Analysis of the Topological Structure and Evolutionary Path of Tujia Folk Song Melodic Profiles Based on Complex Networks

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ABSTRACT Tujia folk songs, as an important component of traditional Chinese music, have developed distinctive melodic structures through longterm oral transmission and intergenerational inheritance. From a signal-analysis perspective, their melodic contours can be regarded as discrete pitch-transition sequences, similar to the topological modelling of propagation paths in complex engineering networks. This study introduces complex network theory to model pitch movement in Tujia folk song melodies and constructs directed weighted networks for different historical periods and regional branches. A melodic database containing more than 200 Tujia folk songs was established, pitch sequences were extracted, and pitch-transition networks were formed. Topological indicators, including node degree, clustering coefficient, average path length, and modularity, were calculated to quantify the internal structural characteristics and evolutionary patterns of melodic contours. The results show that traditional branch folk songs exhibit high clustering coefficients and modularity, indicating stable local pitch movement habits and compact melodic structures. In contrast, modern adapted folk songs show lower network density, longer average path length, and increased randomness and diversity in pitch transitions. Evolutionary path analysis indicates that the melodic contours of Tujia folk songs have shifted from compact to discrete structures and from local constraints to greater global freedom. This topological transition reflects changes in transmission modes, aesthetic orientation, and creative concepts. The study offers a quantifiable framework for traditional music morphology and provides a signal-network analytical perspective that can also inform research on waveform structures, propagation topology, and complex signal systems.

INDEX TERMS complex networks, melodic contour, topological structure, signal propagation, waveform analysis

I. INTRODUCTION

Tujia folk songs are an art form of people songs produced and transmitted by Tujia people during their longterm production and life. Their melodic forms are endowed with deep memories of culture and aesthetic consciousness. Traditional Tujia folk songs are mainly constructed on the five tones scale. and the melodic movement is often the step or leaps and embellishments that are related to the dialect of the region where it is spoken, so as to create their own unique melodic outline. Against the background of social transformation and cultural integration at present, the inheritance and development of Tujia folk songs have a new trend. While retaining traditional features, the melodic forms are also exhibiting tendencies of structural simplification and range expansion. Although rhythmic regularization is also an observed trend in modern adaptations, this study focuses specifically on the topological evolution of pitch movement to isolate the melodic contour's internal logic. How to understand the correct internal logic of these changes from a structural perspective has become a methodological problem that is in dire need of to be addressed in traditional music researches. Complex network theory has shown unique explanatory power in the area of music structure analysis in recent years. Elements such as pitch, rhythm and harmony in a piece of music may be considered nodes in a network, where adjacency or transformation relations between elements constitute the edges of the network. Through topological analysis of the network, the holistic, hierarchical and dynamical properties of the musical structure can be exposed. Existing research has used complex networks for the analysis of Western classical music, jazz and part of traditional Chinese music; it proved that network parameters can be effectively used for

the characterization of stylistic differences and structures. However, the network analysis of the melodic contours of ethnic minority folk songs is still lacking systematic analysis for Tujia folk songs. This research is concerned with the topological structure of Tujia folk song melodic contours and made use of complex network as a tool for their study to establish the model of pitch movement based on a weighted network. Representative folk song samples of different periods and branches are selected and topological indicators such as degree distribution, clustering coefficient, average path length and betweenness centrality of the melody contours are calculated to quantitatively describe the structural characteristics of melody contours. Based on this, the evolutionary path of Tujia folk song melodic forms is shown. This study is intended to elucidate the underlying mechanisms governing the transmission and evolution of musical forms from an ontological perspective of traditional music from a structural point of view so that a calculable and comparable analytical framework can be established for the research of ethnomusicology.

II. RELATED WORK

Traditional music research has long focused on dimensions such as morphological characteristics, inheritance methods and cultural context . In terms of inheritance practice, the teaching principles of prioritizing hearing, combining imitation and variation, the reconstruction of dissemination paths by digital media, and the impact of virtual performances on community interaction patterns have jointly constituted multiple issues in contemporary traditional music research . Johansson [1] found that learning improvisation in traditional music relies on a unique set of teaching principles, including prioritizing hearing, combining imitation and variation, and focusing on rhythm and emotional experience. Simatupang et al. [2] believe that digital media not only helps the revival of traditional music, but also provides a feasible path for the innovation of traditional art in the digital age. Saputra et al. [3] combined technology with traditional teaching to effectively promote the digital preservation and innovative inheritance of traditional music. Mygdanis [4] provided an operable software design example for the integration of traditional music teaching and modern technology. Pessina [5] focused on the impact of the transformation of traditional music festivals to be held in a virtual form on music culture dissemination, community interaction and participation experience. Kapoyos et al. [6] sorted out the changes in the transmission path, teaching methods and cultural significance of Bia music across different generations. de Freitas and de Carvalho [7] analyzed the use of traditional music in public ceremonies, education system and national cultural festivals after Mozambique's independence. Larasati et al. [8] pointed out that interdisciplinary cooperation and the introduction of digital technology have become new trends in the field of traditional music. Addaquay [9] explored the challenges and coping strategies faced by traditional music in contemporary transmission. Chen and Li [10] analyzed the historical evolution of guzheng playing techniques and its socio-cultural background. Based on this, this paper takes Tujia folk songs as the research object, introduces complex network method, focuses on the topological structure of its melodic contour, and quantitatively analyzes the structural characteristics and evolution path of melodic forms in different periods and branches by constructing a relational model of pitch movement. It aims to provide a computable and comparable analytical framework for the ontological study of traditional music and respond to the internal mechanism of transmission and evolution from the structural depth.

III. METHODS

A. SELECTION OF MELODY SAMPLES AND PITCH SEQUENCE ENCODING

This study selected Tujia folk songs as the analytical sample, adhering to the principles of regional representativeness, branch diversity, and temporal span. The research team selected 216 complete folk songs with a clear lineage from published collections of Tujia folk songs, archival recordings, and field surveys. Divided by branch, these include 68 Tujia folk songs from western Hunan, 74 from western Hubei, 51 from southeastern Chongqing, and 23 from northeastern Guizhou. Divided by time, 125 songs were collected before the 1980s and are categorized as belonging to the traditional period; 91 songs were categorized as belonging to the modern period. This 1980s threshold is selected based on the significant shift in China's cultural landscape following the Reform and Opening-up policy, which introduced Western pop influences and professionalized conservatory-style composition to ethnic regions, fundamentally altering the oral transmission lineage of Tujia music. All songs are recorded in staff notation or numbered musical notation, with clear and complete melodic lines. The pitch sequence encoding process first extracts the main melody pitch sequence of each folk song, removes the duration of the same pitch due to repeated pitches, and retains only the turning points where the pitch changes, forming a pitch movement sequence. While the duration of repeated pitches is simplified to turning points to emphasize contour movement, the weighted edges in the subsequent network construction partially account for structural importance by reflecting the frequency of transitions back to core pitches. Additionally, for future iterations, incorporating a duration-weighted node system would more accurately mirror the auditory experience where long-held notes define structural gravity. The pitch value is digitally represented by MIDI pitch number, with middle C corresponding to a value of sixty, and each semitone increases by one. For cases where the actual pitch has slight pitch changes due to differences in the singer, the notated pitch is used to ensure the consistency of the encoding. After the pitch sequence is encoded, the pitch movement direction of each folk song's melody outline is marked, including three basic movement types: ascending, descending, and unison. Unison is only treated as a self-loop edge between nodes in the pitch movement sequence and is

regarded as a special edge type in the subsequent network construction [11,12].

B. METHOD FOR CONSTRUCTING MELODIC CONTOUR NETWORKS

The melody contour network uses pitch as nodes and pitch transformation relationships as edges to construct a directed weighted network. If the same pitch transformation relationship appears multiple times in the melody, the weight of the corresponding edge is incremented by one. Each sample network constructed in this way is a directed weighted network. The number of nodes in the network depends on the number of pitches actually used in the folk song, and the number of edges depends on the diversity of pitch transformation relationships and their repetition frequency [13]. For folk songs from different branches and periods, separate melodic contour networks were constructed. To facilitate group comparisons, branch-level and period-level aggregation networks were further constructed. Within each branch or period, the transformation relationships of all samples were accumulated to form a comprehensive network representing the melodic contour characteristics of that branch or period. In the construction of the aggregation network, nodes represent all pitches that appeared within that branch or period, and the edge weights are the total frequency of that transformation relationship across all samples. Through the aggregation network, pitch movement preferences and structural stability at the group level can be observed.

C. SELECTION AND CALCULATION OF TOPOLOGICAL CHARACTERISTIC INDICATORS

To quantify the structural characteristics of the melody contour network, this study selects the following topological indices for calculation. Node degree is a fundamental metric for measuring the connectivity of nodes. In directed networks, node degree is divided into in-degree and out-degree. In-degree represents the number of transitions with a given pitch as the target, while out-degree represents the number of transitions with a given pitch as the starting point. The total degree of a node reflects the activity level of that pitch in the melodic movement, and the ratio of in-degree to out-degree reflects the relative importance of that pitch as a melodic target point versus a melodic starting point. In aggregate networks, the weighted in-degree and weighted out-degree of each node are calculated, with the weighted degree reflecting the impact of transition frequency. Clustering coefficients are used to measure the degree to which local clusters are formed among network nodes. For directed weighted networks, the calculation of clustering coefficients takes into account the direction and weight of the edges, reflecting whether there is a mutual conversion relationship between adjacent pitches of a certain pitch. A high clustering coefficient indicates that the pitch movement in the melody has local clustering, that is, a tight small group of pitch conversions is formed around a few core pitches, and the melody often repeats and detours in a local range [14,15].

IV. RESULTS AND DISCUSSION

A. COMPARISON OF THE TOPOLOGICAL STRUCTURES OF FOLK SONG MELODY NETWORKS FROM DIFFERENT BRANCHES

Melodic contour aggregation networks were constructed for Tujia folk songs from four branches: western Hunan, western Hubei, southeastern Chongqing, and northeastern Guizhou. Various topological indices were calculated. The western Hunan branch folk songs had 16 network nodes, 87 edges, and a network density of 0.3625; the western Hubei branch had 14 network nodes, 72 edges, and a network density of 0.3967; the southeastern Chongqing branch had 18 network nodes, 93 edges, and a network density of 0.3037; and the northeastern Guizhou branch had 12 network nodes, 41 edges, and a network density of 0.3106. While the sample size for Northeast Guizhou (n=23) is smaller than that of Western Hubei (n=74), preliminary normalization suggests the observed modularity remains characteristic of the branch; however, these specific density comparisons should be interpreted as indicative rather than definitive until a more balanced corpus is analyzed. The network densities of the western Hunan and western Hubei branches were significantly higher than those of the southeastern Chongqing and northeastern Guizhou branches, indicating that the former two branches have richer and more diverse pitch transformation relationships.

TABLE 1. Comparison of melodic contour network topology indices of different branches of Tujia folk songs

Branch	Number of nodes	Number of sides	Network density	Average clustering coefficient	Average path length	Modularity
Xiangxi	16	87	0.3625	0.674	2.31	0.412
Western Hubei	14	72	0.3967	0.702	2.08	0.387
Southeast Chongqing	18	93	0.3037	0.591	2.65	0.456
Northeast Guizhou	12	41	0.3106	0.638	2.44	0.483

In terms of clustering coefficients, the western Hubei branch had the highest average clustering coefficient of 0.702, followed by the western Hunan branch with 0.674, the northeastern Guizhou branch with 0.638, and the lowest clustering coefficient of the southeastern Chongqing branch, at 0.591. The high clustering coefficients indicate that the folk songs in the western Hubei branch have more local clustering characteristics in its pitch movement. Pitch transitions frequently occur in several close-related pitch subgroups giving rise to a distinctive structure of pitch clusters in the melodic form. The western Hunan branch, to a lesser extent, also shows an occurrence of high density of local clustering, but the network density is higher, and the diversity of the pitch transition relationships can dilute the high local clustering to some extent. The trend of an average path length is opposite to the trend of the clustering coefficient. The western branch of Hubei has the shortest average path

(2.08), followed by the western branch of Hunan (2.31), the northeastern branch of Guizhou (2.44) and the southeastern branch of Chongqing (2.65). The short average length of paths implies that there are fewer transitions necessary to reach other pitches from any given pitch - in other words, there is a better overall network connectivity. The western Hubei branch folk songs resulted in a short average path length and high clustering coefficient, implying that the melodic network of the folk songs has a combination of both local clustering and global connectivity characteristics, a typical small-world network structure. Modularity is the clarity in the internal community structure of the network. The northeastern Guizhou branch has the highest modularity at 0.483 followed by the southeastern Chongqing branch at 0.456, the western Hunan branch at 0.412, and the lowest modularity of the western Hubei branch at 0.387. High modularity means that the movement of the pitch in the folk songs in north-eastern Guizhou branch are well segmented at community level, with fewer transitions between different pitch groups, and the melodic progressions are often limited to specific pitch ranges. This structural characteristic is in line with the fact that the Tujia folk songs in northeastern Guizhou preserve a lot of ancient melodies and have relatively closed melodic progressions. The western branch of Hunan and western branch of Hubei have a relatively low modularity, showing that the pitch transitions in their melodic networks are more cross-community, and the pitch movement has more fluidity. Based on the aforementioned topological indicators, Tujia folk songs of different branches have a lot of differences in melodic contour structures. The melodic networks of the western Hunan branch and the western Hubei branch have high density and clustering coefficients, average path lengths are short, indicating richer and more flexible melodic forms, and the local habituation and comprehensive connectivity of pitch movement between local habits and comprehensive connectivity are more balanced. The southeastern Chongqing and northeastern Guizhou branches have lower network density and higher modularity in form of relatively closed and structurally segmented melody forms. These differences in the structure are closely related with differences in geographical environment, frequency of cultural exchange and methods of transmission among the various branches.

B. COMPARISON OF THE TOPOLOGICAL STRUCTURES OF FOLK SONG MELODY NETWORKS IN THE TRADITIONAL AND MODERN PERIODS

The samples were grouped into traditional and modern periods, and melodic contour aggregation networks for each period were constructed. The traditional period network contained 125 folk songs, and the modern period network contained 91 folk songs. The topological indices of the two networks were calculated and compared. In the traditional period, the network had 23 nodes and 168 edges, with a network density of 0.3318; in the modern period, the network had 29 nodes and 152 edges, with a network density of 0.1874. The network density in the traditional period was significantly higher than that in the modern period, indicating that within the traditional period, melodic movement exhibited high-frequency utilization of a stabilized set of transitions. Although composed within a fixed tonal template, the recurrent and exhaustive use of specific pitch intervals within that framework resulted in a higher network density compared to the more expansive but sparse transitions seen in modern works. In the modern period, the number of nodes increased, but the number of edges decreased, resulting in a significant drop in network density. This suggests that while modern adaptations of folk songs expanded the range of pitch usage, the transitions between pitches became sparser, and the regularity of melodic movement weakened.

TABLE 2. Comparison of the network topology indices of Tujia folk song melodies in the traditional and modern periods

Period	Number of nodes	Number of sides	Network density	Average clustering coefficient	Average path length	Modularity
Traditional period	twenty three	168	0.3318	0.685	2.17	0.394
Modern period	29	152	0.1874	0.532	2.89	0.521

The average clustering coefficient was 0.685 in traditional period and 0.532 in modern period, where the average clustering coefficient of traditional period was significantly high as compared to modern period. This high clustering coefficient indicates that the pitch movement in traditional Tujia folk songs has a strong degree of local clustering, of which, the melody progression frequently forms a tight transition network around a few core pitches. This structural feature corresponds to the repetitive tunes and cyclic melodic development of the Tujia folk songs. The reduced clustering coefficient during the modern period indicates a weakening of pitch movement local clustering and an upsurge of randomness in melodic movement, which creates a break from the old melodic habit of frequently revolving around center pitches. The average path length was 2.17 in the traditional period, and 2.89 in the modern period. This increase in average path length means that in the modern network, the number of transitions from one pitch to other pitches increases from any given pitch, causing the network connectivity efficiency to decrease. Combined with the decrease of network density, it can be concluded that the melodic network in the modern period has a trend towards structural discretization; the transition relationship between pitches is not so tight as the traditional network, and the global movement of pitch needs to pass through more transition chains to be completed. The modularity had increased from 0.394 in traditional period and in the modern period, it had increased to 0.521. This significant increase in modularity suggests the community structure of the melodic network is more conspicuous in the modern period, with the pitches being segregated into multiple sub-groups that are connected densely within themselves, but with scarce interconnections among sub-groups. This change may appear

to contradict the trend of diminishing network density and increasing average path length, but it actually reflects another feature in the melodic structure of modern adapted folk songs, that is, while modern adaptations introduce more chromatic elements and frequent modulations, these features often create distinct functional zones or tonal blocks within a single piece. The increased modularity reflects a structural fragmentation where the melody moves between these diverse but internally cohesive tonal centers, rather than the seamless, integrated flow found in traditional pentatonic frameworks.

C. ANALYSIS OF THE EVOLUTION PATH OF MELODIC OUTLINE

By comparing topological indicators across different branches and periods, the evolutionary path of Tujia folk song melodies can be outlined. From a synchronic perspective, the melodic networks of the four branches exhibit a structural spectrum from high density and low modularity to low density and high modularity. The Xiangxi and Hubei branches are at the higher density and lower modularity end, while the southeastern Chongqing and northeastern Guizhou branches are at the lower density and higher modularity end. This synchronic difference reflects the structural differentiation formed by different branches during long-term transmission and is closely related to the cultural ecology of each branch. From a historical perspective, the melodic contour network has undergone a systematic transformation from the traditional to the modern period, characterized by decreased network density, reduced clustering coefficient, increased average path length, and increased modularity. This transformation can be summarized as an evolutionary path from compact to discrete structure, and from local constraints to global freedom. Traditional folk songs exhibit high density, high clustering coefficient, and short average path length in their melodic networks. Pitch movements are highly concentrated on a few core pitches, with tight local transformation relationships and high overall connectivity, presenting a compact and orderly structural form. Modern folk songs, on the other hand, exhibit low density, low clustering coefficient, long average path length, and high modularity. The range of pitch usage has expanded, but transformation relationships are sparse, local clustering has weakened, structural separations have formed between different pitch groups, and the overall structure tends towards discreteness.

TABLE 3. A comprehensive comparison of the periodic changes and branch differences in the topological characteristics of Tujia folk song melodies

Index	Traditional period mean	Modern period mean	Range of change	The greatest difference between branches
Network density	0.3318	0.1874	-43.5%	0.0930
Average clustering coefficient	0.685	0.532	-22.3%	0.111
Average path length	2.17	2.89	+33.2%	0.57
Modularity	0.394	0.521	+32.2%	0.096

The formation of evolutionary paths is closely related to multiple factors. Changes in the mode of transmission are one of the core driving forces. Traditional Tujia folk songs are mainly transmitted orally, and learners internalize local habits of pitch movement through repeated imitation. These habits are reflected in the melody network as a high clustering coefficient and a stable degree distribution structure. In modern transmission, the widespread use of musical notation and digital audio allows learners to more intuitively grasp the overall outline of the melody, but the degree of internalization of local pitch movement habits is weakened, which is reflected in the network as a decrease in the clustering coefficient and a reduction in network density. The shift in creative concepts has also influenced the evolution of melodic contours. Traditional Tujia folk songs are mostly composed and adapted within a fixed tonal framework, emphasizing consistency in branch styles, with melodic progression following implicit rules of pitch movement. Modern adaptations of folk songs place greater emphasis on personalized expression and stylistic innovation. Creators intentionally break through traditional tonal frameworks, introducing a wider range of pitch materials and more flexible pitch combinations, leading to a diversification and decentralization of pitch transitions, a decrease in network density, and an increase in modularity. The evolution of aesthetic preferences has also left structural traces in the evolutionary path. The aesthetics of traditional Tujia folk songs emphasize the fluency, repetition, and stability of melody, with pitch movements forming a cyclical structure around the core pitch. This manifests in the network as a high clustering coefficient and a short average path length. Modern aesthetics tend to pursue contrast, tension, and unexpected effects in melody. Creators intentionally set leaps, turns, and irregular pitch combinations in pitch movements, leading to the discretization and modularization of the network structure.

V. CONCLUSION

This study, based on complex network theory, systematically analyzes the topological structure and evolutionary path of the melodic contours of Tujia folk songs. By constructing a directed weighted network of pitch motion, topological indices such as network density, clustering coefficient, average path length, and modularity are calculated to quantitatively describe the melodic morphological characteristics of Tujia folk songs from different branches and periods, and on this basis, the evolutionary path of the melodic contours is outlined. By transforming melodic contours into network structures, the habitual characteristics, local clustering, and global connectivity of pitch movement can be intuitively captured, providing a structural explanation for understanding the differences and evolution of melodic forms across different branches and periods. The methods and conclusions of this study have certain reference value for expanding the quantitative research pathways in ethnomusicology and deepening the understanding of the

evolutionary patterns of minority musical forms. Future research could further incorporate rhythmic elements and modal characteristics into the network model, constructing a multi-dimensional framework for musical structure analysis, and exploring the correlation mechanisms between network topological features and auditory perception and aesthetic evaluation.

AUTHOR CONTRIBUTIONS

Conceptualization –Hua Xiang and Saina Chen; methodology – Hua Xiang and Saina Chen; investigation – Hua Xiang and Saina Chen; writing-original draft preparation – Hua Xiang and Saina Chen. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

[1] M. Johansson, "Improvisation in traditional music: learning practices and principles," Music Education Research, vol. 24, no. 1, pp. 56–69, 2022, doi: 10.1080/14613808.2021.2007229.
[2] G. L. F. Simatupang, R. Safrina, and R. T. Rakhman, "Revitalization of traditional music through digital learning media for Gambang Kromong 5.0 innovation study," International Journal of Studies in International Education, vol. 2, no. 3, pp. 05–09, 2025, doi: 10.62951/ijsie.v2i3.321.
[3] D. N. Saputra, A. Cahyono, U. Utomo, et al., "Integrating Tradition and Technology: Digital Audio Workstation-Based Learning for Traditional Music Preservation," Resital: Jurnal Seni Pertun-jukan, vol. 25, no. 2, pp. 321–337, 2024, doi: 10.24821/resital.v25i2.13913.
[4] Y. Mygdanis, "Designing an educational musical software combining traditional mu-sic-pedagogical methods and emerging technologies: The case of Synth4Kids," International Journal on Integrating Technology in Education, vol. 11, no. 2, pp. 103–120, 2022, doi: 10.5121/ijite.2022.11207.
[5] L. Pessina, "Encountering Irish traditional music through virtual space: the experience of FleadhFest 2021," International Journal of Event and Festival Management, vol. 15, no. 1, pp. 62–84, 2024, doi: 10.1108/IJEFM-12-2022-0106.
[6] R. J. Kapoyos, S. Suharto, and S. Syakir, "Bia music: Traditional music heritage and preserving tradi-tion across generations," Harmonia: Journal of Arts Research and Education, vol. 22, no. 2, pp. 298–310, 2022, doi: 10.15294/harmonia.v22i2.37619.
[7] M. R. de Freitas and J. S. de Carvalho, "Performing a culture, staging the revolution: Choral singing and traditional music as nation-building tropes in post-colonial Mozambique," Nations and Na-tionalism, vol. 28, no. 1, pp. 211–230, 2022, doi: 10.1111/nana.12807.
[8] Y. G. Larasati, H. Fernando, I. Abdullah, et al., "Bibliometric analysis of 20 years of traditional mu-sic research in Asia," Resital: Jurnal Seni Pertunjukan, vol. 25, no. 3, pp. 392–413, 2024, doi: 10.24821/resital.v25i3.14983.
[9] A. P. Addaquay, "Traditional music and dance preservation in Ghana: Navigating authenticity and globalization," Legon Journal of the Humanities, vol. 36, no. 1, pp. 145–162, 2025, doi: 10.4314/ljh.v36i1.6.
[10] H. Chen and Y. Li, "Archaeological insights into the evolution of chinese traditional music: the in-fluence of Guzheng playing techniques," Mediterranean Archaeology and Archaeometry, vol. 23, no. 1, pp. 296–296, 2023, doi: 10.5281/zenodo.13710047.
[11] T. Mondol and D. G. Brown, "Grammar-based compression and its use in symbolic music analysis," Journal of Mathematics and Music, vol. 17, no. 1, pp. 133–150, 2023, doi: 10.1080/17459737.2021.2002956.
[12] J. Jumriani, M. Muhaimin, M. Mutiani, et al., "Efforts to Preserve Traditional Music through So-cial Knowledge Subjects," Journal of Education and Learning (EduLearn), vol. 18, no. 1, pp. 140–147, 2024, doi: 10.11591/edulearn.v18i1.20838.
[13] T. Yu and S. Chuangprakhon, "Promoting Traditional Music Literacy: A Case Study of Tuhu Preservation through School Education," International Journal of Education and Literacy Studies, vol. 13, no. 1, pp. 49–55, 2025, doi: 10.7575/aiac.ijels.v.13n.1p.48.
[14] S. Sularso, M. Jazuli, D. Djatiprambudi, et al., "Revitalizing cultural heritage: Strategies for teach-ing Indonesian traditional music in elementary schools," International Journal of Education and Learning, vol. 5, no. 1, pp. 79–88, 2023, doi: 10.31763/ijele.v5i1.1016.
[15] I. H. Wardhana, C. E. Permana, and M. Puspitasari, "Adaptation of Betawi traditional music performers to preserve their existence in a new normal era," Humaniora, vol. 13, no. 3, pp. 225–230, 2022, doi: 10.21512/humaniora.v13i3.7966.