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Investigating the Long-Term Impact of Continuous and Transitioned Intelligent Tutoring Systems in Ear Training

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Abstract

Background and Aim: Ear training is a critical component of music education, enabling musicians to develop auditory perception, pitch recognition, and musical comprehension. Traditional ear training methods often rely on instructor-led drills and passive listening exercises, which may not accommodate individual learning paces and provide immediate feedback. Intelligent Tutoring Systems (ITS) have emerged as a promising solution, offering personalized, adaptive learning experiences. However, the long-term impact of ITS on ear training remains underexplored. This study aims to evaluate the effectiveness of continuous ITS exposure and the impact of transitioning from Sight-Singing and Ear Training Master (SSETM) to Yin-Ke (YK) over two semesters.

Materials and Methods: A quasi-experimental design was employed, involving 85 undergraduate students (64.7% female and 35.3% male) at a university in China. Participants were divided into two groups: Group A used YK continuously for both semesters, while Group B transitioned from SSETM in the first semester to YK in the second semester. Performance was assessed through pre- and post-tests measuring four auditory skills: aural dictation, interval recognition, chord recognition, and melodic dictation. Data were analyzed using paired samples t-tests to evaluate within-group improvements and Repeated Measures ANOVA to examine the effects of time and the transition to YK on skill development.

Results: The results indicate that ITS significantly improved students' auditory skills over the course of two semesters. Group A (continuous YK exposure) showed significant gains in aural dictation ($p < .001$), chord recognition ($p = .018$), and melodic dictation ($p = .002$). Group B (SSETM to YK transition) demonstrated significant improvements in aural dictation ($p < .001$), interval recognition ($p = .002$), and chord recognition ($p < .001$). A Repeated Measures ANOVA confirmed that time had a significant effect on aural dictation ($p = .023$, $\eta^2 = 0.061$), interval recognition ($p = .006$, $\eta^2 = 0.09$), and chord recognition ($p = .012$, $\eta^2 = 0.074$), while melodic dictation showed only marginal improvement ($p = .079$, $\eta^2 = 0.037$). A significant interaction effect for chord recognition ($p = .004$, $\eta^2 = 0.098$) suggests that Group B experienced greater improvement in this skill after transitioning to YK. Post hoc comparisons confirmed significant gains in aural dictation ($p < .001$), interval recognition ($p = .037$), and chord recognition ($p < .001$), while melodic dictation did not show a significant improvement ($p = .786$). This indicates that neither intervention method substantially enhanced this skill. Group B's significant gains after adopting YK confirm its superiority over SSETM in facilitating ear training. These findings confirm the long-term effectiveness of ITS, particularly for aural dictation, interval recognition, and chord recognition, while suggesting that additional instructional strategies may be needed to improve melodic dictation.

Conclusion: This study provides empirical support for the sustained effectiveness of ITS interventions in ear training, demonstrating that both continuous and transitioned ITS interventions improve auditory skills. The findings confirm YK's superiority over SSETM, reinforcing its role as a viable instructional tool. However, the limited progress in melodic dictation suggests the need for supplementary pedagogical strategies. Future research should expand the sample size and include multiple universities to enhance generalizability. Investigating ITS applications at different educational levels, such as high school and middle school, could assess broader applicability. Additionally, exploring teachers' perspectives and their integration of ITS into instruction would provide valuable insights into adoption challenges and instructional effectiveness.

Keywords: Intelligent Tutoring Systems; Ear Training; Yin-Ke; Sight-Singing and Ear Training Master

Introduction

Ear training is the process of developing a relationship between musical elements such as rhythm, melody, and harmony with notations by which music is represented (Horacek & Lefkoff, 1989). As a

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fundamental aspect of music education, it enables musicians to develop critical listening skills, enhance musical comprehension, and improve overall proficiency (Mavromatis & Brown, 2008; Shakya, 2024). Traditionally, ear training has been delivered through teacher-led instruction, textbook guidance, rote repetition, memorization, and passive practice. However, these conventional methods often struggle to accommodate individual learning paces, provide real-time feedback, and sustain student engagement. Consequently, there has been increasing interest in leveraging Intelligent Tutoring Systems (ITS) to enhance ear training by offering personalized learning experiences, adaptive exercises, and immediate feedback (Mousavinasab et al., 2021).

Intelligent Tutoring Systems have transformed music education by offering adaptive and personalized learning experiences that surpass traditional teaching methods (Fischer et al., 2018). Notably, their application in institutions such as the Carlos Valderrama Conservatory in Peru highlights their effectiveness in improving music education, particularly in specialized areas like ear training and rhythm sense(Rosas-Rodriguez et al., 2022; Wash, 2019). These systems allow learners to progress at their own pace, benefiting students who struggle with conventional approaches (Della Ventura, 2023; Wash, 2019). ITS technologies have demonstrated their effectiveness in various music-related subjects, including pitch feature extraction(Jiang, 2022; Phon-Amnuaisuk & Chee, 2005) and music composition (Holland, 2013; Mavromatis & Brown, 2008; Ventura, 2022), reinforcing the suitability of ITS-based educational approaches for music learning. Platforms like Ear Master exemplify how customized exercises for sight-singing and ear training can enhance students' learning experiences and outcomes (Della Ventura, 2023). Consequently, the integration of AI-driven ITS systems has emerged as a promising strategy to increase student engagement, motivation, and long-term retention in music education (Gunawan et al., 2020).

Despite these advantages, implementing ITS interventions in ear training presents several challenges. A primary concern is the accurate assessment of auditory inputs, as ITS must process complex musical data, including pitch, rhythm, and tempo, with high precision (Zhang & Talagala, 2023). Additionally, effective feedback mechanisms remain a challenge, as human instructors provide nuanced, context-sensitive responses that are difficult to replicate through automated systems(Corbett & Anderson, 2001). Furthermore, integrating advanced AI and AR technologies into ITS requires significant technical expertise and institutional investment (Lampropoulos, 2023; Leon, 2024). Pedagogical considerations also play a role, as ITS is traditionally designed for cognitive learning rather than skill-based training, making it essential to align system design with musical learning objectives (Goldberg et al., 2017). Ethical concerns regarding AI fairness, data privacy, and security must also be addressed when implementing ITS for music education (Aïmeur et al., 2006; Watanabe, 2024). While research highlights the potential of ITS, overcoming these challenges is crucial for maximizing its effectiveness in ear training.

Nevertheless, numerous studies have explored short-term ITS interventions, little research has examined the longitudinal impact of ITS in ear training across multiple semesters. Prior studies in technology-based pedagogy suggest that digital learning tools can positively impact long-term student performance, independent of demographic variables (Marc et al., 2015). Similarly, research on Technology-Enhanced Learning has shown that digital learning platforms contribute to sustained improvements in skill acquisition and retention over extended periods (Kurvinen et al., 2020). However, existing literature has yet to comprehensively address whether continuous ITS exposure leads to long-term benefits in ear training or whether transitioning between different ITS applications, such as from Sight-Singing and Ear Training Master (SSETM) to Yin-Ke (YK), results in greater improvements over time, reflecting an interaction effect between time and group.

This study aims to evaluate the effectiveness of continuous and transitional ITS interventions in ear training over two semesters. Specifically, it examines whether continuous ITS exposure leads to sustained improvement and whether transitioning between different ITS applications results in an interaction effect on skill development over time. To achieve these objectives, the study employs a quasi-experimental design with two groups: Group A, which used YK continuously for two semesters, and Group B, which

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transitioned from SSETM in the first semester to YK in the second semester. The following research questions and hypotheses guide this study:

RQ1: Do continuous ITS interventions significantly enhance students' ear training performance?

RQ2: Do students' ear training performance improve across semesters under ITS interventions?

RQ3: Do the patterns of performance improvement differ significantly between groups over two semesters?

H_a1: Continuous ITS interventions significantly improve students' ear training performance, whether they used YK continuously or transitioned from SSETM to YK.

H_a2: Students' performance improves significantly across semesters under ITS interventions.

H_a3: The patterns of performance improvement differ significantly between groups over two semesters.

By analyzing pre-test and post-test scores, as well as within-group and between-group comparisons, this study seeks to provide empirical insights into the long-term impact of ITS interventions in ear training. The findings will contribute to the ongoing discourse on educational technology in music instruction and inform best practices for ITS integration in structured learning environments.

Research Objectives

1. To evaluate the effectiveness of continuous ITS interventions in enhancing students' ear training performance.
2. To examine whether students' ear training performance improves across semesters under ITS interventions.
3. To compare the patterns of performance improvement between groups over two semesters.

Literature review

Intelligent Tutoring Systems in Music Education

Intelligent Tutoring Systems (ITS) in music education leverage artificial intelligence (AI) to enhance personalized learning experiences, address traditional teaching limitations, and foster student engagement. These systems utilize AI technologies to provide tailored feedback, adaptive learning pathways, and interactive content, significantly improving educational outcomes.

Xu (2024) showed a dramatic increase in student interest in music from 21 to 120 when using an AI-based system, highlighting its effectiveness in engaging learners. Similarly, Merchán Sánchez-Jara et al. (2024) emphasized the role of AI-driven assessment systems in providing immediate feedback, which is crucial for skill development in music education. The use of advanced algorithms in ITS has been shown to significantly improve students' music literacy and sound recognition skills (Hou, 2024). While ITS in music education presents numerous advantages, some educators express concerns about over-reliance on technology, fearing it may diminish the human element of teaching. Balancing AI integration with traditional pedagogical approaches remains essential for holistic music education (Marmoah et al., 2024).

Intelligent Tutoring Systems in Ear Training

Intelligent Tutoring Systems (ITS) have transformed ear training by providing personalized feedback, adaptive learning paths, and interactive exercises, effectively addressing the limitations of traditional methods. These technologies enhance learner engagement, skill acquisition, and long-term retention, making them valuable tools in music education. Various applications of ITS in ear training have demonstrated their effectiveness across different learning contexts, age groups, and skill levels. In gamified training programs, ITS has been applied to improve auditory perception through interactive exercises. This ear training game enhances engagement and facilitates skill improvement in audio engineering tasks. Additionally, it has been found to positively impact speech understanding in noise, demonstrating its broader benefits beyond trained auditory skills (Kim & Cozzarin, 2023). Similarly, ITS-based platforms like Smart Music and Ear Trainer have significantly improved motivation and performance in university-level ear training courses by offering real-time feedback and individualized learning paths(Schüler, 2021).

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These platforms align well with structured music education curricula, reinforcing interval, chord, and melody recognition through interactive and self-paced learning. ITS has also shown promise in early-stage ear training. Research on ITS-based IOS applications designed for children aged 6-11 indicates their effectiveness in enhancing user engagement and structured progress evaluation, thus supporting foundational ear training skills development (Serdaroglu, 2018). Virtual Reality (VR)-based ITS introduces immersive auditory training environments, expanding beyond traditional screen-based learning. Studies indicate that VR-based ITS enhances spatial auditory perception and interval recognition by utilizing spatialized audio, which improves listening accuracy and musical perception (Fletcher et al., 2019). Overall, research on ITS in ear training highlights its potential to improve skill acquisition and learning efficiency across diverse contexts.

Technological Pedagogical Content Knowledge

The Technological Pedagogical and Content Knowledge (TPACK) model is an insightful framework for understanding the effective integration of technology into educational settings. This model emphasizes the critical role of three core knowledge domains: technological, pedagogical, and content knowledge. The essence of TPACK lies not merely in these domains individually but rather in their intersection and interaction, which crucially informs teachers' decisions regarding technology selection, pedagogical strategies, and content delivery. TPACK shifts the emphasis away from technology itself, focusing instead on how technology can facilitate students' attainment of educational objectives. It underscores the importance of teachers understanding the specific content and pedagogical requirements of their subjects, enabling them to evaluate the benefits and limitations of various technologies. This understanding leads to informed decisions about using technology in a way that aligns with their teaching goals (Bauer, 2013).

TPACK is a vital theoretical construct that outlines the necessary knowledge base for educators to integrate technology effectively in their teaching practices. It underscores the synergy between a teacher's content knowledge, pedagogical expertise, and technological proficiency. This framework is essential for modern educators, guiding the alignment of these domains to achieve successful technology integration in education (Koehler & Mishra, 2009; Niess, 2016; Voogt et al., 2013). TPACK's development is key to enhancing technology-enriched teaching, recognizing the complexity of teaching with technology and the importance of a holistic understanding that melds content, pedagogy, and technology (Mishra & Koehler, 2006). Research on TPACK delves into its theoretical underpinnings, practical applications, methods of assessment, and strategies to cultivate this form of knowledge in educators.

Aural Dictation

According to Renzoni (2022), aural dictation skill involves the proficiency in recognizing and reproducing various musical elements through the act of ear transcription. Arapgirlioğlu and Özaltunoğlu (2012) define dictation as a criterion for the skill of using the relationship between sounds and symbols in music education. It allows for an understanding of how well a student comprehends the melody, harmony, and rhythm, which are the basic elements of a musical work. Aural skills encompass the ability to recognize, understand, and reproduce music that one hears (Merritt & Castro, 2020).

Interval Recognition

According to Fletcher et al. (2019), interval recognition refers to the ability to identify and distinguish the distance between two musical pitches or notes. Interval recognition refers to the ability to identify and distinguish between different musical intervals, which are the pitch relationships between two notes. It is an important auditory skill that musicians need to develop (Killam et al., 1975).

Chord Recognition

In the article by McVicar et al. (2011), chord recognition is the task of automatically reconstructing chord annotations from audio. In chord recognition systems, as outlined by McFee and Bello (2017), the term chord recognition refers to the automated identification and labeling of chords in an audio signal.

Melodic Dictation

By Buonviri (2019) and Cornelius and Brown (2020), melodic dictation is defined as a cognitive task involving the transcription of a heard melody into musical notation. According to Baker et al. (2018),

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Melodic dictation is the process of listening to music and then attempting to reproduce the melody either verbally or in written form based on what is heard.

Yin-Ke

The YK application is developed with the mission of simplifying and enhancing the efficiency of music teaching and learning. It serves as an intelligent music education platform, tailored for various educational settings, including schools, homes, and broader social environments. In the area of sight-singing and ear training, the YK application offers specialized training content and user-friendly teaching software to enhance both the teaching and learning experiences.

Sight-Singing and Ear Training Master

The Sight-Singing and Ear Training Master application is a comprehensive music learning tool designed to assist users in enhancing their vocal pitch, rhythm, and overall musicality. Leveraging cutting-edge AI technology, the application offers a suite of essential features such as a guitar tuner, score management, and a metronome, alongside advanced functionalities like audio extraction, spectrum analysis, and arrangement capabilities.

Research Framework

Figure 1 shows the research framework.

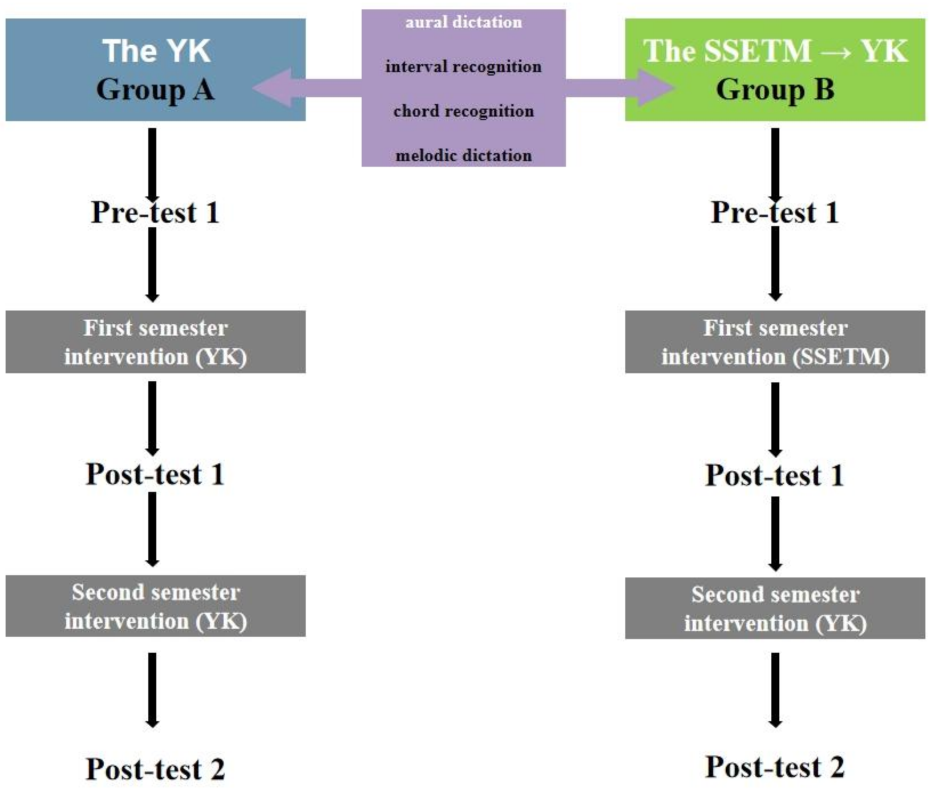

Figure 1 Research Framework

Methodology

Research design

This study employed a quasi-experimental design to examine the long-term impact of ITS interventions on students' ear training performance over two semesters. The study specifically aimed to evaluate the effectiveness of continuous ITS exposure and to determine whether transitioning from SSETM to YK would yield comparable improvements.

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Two groups of students participated in the study, each receiving different interventions in the first semester but both using YK in the second semester. Group A received YK instruction in both semesters. Group B received SSETM intervention in the first semester but switched to YK in the second semester based on prior research, which indicated that YK was more effective than SSETM. Pre-tests and post-tests were conducted each semester to track performance changes over time. The second semester YK intervention lasted 12 weeks, after which a post-test was administered to measure students' progress in auditory skills, as shown in Figure 1.

Phase One (Weeks 1–4)

The first phase aimed to establish a smooth transition for Group B from SSETM to YK while maintaining a natural learning environment for Group A, which had already been using YK in the first semester. This phase primarily focused on ensuring that all students had access to the YK technology, addressing software compatibility issues, and fostering independent learning engagement for Group A.

Since Group A had prior experience with YK, no structured classroom activities were mandated during the first four weeks. Instead, a self-directed learning approach was adopted to allow students to explore and engage with the application at their own pace. Students were encouraged to continue their training autonomously, fostering intrinsic motivation and independent learning habits. Throughout this period, the instructor did not impose specific usage requirements or interventions, ensuring that engagement with YK was entirely voluntary.

For Group B, the initial focus was on technical onboarding and ensuring all students had full access to the YK before formal instruction began. In Week 1, students were provided with the software installation package and detailed instructions for downloading and setting up YK. The instructor actively assisted students in troubleshooting technical issues, including software compatibility, login difficulties, and device-related concerns. Dedicated troubleshooting sessions were conducted to ensure all students could successfully access the YK without disruptions. From Weeks 2 to 4, the instructor introduced structured, in-class training on how to effectively utilize YK for ear training and sight-singing practice. This process included hands-on demonstrations to familiarize students with the YK's interface, key functionalities, and essential practice modules. Supervised practice sessions were incorporated, allowing students to explore YK while receiving real-time guidance from the instructor. During this phase, students were given a four-week pre-use period to interact with YK, adapt to its features, and gain confidence in using the YK before the formal intervention phase began.

Throughout the entire phase, the instructor remained available to address students' questions, provide additional clarification, and resolve any technical issues as they arose. This preparatory period ensured that by the time the structured intervention commenced, all students had a functional understanding of YK and were prepared to integrate it effectively into their learning process.

Phase two (Weeks 5–16)

The second phase constituted the formal intervention period, during which both Group A and Group B engaged in structured learning activities using YK. Since the baseline assessment had already been completed in the first semester, the second semester focused on post-test evaluation at the end of Week 16.

Throughout this phase, both groups followed a structured instructional approach, integrating the YK into regular coursework. The learning process was divided into three components: pre-class preparation, in-class learning activities, and post-class assignments. This structured model ensured that students progressively engaged with the material, reinforcing their learning at each stage.

In the pre-class preparation phase, students are required to complete assigned practice modules on the YK according to the course syllabus. These modules include interval recognition, chord recognition, and melodic dictation, designed to help students reinforce their foundational skills through independent practice before class. This approach enhances their sensitivity to ear training and establishes a strong cognitive foundation for in-class interactions.

During the in-class learning phase, the instructor uses YK to provide students with real-time guidance and interactive practice. Using the Seewo Interactive Whiteboard (IWB), instructors leverage YK's

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interactive features to engage students in ear training through question-and-answer activities, enhancing their immediate response ability and recognition accuracy. Subsequently, students participate in collaborative group practice, utilizing YK for interactive training, which strengthens skill mastery through peer learning. This structured classroom model not only encourages active student participation but also provides immediate feedback and personalized instructor guidance, optimizing the learning experience.

In the post-class assignment phase, students are required to independently complete personalized practices on the YK to further consolidate their learning outcomes. These assignments encourage students to apply the skills acquired in class, fostering continuous improvement through repeated practice and deepening their overall understanding.

During this structured implementation period, notable differences between the two groups emerged. Group A, having already used YK for a full semester, experienced no technical difficulties and integrated the software into their learning routine. In contrast, Group B encountered several challenges despite the preparatory period in Weeks 1–4. Some students in Group B struggled to locate specific training modules, leading to incomplete assignments. A subset of students faced software compatibility issues, preventing them from downloading or accessing YK smoothly. The instructor observed that Group B required more frequent guidance to navigate the software, troubleshoot issues, and develop familiarity with its features.

These observations suggest that prior exposure to YK may have played a critical role in students' adaptation and engagement with the ITS intervention. While Group A exhibited autonomous learning behaviors, Group B required additional support to integrate YK into their learning routine effectively.

By the end of Week 16, both groups completed the post-tests, which served as the primary measure of intervention effectiveness. These assessments provided quantitative insights into students' progress and the long-term impact of Group A versus Group B.

Participants

The participants of this study consisted of 85 undergraduate students enrolled in sight-singing and ear training courses at a university in China. These students, aged between 18 and 20, were all in their first year of study. The participants came from diverse musical backgrounds, including vocal performance (both Ethnic and Classical) and instruments (both Western and Chinese traditional). All students had foundational knowledge in music theory and experience in instrument playing or singing, primarily gained from their high school education. Their primary motivation for participating in these courses was to further enhance their auditory skills.

The participants were divided into two groups, with a total of 55 female and 30 male students. Group A initially consisted of 45 students, but one student withdrew in the second semester, resulting in a final count of 44 students (29 females and 15 males), accounting for 51.8% of the total sample. Group B included 41 students (26 females and 15 males), representing 48.2% of the total sample. The distribution of participants across the two groups was relatively balanced, ensuring comparability in sample composition. The detailed information is shown in Table 1.

Research Instruments

The research instruments employed in the study include a pre-test and a post-test. The performance tests were essential for assessing participants' auditory skills across different intervention phases. These tests, administered as pre-tests and post-tests, were designed to evaluate students' skills before and after the interventions. The pre-test, conducted in Week 5 of the first semester, established a baseline for each student's ear training ability, while the post-test, administered in Week 16 of both semesters, measured progress following the intervention.

The test content covered four key skill areas: aural dictation, interval recognition, chord recognition, and melodic dictation. Each section was evaluated based on standardized criteria adopted from a university in China, ensuring consistency and objective assessment. The allocation of scores followed a structured framework. The consistency between pre- and post-test assessments ensured comparability and provided valuable data on the long-term effectiveness of ITS.

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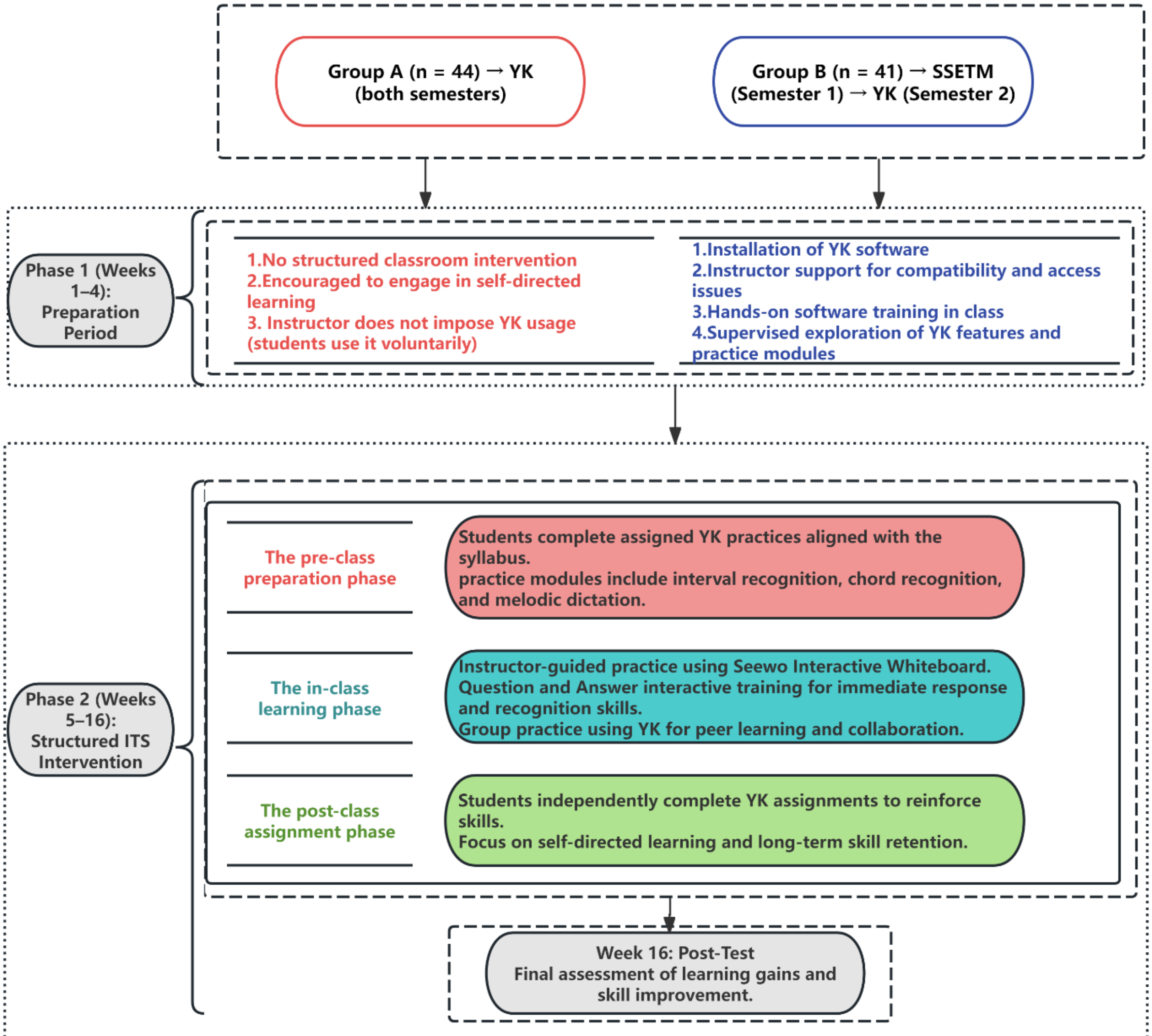

Figure 2 Research Treatment

Table 1 Demographic Information of Samples

		Gender		**Total**
		female	**male**	
Group	A	29	15	44
	B	26	15	41
Total		55	30	85

Data collection

The researcher systematically evaluated participants' performance using a 50-point written test based on the syllabus criteria. The test assessed three key auditory skills: interval recognition (10 points), chord recognition (20 points), and melodic dictation (20 points). The overall aural dictation score was derived from the combined performance in these three subskills, with a total score of 50 points.

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Quantitative data analysis was conducted using SPSS 26.0. Meticulous attention was given to data entry to ensure accuracy and reliability. Once the data were entered, statistical analyses were performed to examine trends, differences, and significance levels. The findings were then systematically interpreted to provide insights into the effectiveness of the ITS intervention on students' ear training performance.

Data Analysis and Results

Descriptive Statistics

Descriptive statistics were used to analyze pre-test and post-test scores for ear training performance across two semesters. The analysis examined the mean (M) and standard deviation (SD) of each skill, comparing performance between Group A and Group B. This section provides an overview of the observed changes in aural dictation, interval recognition, chord recognition, and melodic dictation.

For aural dictation, Group A showed improvement, increasing from 29.68 (SD = 6.94) to 33.8 (SD = 6.68), while Group B also demonstrated progress, improving from 27.95 (SD = 6.56) to 33.8 (SD = 7.52). In interval recognition, Group A's mean score rose slightly from 6.07 (SD = 2.13) to 6.36 (SD = 1.95), while Group B improved from 5.41 (SD = 1.85) to 6.46 (SD = 1.95). For chord recognition, Group A increased from 12.59 (SD = 4.04) to 14.05 (SD = 3.92), whereas Group B improved from 11.56 (SD = 3.27) to 15.37 (SD = 3.27). Lastly, in melodic dictation, Group A demonstrated an increase from 11.02 (SD = 4.17) to 13.39 (SD = 3.15), while Group B's improvement was more modest, rising from 10.98 (SD = 3.72) to 11.98 (SD = 3.82), as shown in Table 2.

Descriptive statistics reveal notable differences in performance trends across the two semesters. Before intervention (pre-test in the first semester), Group B exhibited higher baseline scores across all measured skills compared to Group A. However, following the first-semester intervention, where Group A utilized YK while Group B received SSETM, Group B's post-test scores were lower than those of Group A in all skill areas. This suggests that YK may have contributed to greater improvements in ear training compared to SSETM during the first semester. In the second semester, as both groups transitioned to YK intervention, Group B caught up and, in some cases, outperformed Group A in post-test scores. Specifically, aural dictation scores were equalized between the two groups, while Group B surpassed Group A in interval and chord recognition. However, melodic dictation remained lower in Group B compared to Group A, indicating that the transition to YK may not have been equally effective across all skills.

These findings suggest a clear shift in performance trends following the transition to YK, highlighting potential differences in the effectiveness of continuous versus transitioned ITS interventions. The subsequent inferential statistical analysis will examine whether these observed differences are statistically significant and assess the impact of intervention type on skill development across two semesters.

These observed trends suggest potential differences in skill development across groups and semesters, particularly in how the ITS intervention impacted students' performance in different skills. To determine the statistical significance of these findings, paired samples t-tests were conducted to assess within-group improvements (RQ1), a Repeated Measures ANOVA was performed to examine the effect of time on students' performance across semesters (RQ2), and a Repeated Measures ANOVA was utilized to analyze whether performance improvement patterns differed significantly between the groups (RQ3). The results of these analyses were presented in the following sections.

Table 2 Descriptive statistics

	Group	Mean	Std. Deviation
Aural-post-1	A	29.68	6.944
	B	27.95	6.557
	Total	28.85	6.776
Aural-post-2	A	33.8	6.681
	B	33.8	7.521

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	Group	Mean	Std. Deviation
	Total	33.8	7.056
Interval-post-1	A	6.07	2.128
	B	5.41	1.857
	Total	5.75	2.017
Interval-post-2	A	6.36	1.954
	B	6.46	1.951
	Total	6.41	1.941
Chord-post-1	A	12.59	4.037
	B	11.56	3.271
	Total	12.09	3.702
Chord-post-2	A	14.05	3.917
	B	15.37	3.269
	Total	14.68	3.659
Melodic-post-1	A	11.02	4.168
	B	10.98	3.718
	Total	11	3.934
Melodic-post-2	A	13.39	3.149
	B	11.98	3.818
	Total	12.71	3.538
Aural-pre-1	A	23.27	7.531
	B	23.88	7.336
Interval-pre-1	A	4.02	1.785
	B	4.12	1.327
Chord-pre-1	A	9.32	4.022
	B	9.46	3.95
Melodic-pre-1	A	9.93	4.195
	B	10.29	4.44

Note: Aural-post-1 = aural dictation post-test score in the first semester, Aural-post-2 = aural dictation post-test score in the second semester. Interval-post-1 = interval recognition post-test score in the first semester, Interval-post-2 = interval recognition post-test score in the second semester. Chord-post-1 = chord recognition post-test score in the first semester, Chord-post-2 = chord recognition post-test score in the second semester. Melodic-post-1 = melodic dictation post-test score in the first semester, Melodic-post-2 = melodic dictation post-test score in the second semester. Aural-pre-1 = aural dictation pre-test score in the first semester, Interval-pre-1 = interval recognition pre-test score in the first semester, Chord-pre-1 = chord recognition pre-test score in the first semester, Melodic-pre-1 = melodic dictation pre-test score in the first semester.

Inferential statistics

Since both groups received the YK intervention in the second semester, their final performance may not directly reflect differences in instructional interventions. Therefore, our analysis primarily focuses on within-group comparisons: evaluating the effectiveness of continuous YK intervention in Group A and the impact of transitioning from SSETM to YK in Group B.

To address Research Question 1, paired samples t-tests (see Table 3) were conducted to evaluate the effectiveness of ITS in improving students' performance across four skill areas after two semesters of intervention.

For Group A, statistically significant improvements were observed in students' aural dictation ($t(43) = -4.21$, $p < .001$), chord recognition ($t(43) = -2.45$, $p = .018$), and melodic dictation ($t(43) = -3.33$, $p = .002$). Conversely, there was no statistically significant difference in students' interval recognition (t (43)

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= -0.69, p = .492). These results suggest that continuous YK interventions were effective in enhancing students' aural dictation, chord recognition, and melodic dictation skills, but had a limited impact on interval recognition during the intervention period.

For Group B, paired t-tests revealed statistically significant improvements across three measured skills. Specifically, aural dictation improved significantly (t (40) = -7.88, p < .001), as did interval recognition (t (40) = -3.30, p = .002), chord recognition (t (40) = -7.64, p < .001). Conversely, there was no statistically significant difference in students' melodic dictation (t (40) = -1.79, p = .082). These findings indicate that transitioning from SSETM to YK interventions was effective in enhancing students' aural dictation, interval recognition, and chord recognition skills, but the impact on melodic dictation was not statistically significant.

Table 3 Paired samples t-tests

		N	Mean(SD)	t	Sig.
A	Aural dictation	44	29.68 (6.94) 33.8 (6.68)	-4.21	.000***
	Interval recognition	44	6.07 (2.13) 6.36 (1.95)	-0.69	.492
	Chord recognition	44	12.59 (4.04) 14.05 (3.92)	-2.45	.018*
	Melodic dictation	44	11.02 (4.17) 13.39 (3.15)	-3.33	.002**
B	Aural dictation	41	27.95(6.56) 33.8(7.52)	-7.88	.000***
	Interval recognition	41	5.41(1.86) 6.46(1.95)	-3.30	.002**
	Chord recognition	41	11.56(3.27) 15.37(3.27)	-7.64	.000***
	Melodic dictation	41	10.98(3.72) 11.98(3.82)	-1.79	.082

Note: * p≤0.05; ** p≤0.01; *** p≤0.001.

The results highlight the effectiveness of ITS interventions, with Group A demonstrating sustained improvements in three skill areas through continuous YK use, and Group B showing significant improvements across three skills after transitioning from SSETM to YK.

The results demonstrate that ITS interventions significantly enhanced students' performance in auditory skills over the course of two semesters. While Group A showed sustained improvements in aural dictation, chord recognition, and melodic dictation, Group B exhibited significant gains in aural dictation, interval recognition, and chord recognition. However, interval recognition in Group A and melodic dictation in Group B did not improve significantly, suggesting that the effectiveness of ITS interventions may vary across specific skills.

To address Research Question 2, a Repeated Measures ANOVA was conducted to evaluate whether students' performance significantly improved across different semesters under the ITS intervention, with the first semester pre-test scores used as covariates for analysis. Specifically, this analysis assessed whether the passage of time (comparing the first and second semesters) had a significant effect on students' performance in ear training (see Tables 4 and 5).

In aural dictation, the main effect of Time demonstrated a statistically significant improvement from the first semester (M = 28.811) to the second semester (M = 33.795), with F (1, 82) = 5.334, p = .023, η^2 = 0.061. Pairwise comparisons confirmed that the mean difference between the first semester and the second semester was statistically significant (MD = -4.984, p < .001). This indicates a small but statistically

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significant effect, suggesting that students improved their aural dictation performance across the two semesters after the ITS intervention.

In interval recognition, the main effect of Time showed a statistically significant improvement from the first semester (M = 5.74) to the second semester (M = 6.413), with F (1, 82) = 8.122, p = .006, and Partial η^2 = 0.09. Pairwise comparisons confirmed that the mean difference between the first and second semester was statistically significant (MD = -0.673, p = .013). This indicates a moderate effect, suggesting that students showed a significant improvement in interval recognition across the two semesters after the ITS intervention.

In chord recognition, the main effect of Time revealed a statistically significant improvement from the first semester (M = 12.057) to the second semester (M = 14.705), with F (1, 82) = 6.6, p = .012, and Partial η^2 = 0.074. Pairwise comparisons showed that the mean difference between the first and second semester was statistically significant (MD = -2.630, p < .001). This indicates a medium effect, suggesting that students improved significantly in chord recognition after the ITS intervention.

In melodic dictation, the main effect of Time showed a trend toward improvement from the first semester (M = 10.997) to the second semester (M = 12.679), but this result was not statistically significant with F (1, 82) = 3.165, p = .079, and Partial η^2 = 0.037. However, pairwise comparisons showed a statistically significant mean difference of -1.682 (p < .001), indicating a marginal but meaningful improvement in melodic dictation across the two semesters.

Table 4 The Effect of Time

Measure	Mean Square	F	Sig.	Partial η²
Aural dictation	88.186	5.334	.023*	0.061
Interval recognition	23.956	8.122	.006**	0.09
Chord recognition	43.198	6.6	.012*	0.074
Melodic dictation	28.287	3.165	.079	0.037

Note: * p≤0.05; ** p≤0.01; *** p≤0.001. Results of Repeated Measures ANOVA for the Effect of Time on Auditory Skills.

Table 5 Time Pairwise Comparisons

Comparison		Mean Difference	Std. Error	Sig.
First semester	Second semester			
Aural dictation		-4.984	0.624	.000***
Interval recognition		-.673	0.264	.013*
Chord recognition		-2.630	0.393	.000***
Melodic dictation		-1.682	0.459	.000***

Note: * p≤0.05; ** p≤0.01; *** p≤0.001.

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Table 6 The Effect of Time ✻ Group

Measure	df	Mean Square	F	Sig.	Partial η²
Aural dictation	1	31.939	1.932	.168	0.023
Interval recognition	1	6.583	2.232	.139	0.026
Chord recognition	1	58.582	8.951	.004**	0.098
Melodic dictation	1	19.269	2.156	.146	0.026

Note: * p≤0.05; ** p≤0.01; *** p≤0.001. Results of Repeated Measures ANOVA for the Effect of Time * Group on Auditory Skills.

Table 7 Post Hoc Comparisons - Time ✻ Group B

Comparison		Mean Difference	Std. Error	t	Sig.
First semester	Second semester				
Aural dictation		-5.852	0.898	-6.513	.000***
Interval recognition		-1.0667	0.379	-2.812	0.037*
Chord recognition		-3.8	0.565	-6.73	.000***
Melodic dictation		-1.008	0.661	-1.526	.786

Note: * p≤0.05; ** p≤0.01; *** p≤0.001.

To address Research Question 3, a Repeated Measures ANOVA was conducted to determine whether the patterns of performance improvement differed significantly between groups over two semesters, with the first semester's pre-test scores used as covariates for analysis. The interaction effect of Time × Group was analyzed across four skills to assess whether students' progress varied depending on the instructional method. The results are summarized in Tables 6 and 7.

The analysis revealed a significant interaction effect for chord recognition between the groups ($F(1, 82) = 8.951$, $p = 0.004$, $\eta^2 = 0.098$), indicating that the pattern of improvement in this skill varied depending on whether students received continuous YK exposure or transitioned from SSETM to YK. However, no significant interaction effects were observed for aural dictation ($F(1, 82) = 1.932$, $p = 0.168$, $\eta^2 = 0.023$), interval recognition ($F(1, 82) = 2.232$, $p = 0.139$, $\eta^2 = 0.026$), or melodic dictation ($F(1, 82) = 2.156$, $p = 0.146$, $\eta^2 = 0.026$). These results suggest that, apart from chord recognition, the overall improvement trends in the remaining skills were relatively similar across groups, regardless of the initial intervention method.

To further investigate these trends, post hoc comparisons for Group B were conducted. The results showed significant improvements in aural dictation ($MD = -5.852$, $t(82) = -6.513$, $p < .001$), interval recognition ($MD = -1.0667$, $t(82) = -2.812$, $p = 0.037$), and chord recognition ($MD = -3.8$, $t(82) = -6.73$, $p < .001$). However, no significant difference was found in melodic dictation ($MD = -1.008$, $t(82) = -1.526$, $p = 0.786$), indicating that neither intervention method produced substantial progress in this skill.

These statistical findings are further illustrated in Figure 3, which depicts the performance improvement patterns across two semesters for both groups in all four skill areas. The overall trend shows

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that both groups improved over time, but the magnitude and trajectory of improvement varied by skill. In aural dictation, both Group A and Group B reached similar final performance levels in the second semester, suggesting that YK was effective in enhancing this skill, regardless of whether students used it continuously or transitioned from SSETM. In interval recognition and chord recognition, Group B demonstrated a steeper improvement trajectory in the second semester after transitioning to YK, surpassing Group A in final performance. This aligns with the statistical results, where significant gains were found in these skills for Group B, reinforcing the effectiveness of transitioning to YK for these skills.

In melodic dictation, however, Group A showed a greater increase compared to Group B, implying that continuous exposure to YK may have provided an advantage in this skill. This aligns with the non-significant findings for Group B in the post hoc analysis, suggesting that the transition from SSETM to YK may not have been as beneficial for melodic dictation as it was for other skills. The most pronounced interaction effect was found in chord recognition, where Group B outperformed Group A in the second semester, indicating that the transition to YK yielded a stronger improvement effect for this skill compared to those who used YK continuously.

Overall, these findings highlight the differential impact of continuous versus transitioned ITS interventions on auditory skills. While continuous YK exposure provided stable improvements across all skills, transitioning from SSETM to YK produced notable gains in aural dictation, chord recognition, and interval recognition. However, the lack of significant improvement in melodic dictation suggests that additional instructional strategies may be necessary to optimize learning outcomes in this skill.

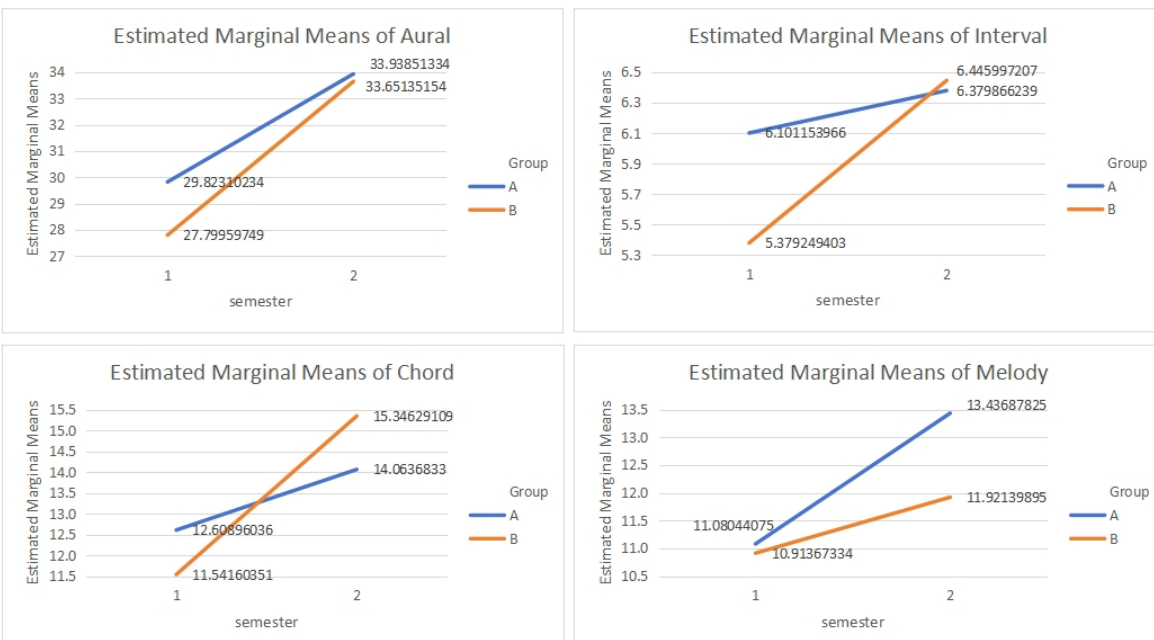

Figure 3 Time ✻ Group

Discussion

This study investigated the effectiveness of ITS interventions in ear training, comparing continuous exposure to YK (Group A) and the transition from SSETM to YK (Group B) over two semesters. The findings provide empirical evidence on the long-term impact of ITS on students' auditory skill development.

The first research question sought to determine whether continuous ITS interventions significantly enhance ear training performance. The results from paired samples t-tests revealed that Group A demonstrated sustained and consistent improvements in aural dictation and chord recognition. However, interval recognition did not show a statistically significant increase. Similarly, Group B exhibited significant gains in aural dictation, interval recognition, and chord recognition, while melodic dictation remained unchanged. This suggests that while ITS is effective in improving certain auditory skills, its long-term impact on interval recognition and melodic dictation may be more limited. These findings align with previous studies highlighting the effectiveness of ITS in improving sight-singing and ear training (Della Ventura, 2023).

The second research question explored whether students' performance improved across semesters under ITS interventions. The results from Repeated Measures ANOVA indicated a significant main effect of time, showing that students exhibited overall performance gains from the first to the second semester, particularly in aural dictation, interval recognition, and chord recognition. However, while melodic dictation showed a trend toward improvement, it was not statistically significant in either group. These findings support previous studies emphasizing that ITS-based platforms have significantly improved motivation and performance in university-level ear training courses (Schüler, 2021). However, the lack of significant improvement in melodic dictation suggests the need for more effective pedagogical approaches, such as using pitch systems that emphasize scale degree function, rhythm systems that reinforce meter, and advocating for listening to a dictation in its entirety before beginning to transcribe (Paney & Buonviri, 2017).

The third research question aimed to determine whether the patterns of performance improvement differed significantly between groups over two semesters. The findings revealed a significant interaction effect for chord recognition, indicating that the trajectory of improvement in this skill varied depending on whether students had continuous exposure to YK or transitioned from SSETM to YK. Group B showed greater gains in chord recognition compared to Group A, suggesting that YK was more effective than SSETM in enhancing this skill. This finding underscores the sustained effectiveness of YK as an ITS intervention, reinforcing the notion that its structured, technology-assisted approach provides superior auditory training benefits over SSETM.

Despite significant improvement patterns in chord recognition, the lack of significant interaction effects in aural dictation, interval recognition, and melodic dictation suggests that the overall improvement trends in these skills were similar across both groups, regardless of their initial training method. However, post hoc analysis revealed that Group B exhibited greater gains in aural dictation, interval recognition, and chord recognition after transitioning to YK, while Group A demonstrated stable progress across both semesters. This further reinforces YK's effectiveness, as students in Group B, who had initially trained with SSETM, showed marked improvement once they adopted YK. Moreover, the comparable final performance levels in aural dictation between groups indicate that YK consistently supported skill development across different instructional backgrounds. Melodic dictation, however, remained the least improved skill across both groups, with Group A exhibiting slightly greater gains compared to Group B. This suggests that continuous exposure to YK may provide a cumulative advantage in this skill, whereas transitioning from SSETM to YK might not yield immediate benefits. The non-significant improvement in Group B's melodic dictation performance further highlights the limitations of ITS in developing this skill and suggests the need for additional pedagogical interventions to enhance ITS-based melodic dictation training.

Overall, these findings provide strong empirical support for the long-term effectiveness of YK as an ITS intervention in ear training. The superior gains observed in Group B after transitioning from SSETM to YK not only confirm YK's sustained impact but also suggest that it is more effective than SSETM in facilitating auditory skill development. The results also emphasize that while continuous YK exposure fosters stable progress across multiple skills, certain areas, such as melodic dictation, may require supplementary instructional strategies to optimize learning outcomes. These insights contribute to the broader discussion on ITS effectiveness in music education, reinforcing the necessity of integrating ITS with instructor-led methodologies to achieve comprehensive auditory skill development.

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Conclusion

This study provides empirical evidence supporting the long-term effectiveness of ITS interventions in ear training, demonstrating that both continuous YK exposure and the transition from SSETM to YK led to significant auditory skill improvements over two semesters. The findings indicate that ITS-based training effectively enhances aural dictation, interval recognition, and chord recognition, with YK proving to be a more effective intervention than SSETM. However, the limited progress observed in melodic dictation suggests that ITS alone may not fully address the cognitive demands of this skill, highlighting the need for additional instructional strategies.

These findings contribute to the broader discussion on technology-enhanced learning in music education from multiple perspectives. From a teaching perspective, ITS provides instructors with an effective tool for personalized learning, reducing reliance on repetitive drills and allowing more time for targeted pedagogical interventions. From a student perspective, ITS fosters self-directed learning by offering adaptive exercises, real-time feedback, and individualized training pathways, supporting long-term skill retention. For software developers, the study highlights areas for improvement in ITS design, particularly in addressing complex skills like melodic dictation through AI-driven feedback, multimodal exercises, and improved user adaptability.

Future research should focus on expanding the sample size and including participants from multiple universities to improve the generalizability of the findings. Additionally, exploring ITS interventions across different educational levels, such as high school and middle school, could provide insights into its broader applicability. Another valuable direction would be investigating teachers' perceptions and integration of ITS into their instruction, identifying factors that influence their willingness and ability to incorporate technology into ear training instruction.

Recommendation

Based on the findings of this study, several recommendations are proposed to enhance the implementation and effectiveness of ITS in ear training.

First, from a pedagogical perspective, teachers should consider integrating ITS as a supplementary tool rather than a sole instructional method. Teachers should combine ITS-based exercises with instructor-led reinforcement. Additionally, training programs should be provided to instructors to help them effectively integrate ITS into their curriculum and maximize its benefits.

Second, from a student learning perspective, ITS should be utilized to encourage self-directed learning by leveraging its adaptive learning features and immediate feedback mechanisms. Students can benefit from using ITS beyond the classroom setting, engaging in personalized practice sessions that align with their progress. Furthermore, educators should guide students in using ITS, focusing on weak skills to ensure comprehensive skill development.

Finally, for software developers, there is a need to refine ITS design by incorporating advanced AI-driven feedback mechanisms and multimodal learning strategies. Future iterations of ITS should address the challenges of melodic dictation by integrating interactive vocal training, rhythm-based exercises, and real-time auditory analysis. Customizable difficulty levels and personalized learning pathways could further enhance the effectiveness of ITS, ensuring that students at varying proficiency levels receive appropriate instructional support.

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