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Digital Technology-Assisted Collaborative Piano-Clarinet Learning: A Biobehavioral Analysis of Motor Coordination, Respiratory Patterns, and Performance Responses

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Abstract

Collaborative piano–clarinet performance requires instrument-specific skills, attentive listening, and coordination of bodily processes. However, learning remains constrained by limited resources and the use of technology to analyze performance. This study aimed to investigate perceptions of the importance of, needs for, and conditions supporting digital technology integration at Shenyang Conservatory of Music, China, and to design a needs assessment approach and a biobehavioral research framework for a subsequent study. The first phase employed a mixed-methods design. Data were collected using a five-point Likert-scale questionnaire administered to 410 students and interviews with seven experts. Quantitative data were analyzed using percentages, means, and standard deviations, while qualitative data were subjected to content analysis. The findings were then integrated to inform proposals for the subsequent phase. The results indicated that information sharing and technology integration received a mean score of 4.59, while performance technique received a mean score of 4.60. Performance psychology and collaboration and interdisciplinary collaboration each received a mean score of 4.62. The experts identified sound balance, breath management, and rhythmic coordination as areas for development and proposed multitrack audio recording, a shared resource repository, and the development of instructors' digital skills. The proposed needs assessment therefore encompasses current and desired conditions, resource readiness, and feedback formats. The proposed biobehavioral research framework includes measures of respiratory duration, movement coordination, onset asynchrony, and performance quality. Data are to be recorded on a common time reference and analyzed using repeated measurements. In applying the findings, activities involving recording, listening, discussion, and repeated performance should be linked with co-teaching and institutional support systems. This approach has the potential to support quality education under Sustainable Development Goal 4 and

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partnerships under Sustainable Development Goal 17. However, the existing data reflect participants' perceptions; the proposed framework and the effectiveness of feedback require testing with physiological and actual performance data in the next phase of research.

Keywords: biobehavioral analysis, clarinet-piano, collaborative learning, digital technology integration, SDGs

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Introduction

Collaborative performance involving two instruments is a creative process that requires instrument-specific skills alongside listening, anticipation, and adaptation between performers. These capacities enable performers to coordinate rhythm, sound balance, musical phrasing, and interpretation toward a shared artistic direction. Solo performance ability alone is therefore insufficient for collaborative work, particularly when the instruments differ in their mechanisms of sound production and physical demands, as is the case with the piano and clarinet. The piano produces its sound by means of a hammer mechanism, triggered by pressing the keys. The pedals of the piano are used to modify the resonance of the instrument. To play the clarinet you have to control the breathing, the vibration of the reed and the fingering. Such differences mean that performers also have to coordinate the beginnings and endings of sounds, breathing pauses, how phrases connect and dynamics appropriate to each instrument's role. Re-entry after rests and changes in tempo also depend on auditory and movement cues understood by both performers. These elements contribute to the unity of piano–clarinet duo performance (D'Amario et al., 2022). This concept is also evident in piano–singer duos. D'Amario et al. (2023) found that pianists and singers coordinated their head movements in relation to shared levels of musical phrase structure and that these movements were associated with leader–follower patterns under certain conditions of the musical piece, performance context, and performance take. In addition, clarinetists' breath management should be considered alongside temporal coordination because disruption of breathing reduced both respiratory and behavioral coordination between musical partners. This finding demonstrates a connection between physiological processes and coordination in performance (Yi & Palmer, 2026). Accordingly, collaborative piano–clarinet learning should consider the relationships among acoustic outcomes, breath management, and movement coordination to develop a systematic understanding of performers' responses to one another.

Digital technology provides opportunities to use evidence generated during practice to support listening and reflection in music learning. Audio and video recordings, analyses of acoustic characteristics, and shared performance recordings can help learners review their work, discuss problems, and establish shared goals. Such processes support musicians' awareness of their practice methods and encourage them to examine their learning strategies (López-Íñiguez & McPherson, 2024). For piano–clarinet duos, learning activities can be designed to help students examine sound onsets at points requiring simultaneous performance, assess sound balance and phrase connections, and observe gestural cues in video recordings before adjusting and rerecording their performance. As another example, piano–singer duos can use technology to record head movements, audio, and MIDI data before and after rehearsal. With this data it is possible to analyze movement together with acoustic information and to study leader-follower relationship between piano and singer in collaborative performance (D'Amario et al., 2023). Furthermore, recording respiration with sensors alongside audio and movement data on a common time reference is proposed as an approach for future investigation. This would allow researchers to analyze how breath preparation and movement relate to phrase entry and a partner's response. The rationale is that effective coordination in producing a melody together is associated with respiratory and behavioral coordination between partners. This line of inquiry allows for the analysis of physiological data in conjunction with acoustic findings, but its application needs to be explored more in the case of clarinetists, who produce sound through the direct use of their breath (Yi & Palmer, 2026). These considerations indicate that the application of digital technology requires clearly defined learning objectives, assessment criteria, and methods of interpreting data. Equipment availability, digital skills, and instructor support must

also be considered so that feedback can be connected to changes in practice that can be monitored and evaluated.

A needs assessment is therefore an important step in identifying which aspects of collaborative performance learning should be developed and which supporting conditions are required. Such an assessment examines perceived importance of performance technique, collaboration, the use of digital information, and the constraints faced by learners and instructors. However, perception data alone cannot explain bodily processes during performance or establish the effectiveness of technology. The results of the needs assessment must therefore be linked to a proposed biobehavioral research framework (National Library of Medicine, n.d.; Office of Behavioral and Social Sciences Research, n.d.). This framework considers relationships among physiological processes, coordination behaviors, and acoustic outcomes through measurable indicators, including inhalation and exhalation duration, the interval between breath preparation and sound onset, coordination of head or torso movements, and onset asynchrony between instruments. These indicators must be interpreted in relation to each instrument's role and the structure of the musical work. Accordingly, this study presents findings on the needs and supporting conditions for integrating digital technology into collaborative piano–clarinet learning at Shenyang Conservatory of Music. The findings are then synthesized with relevant literature to propose a biobehavioral research framework for testing collaborative piano–clarinet learning in a second phase. The proposed relationships are not regarded as confirmed by physiological measurements in the present study.

Research Objectives

1. To investigate perceptions of the importance of, needs for, and conditions supporting the integration of digital technology into collaborative piano–clarinet learning at Shenyang Conservatory of Music.
2. To design a needs assessment approach and a biobehavioral research framework for a subsequent research plan.

Methodology

This study comprises two interconnected phases. Phase 1, which has already been completed, employed a mixed-methods approach to assess the needs and supporting conditions for integrating digital technology into collaborative piano–clarinet learning. It consisted of quantitative and qualitative components. In the quantitative part, the population was 1,725 students who were enrolled in piano, orchestral instrument and music education programs in Shenyang Conservatory of Music. The researchers used simple random sampling and got 410 completed questionnaires. The questionnaire employed a five-point rating scale and addressed the educational environment, competencies, curriculum, performance techniques, and collaboration. Its content validity was examined by five experts using the index of item–objective congruence (IOC), and it was piloted with 30 participants who were separate from the main sample. For the qualitative component, the participants were seven experts whose fields of expertise included piano, clarinet, music psychology, aural skills, and performance. Data were collected through face-to-face interviews. Quantitative data were analyzed using percentages, means and standard deviations and qualitative data were analyzed using content analysis. The researchers then examined the points of convergence and divergence between the two sets of data. For Phase 2, the planned follow-up study, the researchers will synthesize the first-phase findings with literature on breathing in clarinet performance, movement coordination in musical performance, and technologies for performance analysis. This synthesis will inform the design of a biobehavioral research framework linking these data with feedback. The researchers will prepare a table connecting the findings with academic evidence, operational definitions, indicators, instruments, and analytical approaches. The proposed indicators include clarinetists' respiratory duration, movement coordination between performers, onset asynchrony between the piano and clarinet, and the quality of collaborative musical performance. The researchers plan to record data on a common time reference and use repeated-measures analysis while considering piano and clarinet skill levels, performers' familiarity with their partners, and the characteristics of the musical works.

Findings and Discussions

Perceptions of the Importance of, Needs for, and Conditions Supporting Digital Technology Integration in Collaborative Piano–Clarinet Learning at Shenyang Conservatory of Music

Perceived Importance

The survey with 410 students found that information sharing and technology integration received a mean score of 4.59 (SD 0.718), while performance technique received a mean score of 4.60 (SD = 0.700). Performance psychology and collaboration received a mean score of 4.62 (SD = 0.700), and interdisciplinary collaboration received a mean score of 4.62 (SD = 0.694). These findings indicate that students valued the use of technology alongside technical skills and interaction between performers. The mean scores for these factors were similar, but these descriptive results do not allow for statistically significant differences to be concluded between them. The results are consistent with Li et al. (2023) who found that music education students liked the use of technology. Li et al. suggested extending the use of technology by structured activities that help learners to use feedback and further assess learning behaviors rather than assuming that positive attitudes automatically lead to independent practice abilities. The expert data also indicated that technology could be used to share resources, review performance recordings, and exchange opinions during practice. The experts therefore proposed linking technology use with skill development and interaction between performance partners. This proposal is consistent with Nusseck et al. (2025) reported that listening to one's own piano performance via Disklavier was helpful for self-evaluation and for thinking about changes in expression. However, the progress reported by performers was not clearly apparent to external listeners. This finding supports the use of performance recordings as a tool for reflecting on practice while indicating that perceived improvement should also be examined through external assessment. Perceived importance should therefore be considered in relation to how technology is used in learning activities. For example, the experts indicated that digital technology should be used to analyze performance problems systematically rather than focusing solely on file sharing. This view is consistent with Sandberg-Jurström (2022), who found that providing learners with opportunities to discuss, explore, and make decisions created opportunities for reflection. Accordingly, the sharing of piano–clarinet performance files should be accompanied by analytical questions, listening to the partner's feedback, and agreement on goals before attempting another performance. In this way, digital resources can become part of a collaborative learning process.

Needs

The survey of 410 students found that performance technique received a mean score of 4.60 (SD = 0.700), while information sharing and technology integration received a mean score of 4.59 (SD = 0.718). These findings indicate that students valued technical skills alongside the use of information and digital technology. The findings are consistent with Tang et al. (2025) who proposed a combination of collaborative learning, reflection on practice and the purposeful and ethical use of digital technology to support continuous music learning. They also relate to López-Calatayud and Tejada (2024), who found that beginning violin and viola learners aged 10–11 years used different strategies to regulate their cognition, motivation, behavior, and emotions when practicing and receiving real-time intonation assessment through the Plectrus software. These findings suggest that the learning process should be evaluated in terms of both practice and learners' ability to interpret information produced by digital technology. Such assessment can help identify the particular ways in which learners need to use digital tools. The expert data identified three areas of difficulty in the present study: adjusting piano dynamics in relation to the clarinet, maintaining stable breathing during clarinet performance, and coordinating rhythm. The experts therefore proposed multitrack audio recording to review relationships between instrumental parts, the use of performance recordings for analysis and discussion, and the exchange of files and comments through online channels outside class time. The proposal is consistent with Laithong and Udtaisuk (2024) and Channuwong et al. (2026) who found that instructors need to adjust their musical skills, teaching approaches, and the use of technology. Their findings support the need for instructors to select appropriate functions for online channels, such as exchanging recordings, listening, and discussing performances between practice sessions. The experts also proposed compiling musical scores, performance examples, and ins tractional videos in a shared repository and developing instructors' skills in using platforms and audio

software so that resources could be appropriately connected to practice activities. This recommendation is consistent with Holliman (2022), who found that, after the COVID-19 outbreak, K–12 music teachers in four southeastern states of the United States reported increased technology use and familiarity with distance-learning tools, including audio-recording equipment, online meeting programs, and learning platforms. These findings support the need to develop instructors' capabilities alongside the provision of tools.

Supporting Conditions

The survey of 410 students found that interdisciplinary collaboration received a mean score of 4.62 (SD = 0.694), the concept of co-teaching received a mean score of 4.57 (SD = 0.741), and systematic curriculum organization received a mean score of 4.54 (SD = 0.762). Interdisciplinary collaboration had the highest mean score among the three areas, followed by co-teaching and curriculum organization. This ordering is a descriptive comparison and does not establish statistically significant differences. The findings suggest that the development of piano–clarinet learning should combine staff expertise with coordinated teaching and curriculum planning. The qualitative data support joint planning by piano and clarinet instructors, linking individual skill development with duo rehearsals, and establishing shared assessment criteria for sound balance, rhythm, and musical expression. They also support the development of instructors' ability to use digital tools. This finding is in line with Cheng et al. (2024) who found that primary and secondary music teachers in Hong Kong experienced limitations in both online environments and school conditions. The teachers enhanced their ability to link technological knowledge with content and pedagogy through training, self-directed learning and sharing of lesson plans and resources with colleagues. At an institutional level, the findings suggest a need for rehearsal rooms, audio-recording equipment, digital resource repositories, training and continued opportunities for performance practice. Institutions should also set clear objectives and budgets to link the use of technology systematically to the curriculum and practical training. This recommendation is consistent with Merrick and Joseph (2023) who reported that Australian music educators became more confident in using information technology, music equipment, and software while adapting their teaching during COVID-19. The study also suggested professional learning, teacher preparation and long-term planning for online learning. These findings support institutional planning for resources and continuing staff development.

Needs Assessment Approach and a Biobehavioral Research Framework for the Subsequent Research Plan

The Phase 1 results serve as the foundation for the design of the next study. They connect the importance attributed to performance technique, information sharing, collaboration, and support systems with the problems identified by experts: adjusting dynamics between instruments, maintaining stable breathing in clarinet performance, and coordinating rhythm. The design for the subsequent research comprises two components: a needs assessment specific to practice activities and a proposed biobehavioral research framework that specifies variables, instruments, and analytical approaches.

Needs Assessment Specific to Practice Activities

The needs assessment will seek to explain the gap between recognizing the importance of technology and using it to analyze and adjust actual performance. Data will be collected from piano and clarinet learners with collaborative performance experience and from relevant instructors. The assessment will cover current conditions, desired conditions, and constraints on use. Questionnaires will be combined with interviews and a resource survey to distinguish clearly among needs related to performance technique, feedback formats, and supporting conditions, as shown in Table 1.

Table 1 Needs assessment specific to practice activities

Phase 1 findings	**Additional assessment issues**	**Proposed instruments**	**Application of findings**
Performance technique:			
- Learners valued technique	- Frequency and impact of problems	- Questionnaire on current and desired conditions	- Identify practice priorities

- Experts identified problems involving sound balance, breathing, and rhythm.	- Ability to detect and address them - Desired level of skill development.	- interview guide	- Identify indicators requiring attention
Information sharing:			
- Technology use focused more on file sharing than on performance analysis	- Ways of using audio and video recordings - Ability to interpret data - Needs for different feedback formats	- Questionnaire - Interviews *Supported by examples of feedback	- Select ways to present data - Select activities for joint review.
Collaboration:			
- Multitrack recording - Online channels - Shared repositories were proposed	- Access to equipment - Convenience of recording and exchanging information - Resource needs for particular musical works	- Resource survey - Usability questionnaire	- Select tools - Select a data storage system suited to the context
Support systems:			
- Learners valued collaboration, co-teaching, and the curriculum	- Instructor readiness - Time available for duo rehearsal - Shared assessment criteria - Support for facilities, personnel, and budgets	- Questionnaire - Interviews with learners, instructors, and personnel responsible for resources	- Establish implementation conditions and a support plan

Quantitative data will be analyzed using percentages, means, and standard deviations. Gaps between current and desired conditions will be examined for questionnaire items measuring the same construct. Interview data will be analyzed using content analysis to explain reasons and constraints. The findings will then be integrated to prioritize areas for development.

Linking the needs assessment to current and desired conditions is appropriate to elaborate the Phase 1 findings because it can move from the perceptions of importance to more specific development priorities. These are the ability to analyze performance problems, select feedback, and use available tools. This approach is comparable with that of Chen et al. (2025) and Photchanachan et al. (2026), who proposed an information literacy assessment framework for postgraduate teacher education students and gave the highest weight to information behavior and innovation. It is also related to Laithong et al. (2025) that studied the needs of Thai secondary music teachers in terms of technology incorporation. They identified a gap in knowledge regarding the intersection of technology, pedagogy and content, and a need for practical training, learning about music software and structured lesson plans. Researchers should consider the learners' use of the information to set goals, identify problems and change their practice methods when assessing feedback formats. It is not simply about how interested the learners are in the features of digital technology. This is in line with Ou et al. (2025), who conducted a quasi-experimental study with violin majors. Students who used an artificial intelligence–assisted practice application demonstrated improvements in performance and performance confidence. They also reflected on the application's role in goal setting, self-monitoring, and adjustment of practice strategies.

For the assessment of breathing and movement problems, learner and instructor reports should be considered alongside performance observation because a particular movement may serve both

technical and expressive functions. This approach is consistent with Nusseck et al. (2024) examined movement and audio data of clarinetists. They found that during inhalation performers adjusted their bodies to a more upright posture and moved their arms to a more neutral position, while other movements varied between individuals and were linked to musical position. These findings extend the needs assessment by suggesting questions about where in a musical work problems occur, how often and to what effect, and how they are addressed, rather than asking only if learners wish to improve their breathing. The assessment should start with a survey of the resources available at the conservatory, including their readiness for actual use and the results should be compared with the needs reported by learners and instructors. For resources and support systems Development priorities should be determined by considering the importance of each problem, the size of the gap, and implementation feasibility. This would help ensure that selected tools and information systems can be connected continuously with the curriculum and learning activities. Systematic instruction also depends on staff collaboration, time for joint rehearsal, technical support, and data storage. The approach is consistent with the one used by Zhang et al. (2023), who studied models of interdisciplinary collaboration of higher music education institutions in several regions. They found that the variety of collaboration models and their integration in curricula should be developed based on the strengths and context of each institution rather than applying one model everywhere. Yap et al. (2023) also found that course design, technology, instructors, and the learning environment were related to student satisfaction, with course design showing the strongest predictive contribution.

Biobehavioral Research Framework

Biobehavioral research refers to an approach that integrates physiological and behavioral data. In the present study, it focuses on relationships among clarinetists' breath management, movement coordination between performance partners, and musical performance outcomes in the context of perceiving sounds and signals from a partner. It aims to understand bodily processes together with behavioral adaptation and environmental context during musical performance (National Library of Medicine, n.d.; Office of Behavioral and Social Sciences Research, n.d.).

The proposed framework links the Phase 1 findings concerning breathing stability, rhythmic coordination, and sound balance with the study of physiological variables and movement coordination between piano and clarinet performers. It aims to explain relationships among clarinetists' breath management, preparatory and signaling movements between partners, and measurable performance outcomes. Digital technology will be used to record these data on a common time reference and present feedback for learners to listen, discuss, and adjust their practice together. The proposed variables therefore cover bodily processes, coordination behaviors, and acoustic outcomes.

Clarinetists' breathing patterns

Proposed variables and indicators

- Inhalation and exhalation duration
- Variability across performance takes
- The interval between the end of inhalation and sound onset at specified positions

Proposed instruments

- Respiratory belt, such as the BIOPAC TSD201 or ADInstruments Respiratory Belt Sensor
- Audio recording

Analytical questions

- How long does the performer inhale before beginning a musical phrase?
- How does the duration of exhalation relate to phrase length?
- After inhalation, how many milliseconds separate the clarinet onset from the piano onset?
- How do these patterns change across repeated performances or after feedback?

Movement coordination between performers

Proposed variables and indicators

- Displacement and velocity of the head or torso
- Relationships and time lags between performers, particularly at the beginning of a piece and during phrase transitions

Proposed instrument

- Video recording of movement

Analytical questions
- Before the beginning of a piece or a new phrase, which performer moves first to give a cue, for example by nodding or leaning forward?
- How long after the cue does the other performer respond with a movement or begin playing?
- Do the performers' movements occur simultaneously or with a time lag, and how does this relate to simultaneous sound onset?
- When the piano or clarinet leads a phrase, do the roles of signaling and responding change?
- How do time lags and onset asynchrony change across repeated performances or after feedback?
- Are these coordination patterns consistent with performance quality ratings and performers' reported experiences?

Relationships among breathing, movement, and sound

Proposed variables and indicators
- Timing of breath preparation
- Timing of signaling movements
- Sound onset of each instrument

Proposed instrument
- Synchronized recording of respiration, movement, and sound using video

Analytical questions
- Before a phrase begins, does the clarinetist inhale before, during, or after the signaling movement?
- How long is the interval from the end of inhalation to clarinet onset, and when does the piano begin relative to that event?
- When one performer nods or leans forward, how long does it take the partner to respond with movement or sound?
- While the clarinetist pauses to inhale, how do the piano's movement and musical line continue, and when do both performers re-enter the phrase together?
- What breath preparation and signaling patterns occur in takes with closer onset alignment?
- How do these relationships change when the same phrase is repeated or feedback is provided?

Temporal coordination in performance

Proposed variable and indicator
- Onset asynchrony between piano and clarinet, measured in milliseconds at points where the score requires simultaneous performance

Proposed instruments
- Separate audio recordings of the instruments
- MIDI for piano and clarinet

Analytical questions
- Which instrument begins first, and how long afterward does the other instrument begin?
- How many milliseconds separate the onsets at each selected point?
- When the same point is performed repeatedly, how consistent or variable are the timing differences?
- How does asynchrony differ among the beginning of a piece, phrase transitions, and re-entry after rests?
- After feedback, how do mean asynchrony and variability across takes change?
- Do takes with closer onset alignment receive higher togetherness ratings from evaluators?

Quality of collaborative performance

Proposed variables and indicators
- Ratings of rhythm, sound balance, phrase connection, and musical expression

Proposed instrument
- An assessment form completed by evaluators who are unaware of the practice condition

Analytical questions
- **Rhythm:** Do the performers coordinate sound onsets, endings, and tempo changes, particularly at points requiring simultaneous playing or re-entry after rests?
- **Sound balance:** Are important musical lines clearly audible, and do performers adjust dynamics appropriately to their melodic and accompanying roles in each passage?
- **Phrase connection:** Do the melodic lines and breathing pauses match, and how does the piano part keep the phrase going while the clarinetist takes a breath?
- **Musical expression:** Do the performers convey the character, emotion, articulation, and direction of phrases in a consistent manner?

- How closely do evaluators agree in their ratings for each dimension, and which criteria require clearer descriptions?
- Across repeated performances or after feedback, which ratings change, and how are these changes related to breathing, movement, or onset data?

The proposed framework connecting respiration, movement, and sound extends the study of collaborative performance beyond learners' perceptions to examine bodily processes during actual performance. However, linking these variables requires instruments suited to the phenomena being investigated. For example, Almeida et al. (2023) designed the Musical Instrument Performance Capture and Analysis Toolbox (MIPCAT) to capture clarinet performance control variables like blowing pressure, reed position, contact between the performer's tongue and the reed as well as audio and video. These data can be used to study correlations between acoustic features and instrumental control. Sato et al. (2024) developed a device to manipulate the phase relation between melody and respiration and tested six conditions in aligning musical phrases with the respiratory cycle. Their method illustrates how timing within the respiratory cycle can be considered alongside melodic structure. Researchers should therefore consider the function of gestures together with the structure of the musical work, including phrases, melodic transitions, preparation for sound onset, and individual musicians' characteristic patterns, rather than using movement similarity as the sole criterion of quality. This view is supported by the study of Nusseck et al. (2022) who studied clarinetists using three-dimensional movement recording combined with audio data. They discovered that arm and knee movements were related to musical position, and in some passages, to pitch or timbre, but the relationships differed between individuals. The framework has the rationale to look at physiological data and also coordination behavior for respiration. For example, Lange et al. (2022) examined respiration and heart-rate variability in multipart singing among professional singers. They found synchronization of physiological signals and increased respiratory synchronization under a physical-contact condition. This finding suggests that the context of interaction may be related to physiological coordination and supports examining breath preparation together with cues from a performance partner.

Evaluation of the biobehavioral framework should combine bodily data with performance quality and musicians' experiences to avoid an overly narrow interpretation. For example, Bishop (2025) studied piano duos in different states of attention, recording movement and assessing performers' experiences. Shared attention or attention to each other increased the sense of togetherness, but movement indicators did not always capture that experience reliably. Tranchant et al. (2022), who studied interpersonal rhythmic coordination among musicians and nonmusicians, found that pairs with similar natural rates of rhythm production coordinated melody production more accurately, while musicians' experience was associated with increased temporal flexibility in different ways. Therefore, evaluation of the proposed piano–clarinet framework should distinguish among onset timing accuracy, movement coordination, musical quality, and shared experience. Interviews conducted after performers view their performance recordings may also help explain where they intended to give cues or leave space. Testing the biobehavioral framework should thus seek to explain patterns of adaptation appropriate to the musical work, rather than assuming that timing asynchrony or differences in movement should always decrease. For the subsequent research methodology, the researchers will synthesize the Phase 1 findings with the literature to establish operational definitions, select musical locations for analysis, and assess instrument suitability before data collection. The proposed study will compare usual practice with practice supported by feedback on respiration, movement, and sound. Practice duration and recording conditions will be made comparable. If the same duos take part in both conditions, condition order will be alternated while considering possible carryover effects from the first condition. Sample size will be determined with reference to the primary outcome, repeated-measures design, and dependence of data within performance pairs. Ethical procedures and informed consent will cover the recording of participants' bodily data, audio, and images. Consent to participate in the research will be obtained separately from permission to disseminate identifiable information. Before calculating indicators, the analysis will examine signal quality, synchronization error, and missing data. We will establish clear criteria for handling noise and parts of unusable data, so that the identified relationships correctly correspond to the phenomena under study. Then, differences between conditions and over time will be evaluated using approaches that can accommodate multiple observations within the same duo, e.g., mixed-effects

models. The analysis will take into account skill level, partner familiarity and characteristics of the musical works, and, depending on sample size, condition order and possible carryover effects from earlier trials. Results will include estimated differences, effect sizes and confidence intervals with corresponding p-values. Relationships between bodily variables and performance outcomes will be used to describe associations separately from conclusions about the effects of experimental conditions. Changes in bodily processes will not be inferred to cause changes in performance quality on the basis of association alone.

Conclusion and Recommendations

The findings of the study on digital technology integration for collaborative piano–clarinet learning at Shenyang Conservatory of Music indicate that students valued information sharing, technology use, performance techniques, and collaboration among performers and instructors. The expert data helped identify specific areas requiring development: balancing sound between the instruments, managing clarinetists' breathing, and coordinating rhythm. The experts proposed multitrack audio recording, joint review of performance recordings, and online channels for exchanging opinions, alongside the establishment of a shared resource repository and the development of instructors' digital skills. In applying these findings, instructors can design activities in which learners record their performances, identify problems, listen and discuss together, and set goals before attempting another performance. Shared assessment criteria can address rhythm, sound balance, phrase connection, and musical expression. Educational institutions should support these activities by providing equipment, rehearsal spaces, resource repositories, and training responsive to users' needs.

The Phase one findings provide a foundation for designing Phase two, which aims to connect a needs assessment with a proposed biobehavioral research framework. These first results can be used to further evaluate the status quo and the desired status, the readiness of the equipment and the appropriate feedback formats. The research framework is aimed at the objective of identifying variables, instruments and analytical approaches for the subsequent study. This indicates to record data on a common time frame to investigate the correlations among bodily processes, reactions to a performance partner and acoustic outcomes. In Phase two, the instruments should be piloted, and data quality and synchronization should be checked before comparing usual practice with practice supported by feedback. The analysis should include repeated measures on performance pairs, and take into account skill levels, partner familiarity and characteristics of the musical works. This approach would allow for assessment of performance outcomes, usability and feasibility of integrating the approach into actual teaching and learning.

The results are also linked to Sustainable Development Goal (SDG) 4: Quality Education. Providing equipment, rehearsal spaces, and resource repositories that learners can access equitably may support Target 4.3, which aims to ensure equal access to affordable and quality higher education. Practice in recording, analyzing, and using feedback to inform musical decisions is also linked to Target 4.4 on developing skills relevant to employment, whose indicators include information and communications technology skills. These connections should be evaluated in terms of learners' actual access to resources and their ability to use data (United Nations Department of Economic and Social Affairs, n.d.-b). Furthermore, collaboration among music institutions, physiology experts, and technology organizations has the potential to support SDG 17: Partnerships for the Goals if partners establish shared sustainable development objectives and exchange knowledge, expertise, technology, and resources. This approach is consistent with the multistakeholder partnerships described in Target 17.16 (United Nations Department of Economic and Social Affairs, n.d.-a). However, these connections are proposed applications and do not constitute evidence that the targets have already been achieved. Further monitoring is therefore needed to assess access to resources, data-use skills, and the outcomes of collaboration.

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