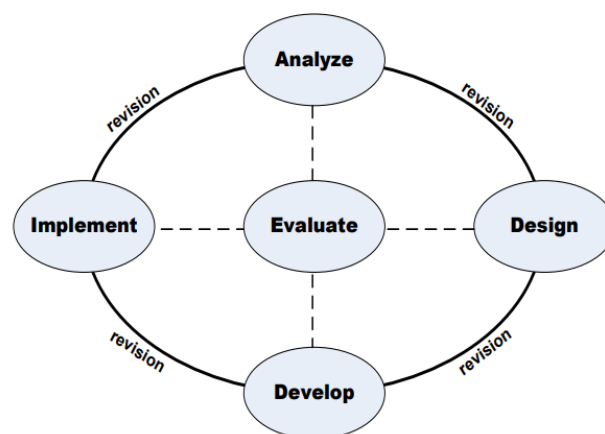


Figure 1. ADDIE Model

In the Analysis stage, the characteristics of Bambu Entel, its existing tuning system, and development needs were identified through observation and interviews. The Design stage involved designing the Bes (B-flat) tuning system based on the instrument's characteristics. In the Development stage, the product was constructed, adjusted, and validated by experts, followed by necessary revisions. The Implementation stage involved testing the revised product with Bambu Entel players to assess its applicability and user responses. Finally, the Evaluation stage assessed the overall product based on expert validation and user responses.

The data were analyzed descriptively. Interview data were analyzed to identify information concerning instrument characteristics, tuning systems, development needs, and user experiences, while questionnaire data were analyzed based on validation and user-response scores. The findings from each stage were used to refine the product and determine its final feasibility. This procedure was expected to produce a feasible Bes (B-flat) tuning system while preserving the musical and cultural characteristics of Bambu Entel.

3. Results

The development of the Bambu Entel traditional musical instrument marking system in Sambuara Village, Talaud Islands Regency, North Sulawesi, revealed that the process of producing and modifying the instrument involves an interaction between local material knowledge, traditional craftsmanship, acoustic considerations, and empirical tuning practices. The principal objective of the development process was to obtain a new pitch, namely B-flat (B $\flat$), while maintaining the characteristic construction and playing principles of Bambu Entel. The findings demonstrate that the development of the new pitch did not require a complete reconstruction of the instrument. Instead, modification was concentrated on the dimensions and acoustic characteristics of the bamboo tube, particularly the opening located at the node. This finding is consistent with research on bamboo-based musical instruments showing that pitch is closely associated with the physical and geometrical characteristics of the bamboo tube, including its length and diameter (Arifin & Pribadi, 2019; Hamdan et al., 2022). In this respect, the development of B-flat can be understood as an adaptation of an existing traditional construction system rather than a replacement of the traditional instrument itself.

Field observations showed that the principal material used to manufacture Bambu Entel is locally identified as *Timbal'lang* or *Lan'no* bamboo. The selection of this material is based primarily on its physical characteristics, including its structural strength, suitability for processing, and ability to produce an appropriate acoustic response. The use of bamboo as a musical-instrument material is scientifically relevant because bamboo possesses a complex hierarchical structure consisting of fibers, parenchyma cells, microfibrils, and pores that influence vibration transmission, resonance, damping, and timbre. Deng et al. (2023) demonstrated that the acoustic performance of bamboo is determined by interactions among its macrostructure, microstructure, and chemical composition. The authors further showed that bamboo fibers contribute to acoustic-vibration efficiency, whereas the cellular structure contributes to resonance and timbral characteristics. Thus, the artisans' empirical selection of particular bamboo material can be interpreted as a form of material knowledge that corresponds with scientifically observable differences in the acoustic behavior of bamboo.

The timing of bamboo harvesting also emerged as an important component of the local production process. According to the informants, bamboo is harvested during the dry season because the material is considered to contain less moisture and to be more stable during subsequent processing. This traditional practice is consistent with research demonstrating that moisture conditions significantly affect the acoustic and mechanical characteristics of bamboo. Deng et al. (2022), for example, found that bamboo acoustic-vibration characteristics are highly sensitive to environmental humidity and moisture content, with changes in relative

humidity influencing specific dynamic elastic modulus, damping, and acoustic conversion efficiency. The findings therefore provide a scientific basis for understanding why local craftsmen pay close attention to harvesting and drying conditions. However, the present study does not establish that dry-season harvesting itself directly produces the B-flat pitch; rather, the finding indicates that material moisture and dimensional stability are important conditions that may influence the subsequent acoustic behavior of the instrument.

After harvesting, the bamboo is cut from the lower section with the largest diameter toward the upper section with a smaller diameter. The observations indicate that the different sections of the culm can nevertheless be utilized because a single bamboo segment bounded by nodes can produce a similar basic pitch when processed according to the traditional technique. This finding illustrates the importance of the bamboo's natural geometry in the construction of *Bambu Entel*. Bamboo is not a perfectly homogeneous cylindrical material; variations in wall thickness, fiber distribution, density, and diameter affect its vibrational characteristics. Hamdan et al. (2022) demonstrated that the dimensions of bamboo tubes influence their fundamental frequencies and resonance characteristics, while Arifin and Pribadi (2019) showed that the relationship between tube geometry and pitch can be modeled mathematically. Consequently, the craftsmen's practice of selecting and cutting particular bamboo sections represents an empirical approach to controlling the physical variables that contribute to pitch production.

Another important stage is the treatment of the bamboo after cutting. The informants reported that the bamboo is immersed in seawater or salt water for approximately two to three days before being dried. Traditionally, this process is understood as contributing to preservation, strengthening the material, and reducing the risk of pest attack. From a scientific perspective, however, the effects of soaking and salt treatment should not be generalized as universally beneficial. Recent experimental research shows that traditional leaching or soaking treatments can alter the density, chemical composition, moisture behavior, mechanical properties, and durability of bamboo (do Amaral et al., 2023). Research on salt-based preservation likewise indicates that the effectiveness of salt treatment depends on concentration, bamboo species, and the biological agents involved. Therefore, the seawater treatment identified in this study is best understood as a **local preservation practice**, while its specific contribution to acoustic quality requires further controlled experimentation.

The drying stage constitutes another important component of the production process. The craftsmen avoid exposing the bamboo directly to intense sunlight and instead dry it in a shaded environment. According to the informants, excessive drying may make the bamboo brittle and reduce its durability. Although the present study did not measure moisture content quantitatively, the practice is consistent with evidence that bamboo is hygroscopic and that variations in moisture and environmental humidity affect its dimensional and acoustic stability. Deng et al. (2022) found that bamboo's acoustic-vibration properties vary according to environmental humidity and moisture conditions. Similarly, Deng et al. (2022) demonstrated that treatment and drying conditions can influence the acoustic-vibration efficiency and dimensional stability of bamboo used for musical instruments. These findings suggest that the traditional shaded-drying practice should not be regarded merely as a customary procedure but as an empirically developed strategy for controlling material conditions before the final tuning process.

The most significant finding of the development process concerns the modification of the node opening to obtain the B-flat pitch. After the bamboo is cut close to the node, an opening is made at the center of the node to function as part of the sound-producing system. The size of this opening is then adjusted progressively until the desired B-flat pitch is achieved. This process confirms that pitch formation in *Bambu Entel* is strongly connected to the physical configuration of the instrument. Research on *angklung* has similarly demonstrated that tube dimensions, particularly length and diameter, have a measurable relationship with

fundamental frequency and resonance. Arifin and Pribadi (2019) developed a mathematical model showing the relationship between the geometrical parameters of bamboo tubes and the generated frequency, whereas Hamdan et al. (2022) demonstrated experimentally that bamboo-tube dimensions and resonance characteristics influence perceived pitch. Thus, the gradual enlargement of the node opening observed in Bambu Entel represents an empirical tuning mechanism in which the craftsman's auditory judgment is used to identify the desired acoustic result.

The tuning process demonstrates that the Bambu Entel production system combines measurable physical parameters with tacit musical knowledge. Unlike industrially manufactured instruments that generally rely on standardized dimensions and measurable tolerances, the craftsmen in this study determine the final sound through repeated cutting, listening, comparing, and adjusting. The instrument is therefore not completed solely when its physical dimensions have been established; it is completed when its acoustic output is judged appropriate by the maker. This finding is particularly significant because recent research on bamboo instruments has demonstrated that perceived pitch cannot always be reduced to a single geometric variable. Hamdan et al. (2022), for example, found differences between individual tube frequencies and frequencies produced through coupled tube vibration. Such findings reinforce the importance of considering both physical measurements and actual acoustic output when developing or modifying traditional bamboo instruments.

The installation of rubber and thick cloth at the lower section of the bamboo represents another distinctive feature of the Bambu Entel construction system. According to the field observations, this covering functions to regulate the direction of air movement and concentrate the sound toward the upper opening. The adjustment is reversible: if the desired B-flat pitch is not achieved after the covering is installed, the covering can be removed and the node opening can be enlarged incrementally. This iterative procedure indicates that the development of Bambu Entel is characterized by a process of continuous acoustic evaluation rather than a fixed sequence of mechanical operations. The finding is consistent with acoustic studies of bamboo instruments, which emphasize the interaction among tube geometry, boundary conditions, resonance, and vibration. Deng et al. (2023) further demonstrated that the structural characteristics of bamboo influence the transmission and dissipation of acoustic energy, while Hamdan et al. (2022) showed that structural coupling can affect the final frequency spectrum of bamboo instruments.

The final outcome of the development process was the successful production of a Bambu Entel capable of producing the targeted B-flat (Bb) pitch while retaining the traditional construction principles of the instrument. The result demonstrates that innovation in traditional musical instruments does not necessarily require the abandonment of inherited production practices. Instead, innovation can occur through controlled modification of selected structural components while maintaining the material, construction logic, and cultural identity of the original instrument. This approach is important for the sustainability of traditional instruments because it allows adaptation to contemporary musical requirements without completely separating the instrument from its cultural context. Research on Bambu Entel itself has documented its position as a traditional instrument of the Talaud Islands and its use in cultural and religious contexts, while Kapoyos et al. (2022) demonstrate that traditional instruments can continue to function as community heritage when knowledge is transmitted across generations.

4. Discussion

The findings indicate that the development of Bambu Entel should be understood as a form of acoustic innovation based on traditional knowledge. The innovation does not replace the traditional instrument but expands its tonal possibilities through a carefully controlled

modification. The achievement of B-flat demonstrates that traditional instruments can be adapted to accommodate additional pitches while retaining their original material and cultural characteristics. Such an approach is particularly relevant to the development of traditional musical instruments because it provides a pathway between cultural continuity and musical innovation. The findings of Maireom et al. concerning Bambu Entel in the Talaud Islands similarly demonstrate that the instrument is embedded in a broader system of traditional musical practice rather than functioning solely as an independent sound-producing object.

The relationship between traditional knowledge and scientific acoustics is particularly evident in the process of pitch determination. The craftsmen's method of enlarging the node opening incrementally is based on auditory evaluation rather than numerical calculation. Nevertheless, the outcome can be explained acoustically through the relationship between the geometry of the instrument and its resonant behavior. Arifin and Pribadi (2019) demonstrate that pitch frequency in bamboo instruments can be associated with physical and geometrical parameters, while Hamdan et al. (2022) show that frequency analysis using oscilloscopic recording and Fast Fourier Transform can identify fundamental frequencies and overtones in bamboo instruments. Consequently, the traditional craftsmen's auditory method and modern acoustic measurement should not be viewed as contradictory approaches. Rather, they represent two different forms of knowledge that can complement one another in the systematic development of Bambu Entel.

The findings also indicate that the absence of standardized dimensions in traditional Bambu Entel production is both a limitation and a source of cultural value. From the perspective of musical instrument engineering, the absence of fixed dimensions may produce variations in pitch, timbre, and consistency among instruments. However, from an ethnomusicological perspective, this flexibility represents the persistence of embodied knowledge within the community. The craftsman's competence is manifested through the ability to recognize appropriate bamboo, judge its condition, manipulate its structure, and evaluate the resulting sound. Thus, standardization should not automatically be understood as the only indicator of quality. A more appropriate approach for Bambu Entel would be to develop acoustic documentation and reference measurements while preserving the traditional manufacturing knowledge.

This approach is supported by recent research on intangible cultural heritage. Gwervevende and Mthombeni (2023) argue that safeguarding indigenous music requires collaboration with cultural practitioners and the development of culturally sensitive transmission models. Their argument is particularly relevant to Bambu Entel because the knowledge required to construct and tune the instrument is not entirely contained in written instructions. Much of the knowledge is embodied in repeated practice and interaction between craftsmen, materials, and sound. Similarly, Kapoyos et al. (2022) found that traditional musical knowledge can be transmitted naturally through community participation and intergenerational learning. Therefore, documenting Bambu Entel should not be limited to recording its final dimensions; it should also document the decision-making processes, terminology, material selection, tuning strategies, and experiential knowledge of its makers.

The cultural significance of Bambu Entel further strengthens the importance of developing the instrument without disconnecting it from its community context. Wibowo and Tumimbang (2022) identify Bambu Entel as a traditional instrument originating from the Talaud Islands and demonstrate that its existence is associated with cultural and religious practices. Their findings also indicate that modernization has contributed to challenges concerning the continued presence of Bambu Entel in community life. The present development therefore has significance beyond the addition of a single pitch. The development of B-flat can become part of a broader revitalization strategy by increasing the instrument's potential for musical arrangement, ensemble integration, education, and

contemporary performance while maintaining its local identity.

The relationship between musical innovation and cultural preservation is also evident in studies of other traditional musical heritage. Li (2023) emphasizes that traditional music functions within broader networks of cultural communication and that preservation requires attention to both the musical form and the social contexts in which musical practices exist. Similarly, López-Angarita et al. (2022) demonstrate that musical traditions can become vehicles for transmitting ecological and cultural knowledge. These perspectives suggest that Bambu Entel should be treated not merely as a technological object requiring acoustic improvement but as a cultural system in which material resources, environmental knowledge, craftsmanship, musical practice, and community identity intersect.

From the perspective of material science, the findings also demonstrate the importance of controlling bamboo quality throughout the production process. Bamboo's acoustic characteristics are influenced by its fiber structure, density, moisture condition, chemical composition, and geometry. Deng et al. (2023) show that the acoustic vibration performance of bamboo results from interactions among these multiscale structural and chemical characteristics. Deng et al. (2022) further demonstrate that humidity significantly affects acoustic vibration behavior. Therefore, the traditional procedures identified in the present study – selection of bamboo, harvesting season, treatment, drying, cutting, node modification, and final tuning – should be regarded as an interconnected production system rather than independent technical steps.

An important implication of the research is that future development should integrate traditional auditory tuning with instrumental acoustic measurement. The successful production of B-flat in this study was determined primarily through auditory sensitivity and repeated adjustment. For further development, however, the pitch should also be measured using a frequency analyzer, tuner, microphone, or FFT-based acoustic system. Such measurement would make it possible to determine the precise fundamental frequency, frequency deviation, harmonic structure, sound-pressure characteristics, and stability of the B-flat Bambu Entel. The approach is supported by Hamdan et al. (2022), who used frequency-spectrum analysis to investigate bamboo instrument pitch, and by Arifin and Pribadi (2019), who demonstrated that physical parameters can be related mathematically to generated frequency. Such integration would strengthen the scientific reproducibility of the Bambu Entel development process without eliminating the role of the craftsman's auditory expertise.

The development of B-flat therefore has two complementary dimensions. Technically, it expands the tonal capacity of Bambu Entel through controlled modification of its acoustic structure. Culturally, it demonstrates that traditional knowledge can remain productive when it is combined with appropriate innovation and documentation. The development should consequently be interpreted not as an attempt to transform Bambu Entel into a standardized modern instrument, but as an effort to strengthen its musical functionality while retaining its traditional identity. This perspective is consistent with contemporary approaches to intangible cultural heritage, which emphasize continuity, community participation, transmission, adaptation, and safeguarding rather than the preservation of cultural practices as completely static forms.

Overall, the study establishes that the successful development of the B-flat pitch results from the interaction of four principal factors: material selection, material treatment and drying, structural modification, and the craftsman's acoustic judgment. The first two determine the physical condition of the bamboo, while the third directly modifies its acoustic behavior and the fourth provides the experiential mechanism through which the desired pitch is identified. The contribution of the present research lies in demonstrating that these traditional procedures can be systematically described and connected with contemporary acoustic research. In this sense, the development of Bambu Entel represents not only a technical modification of a traditional musical instrument but also a model of culturally

grounded innovation that can contribute to the documentation, revitalization, and intergenerational sustainability of Talaud musical heritage.

4. Conclusion

This study concludes that the development of the B-flat (B $\flat$) pitch for the traditional Bambu Entel musical instrument in Sambuara Village, Talaud Islands Regency, demonstrates the potential to enhance the instrument's tonal functionality while maintaining its traditional material, construction principles, and cultural identity. The development process revealed that the acoustic quality of Bambu Entel is determined by the interaction of bamboo selection, harvesting conditions, treatment and drying processes, structural dimensions, modification of the node opening, and the craftsman's auditory sensitivity. The successful development of the B $\flat$ pitch was achieved through gradual modification of the node opening and repeated auditory evaluation, demonstrating that traditional empirical knowledge can function as an effective basis for musical instrument development. At the same time, the findings confirm that the production of Bambu Entel involves embodied and intergenerational knowledge that extends beyond technical construction to include material selection, processing techniques, acoustic judgment, and cultural practices. Therefore, the development of Bambu Entel should not be understood as an attempt to replace its traditional characteristics with a standardized modern system, but rather as a form of culturally grounded innovation that expands its musical possibilities while preserving its distinctive identity. The development of the B $\flat$ pitch may increase the instrument's compatibility with broader musical arrangements and contemporary performance contexts, thereby creating greater opportunities for its continued use and transmission among younger generations. Future research should complement the craftsmen's auditory evaluation with systematic acoustic measurements, including fundamental frequency, harmonic spectrum, pitch deviation, and tonal stability, to establish reproducible technical standards while continuing to respect the traditional knowledge of Bambu Entel makers. In this regard, the study contributes to both the organological development and cultural preservation of Bambu Entel by demonstrating that carefully controlled musical innovation can serve as a strategy for sustaining traditional musical heritage in contemporary contexts.

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Conflict of Interest

The authors declare that there is no conflict of interest related to this research.

Authors' Contribution

Orion Nando Pangalila: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing.

Perry Rumengan: Supervision, Validation, Methodology, Resources, Writing – review & editing.

R. A. Dinar Sri Hartati: Supervision, Validation, Formal analysis, Writing – review & editing.

Statement of the Use of AI

Artificial intelligence (AI) tools were not used for data analysis, interpretation, or the formulation of research findings. AI tools were used solely to assist with language editing and linguistic improvement of the manuscript.

References

- Arifin, P., & Pribadi, I. (2019). Modeling of angklung to determine its pitch frequency. *Acoustical Science and Technology*, 40(3), 178–185. <https://doi.org/10.1250/ast.40.178>
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer. <https://doi.org/10.1007/978-0-387-09506-6>
- Busetto, L., Wick, W., & Gumbinger, C. (2020). How to use and assess qualitative research methods. *Neurological Research and Practice*, 2, 14. <https://doi.org/10.1186/s42466-020-00059-z>
- Deng, L., Chen, X., Chen, F., Liu, X., & Jiang, Z. (2022a). Effect of environmental humidity on the acoustic vibration characteristics of bamboo. *Forests*, 13(2), 329. <https://doi.org/10.3390/f13020329>
- Deng, L., Chen, F., Ren, X., & Jiang, Z. (2022b). An environmentally friendly and efficient method to improve the acoustic vibration performance of bamboo for musical instruments: Nitrogen-protected heat treatment. *Industrial Crops and Products*, 188, 115554. <https://doi.org/10.1016/j.indcrop.2022.115554>
- Deng, L., Xu, H., Chen, F., Liu, X., & Jiang, Z. (2023). Scientific mechanism of bamboo acoustic vibration performance from structure-chemical perspective. *Industrial Crops and Products*, 199, 116785. <https://doi.org/10.1016/j.indcrop.2023.116785>
- do Amaral, L. M., Kadivar, M., Paes, J. B., Batista, D. C., Reis, M. de S., Tarverdi, A., de Godoy Jr., A. L. P., & Savastano Jr., H. (2023). Physical, mechanical, chemical, and durability assessment of water leaching treatment of bamboo. *Advances in Bamboo Science*, 5, 100040. <https://doi.org/10.1016/j.bamboo.2023.100040>
- Gwerevende, S., & Mthombeni, Z. M. (2023). Safeguarding intangible cultural heritage: Exploring the synergies in the transmission of Indigenous languages, dance and music practices in Southern Africa. *International Journal of Heritage Studies*, 29(5), 398–412. <https://doi.org/10.1080/13527258.2023.2193902>
- Hamdan, S., Rahman, M. R., Zainal Abidin, A. S., & Musib, A. F. (2022). Study on vibro-acoustic characteristics of bamboo-based angklung instrument. *BioResources*, 17(1), 1670–1679. <https://doi.org/10.15376/biores.17.1.1670-1679>
- Howard, K. (2022). Musical instruments as tangible cultural heritage and as/for intangible cultural heritage. *International Journal of Cultural Property*, 29(1), 23–44. <https://doi.org/10.1017/S0940739121000436>
- Kapoyos, R. J., Suharto, S., & Syakir, S. (2022). Bia music: Traditional music heritage and preserving tradition across generations. *Harmonia: Journal of Arts Research and Education*, 22(2), 298–310. <https://doi.org/10.15294/harmonia.v22i2.37619>
- Koelsch, S., Cheung, V. K. M., Jentschke, S., & Haynes, J.-D. (2021). Neocortical substrates of feelings evoked with music in the ACC, insula, and somatosensory cortex. *Scientific Reports*, 11, 10119. <https://doi.org/10.1038/s41598-021-89405-y>
- Li, L. (2023). Cultural communication and diversity along the Grand Canal of China: A case study of folk songs in intangible cultural heritage. *Heritage Science*, 11, 66. <https://doi.org/10.1186/s40494-023-00911-w>
- López-Angarita, J., Restrepo, M. P., Guzmán, K., & Escobar, D. (2022). Musical folklore as a tool for social-ecological change in the Colombian Caribbean. *Frontiers in Conservation Science*, 3, 1039430. <https://doi.org/10.3389/fcsc.2022.1039430>
- Maireom, Y., Lumi, D. R. N., & Maragani, M. H. (2023). Musik Bambu Entel: Teknik permainan dan metode pelatihan di Sanggar Musik Tradisional Kabupaten Kepulauan

- Taloud. *Clef: Jurnal Musik dan Pendidikan Musik*, 4(1).
- Matiure, P. (2023). Preserving the tangible material culture of the Shona traditional music legacy: An applied ethnomusicological report. *Journal of Material Culture*, 19(4). <https://doi.org/10.1177/15501906231189216>
- Najoan, X. B., Neman, M. I. E., & Kembuan, R. A. C. (2025). Digitization and virtualization of Minahasan bamboo instruments: Development of a culturally-informed Virtual Studio Technology plugin. *CogITO Smart Journal*, 11(2), 478–491. <https://doi.org/10.31154/cogito.v11i2.895.478-491>
- Pando-Naude, V., Patyczek, A., Bonetti, L., & Vuust, P. (2021). An ALE meta-analytic review of top-down and bottom-up processing of music in the brain. *Scientific Reports*, 11, 20813. <https://doi.org/10.1038/s41598-021-00139-3>
- Schiavio, A., Maes, P.-J., & van der Schyff, D. (2022). The dynamics of musical participation. *Musicae Scientiae*, 26(3), 604–626. <https://doi.org/10.1177/1029864920988319>
- Setiawan, F., Adi, I. K. K., & Mulya, S. (2025). Transformasi dan inovasi Kolotok menjadi alat musik bambu dalam komposisi Kolotouch. *AWILARAS*, 12(1), 1–17.
- Sugiyono. (2019). *Metode penelitian kuantitatif, kualitatif, dan R&D*. Alfabeta.
- Susanto, H., & Indrawan, A. (2024). Pengembangan model pembelajaran Dambus berbasis notasi gitar untuk pelestarian musik tradisional Bangka. *PROMUSIKA*, 12(2), 134–154.
- Wibowo, M., & Tumimbang, M. A. (2022). Eksistensi musik Bambu Entel dalam liturgi ibadah di GERMITA Sasanggelo. *Psalmoz: A Journal of Creative and Study of Church Music*, 3(2), 53–67. <https://doi.org/10.51667/jpsalmoz.v3i2.1016>
- Xiao, J., Wu, Y., Wang, M., & Zhao, Y. (2023). Using choice experiments to assess tourist values for intangible cultural heritage: The case of Changdao fishermen's work song in China. *Journal of Cultural Heritage*, 60, 50–62. <https://doi.org/10.1016/j.culher.2023.01.008>