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A Study on the Impact of Intelligent Speech Enhancement Technology on Classroom Acoustic Environment Improvement and Teaching Effectiveness

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Abstract: With the in-depth advancement of educational informatization, classrooms, as the primary venues for teaching and learning, have increasingly attracted attention with regard to their acoustic environments. Classroom acoustics not only directly affect teaching effectiveness and students' learning experiences, but also constitute a critical factor influencing overall instructional quality. However, in real-world teaching settings, problems such as background noise, reverberation interference, and sound propagation attenuation remain prevalent, particularly in large classrooms or specialized instructional scenarios where acoustic challenges are more pronounced. Consequently, there is a growing need to rely on intelligent speech enhancement technologies driven by deep learning algorithms to provide novel directions for upgrading and optimizing classroom acoustic environments. Against this background, this paper begins by outlining the fundamental principles of intelligent speech enhancement technology and its practical application points in classroom settings, and then focuses on examining its role in improving classroom acoustic conditions as well as its positive impact on teaching effectiveness. The findings are of significant theoretical and practical value for optimizing classroom teaching environments and promoting educational equity.

Keywords: intelligent speech enhancement technology, deep learning, classroom acoustic environment, teaching effectiveness, learning experience

1. Introduction

Intelligent speech enhancement technology has become a standard component in the construction of smart classrooms in many educational institutions. It effectively addresses the long-standing problem of poor audibility in traditional classrooms, significantly improving the auditory learning environment. A growing body of empirical research has demonstrated that, with the support of intelligent speech technologies, both speech intelligibility—commonly measured by the Short-Time Objective Intelligibility (STOI)—and speech quality—often evaluated using the Perceptual Evaluation of Speech Quality (PESQ)—are significantly improved in complex noise environments. These improvements directly reduce students' listening fatigue and cognitive load, thereby enhancing overall teaching effectiveness. As a result, intelligent speech enhancement technology has evolved from an advanced tool for improving teaching experience into a foundational technology for building fair, efficient, and healthy classroom acoustic environments.

2. Principles and Classroom Applications of Intelligent Speech Enhancement Technology

2.1 Principles of intelligent speech enhancement technology

In everyday environments, various sounds coexist, with typical background noise levels reaching approximately 60 dB, comparable to the sound level of normal conversation. In different application scenarios, noise types and their interference with speech vary considerably (Xu et al., 2020). The primary objective of speech enhancement technology is to separate human speech from background noise in such noisy environments and enhance it to ensure clarity and intelligibility.

From a technical perspective, modern speech enhancement approaches commonly employ convolutional neural networks (CNNs) to model and process the time–frequency features of speech and

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noise. Subsequently, decoder networks are used to reconstruct clean speech signals (Yao & Zhang, 2024). Specifically, these models are trained on large datasets containing clean speech and noise samples, enabling them to automatically learn and distinguish the characteristic differences between speech and noise. This learning process allows the model to more accurately extract speech components from mixed signals. The overall process typically involves several key steps: first, noisy audio signals are captured via microphones; second, the collected signals are analyzed to extract relevant speech features; third, pretrained deep learning models suppress noise components while enhancing speech signals; and finally, clean and intelligible speech signals are reconstructed and output.

2.2 Classroom applications of intelligent speech enhancement technology

First, intelligent non-intrusive sound reinforcement systems are widely used in classrooms. These systems effectively suppress acoustic feedback (howling), reduce room reverberation, and lower environmental noise while automatically adjusting output volume to achieve full-scene intelligent sound amplification. During this process, teachers are not required to wear any additional devices and can move freely within the classroom, while students in all seating positions receive clear and evenly distributed sound without noise interference.

Second, specialized speech enhancement solutions have been developed for specific teaching scenarios. For example, to improve audio quality in lecture recording classrooms, speech enhancement methods based on improved deep deconvolutional neural networks have been introduced. Through specially designed network architectures, these methods simultaneously analyze temporal variations and frequency-domain characteristics of speech while incorporating attention mechanisms to focus on relevant speech signals. As a result, the clarity and perceived quality of recorded audio are significantly enhanced, making recorded content easier to understand during post-class review and instructional analysis.

Third, adaptive scene-based speech enhancement technologies dynamically adjust processing strategies according to different classroom scenarios, such as lecturing, group discussions, or breaks. By analyzing multiple acoustic features and using pretrained models to identify the current teaching scenario, the system automatically adjusts relevant parameters to ensure optimal sound performance under varying classroom activities.

3. Effects of Intelligent Speech Enhancement Technology on Classroom Acoustic Environments

3.1 Improving clarity and reducing interference

On the one hand, supported by real-time processing capabilities of hardware systems, intelligent speech enhancement technologies often employ beamforming techniques using microphone arrays installed on ceilings or suspended structures. Through spatial filtering, speech signals from target directions are enhanced while interference from other directions is suppressed (Su, 2024). This approach effectively separates teachers' speech from irrelevant noise sources such as air-conditioning sounds, external classroom noise, and students' page-turning sounds. It amplifies speech from the teacher's direction while attenuating noise from other directions, thereby reducing room reverberation and ensuring speech clarity. Moreover, as teachers move around the classroom, the system dynamically adjusts in real time to maintain consistent volume and clarity across all seating positions, without requiring teachers to raise their voices or manually operate equipment.

On the other hand, deep learning–based approaches have been widely applied to speech enhancement tasks, addressing limitations inherent in traditional techniques (Wang & Feng, 2025). Systems supported by advanced algorithms can perform fine-grained analysis of temporal and spectral characteristics, enabling more precise noise suppression, particularly for sudden and irregular noise. Due to the high computational and training requirements, such methods are especially suitable for scenarios demanding high audio quality, including premium course recordings, distance education platforms, and online classrooms. After adopting these intelligent speech enhancement technologies, both objective clarity metrics and subjective listening quality are significantly improved.

3.2 Enhancing adaptability to diverse teaching scenarios

In practical classroom environments, non-stationary noise is common, and different noise types exhibit distinct characteristics, requiring appropriately matched noise estimation methods for effective tracking (Yao et al., 2012). Consequently, automatic scene recognition has become a core capability of intelligent speech enhancement systems. Whether the scenario involves teacher-led instruction,

student group discussions, or informal classroom activities, the system can automatically identify the current teaching context by analyzing real-time acoustic features. It extracts multiple parameters and uses pretrained analytical models to distinguish between different activity types accurately.

Based on the identified scenario, the system automatically adjusts internal parameters. For example, during teacher-led instruction, noise reduction, echo cancellation, and automatic gain control are fully activated to deliver clear and stable speech to all students. During group discussions, the system shifts focus to microphone sensitivity and directivity adjustments to capture students' voices from various locations clearly. Furthermore, modern systems incorporate self-learning mechanisms based on deep neural networks, improving adaptability during scenario transitions (Xie et al., 2024). Instead of abrupt changes, parameters are adjusted gradually by modifying the mixing ratio between raw and enhanced signals, ensuring seamless auditory transitions and preventing distraction caused by sudden changes in sound characteristics.

3.3 Promoting educational equity and inclusive education

For students with hearing difficulties, intelligent speech enhancement technology offers substantial advantages through personalized parameter adjustments. Teachers can configure system settings to accommodate individual needs. For instance, students with reduced sensitivity to specific frequency ranges can benefit from targeted enhancement of those frequencies. This individualized approach functions as a "customized auditory aid," enabling students with diverse needs to achieve satisfactory listening experiences within standard classroom environments, thereby enhancing educational inclusivity.

In remote teaching contexts, audio quality is influenced by network conditions, microphone quality, and environmental noise. Intelligent speech enhancement technologies leverage advanced algorithms to filter transient noises such as keyboard typing and mouse clicks while ensuring clear and enhanced teacher speech. Additionally, integration with video systems enables automatic visual focus on the active speaker when a student begins speaking (Zhang et al., 2025), thereby enhancing immersion and interaction in remote classrooms and reducing feelings of detachment in online learning.

3.4 Improving synergy with physical acoustic environments

On the one hand, intelligent speech enhancement technology can compensate for deficiencies in classroom physical acoustics. Due to factors such as room shape, size, and construction materials, some classrooms suffer from excessive reverberation or speech blurring. Structural renovation is often costly and may yield limited results. By contrast, algorithm-based electronic signal processing can selectively suppress reverberation caused by multiple reflections, providing a cost-effective and efficient solution for improving existing classroom acoustic conditions.

On the other hand, advanced intelligent speech enhancement systems feature self-adjustment capabilities to adapt to different classroom acoustics. By emitting test signals and analyzing reflections within the space, the system can characterize room acoustics and automatically optimize internal parameters to achieve the best possible speech enhancement performance.

4. Impact of Intelligent Speech Enhancement Technology on Teaching Effectiveness

4.1 Enhancing students' learning experience and outcomes

In traditional classrooms, teachers' voices naturally attenuate with distance and are easily affected by environmental noise. As a result, students seated in the back or corners often struggle to hear clearly, leading to missed information, increased cognitive load, and listening fatigue. With intelligent speech enhancement technology, multiple microphones deployed throughout the classroom enable real-time localization of the teacher. Directional enhancement amplifies the teacher's speech while suppressing noise from other directions. When the teacher approaches the back of the classroom, the system automatically reduces volume in the front while maintaining sufficient clarity in the rear, ensuring consistent sound levels throughout the space and eliminating auditory blind spots.

For students with hearing impairments, who already face challenges due to sound attenuation and noise interference during speech transmission (Zhang & Wang, 2024), intelligent speech enhancement systems provide tailored support that allows them to understand classroom content more easily. This not only boosts academic performance but also enhances confidence, encouraging active participation in discussions and improving communication and social skills.

A representative example can be observed in English listening and speaking classes at Binhe East

Road Primary School in Xiaodian District, Shanxi Province. Previously, teachers found it difficult to provide individualized pronunciation correction in large classes, and students seated farther away often struggled to hear accurate pronunciation. After implementing the iFLYTEK AI-assisted listening and speaking classroom system, each student was equipped with a portable voice response device. The system accurately captured individual pronunciation, provided immediate analysis and scoring, and ensured that all students could clearly hear teachers' instructions and standard pronunciation models. Student feedback indicated improved pronunciation correction and learning outcomes.

4.2 Improving students' ability to sustain attention

First, intelligent speech enhancement technology reduces students' cognitive burden during listening. When speech clarity is ensured, students no longer need to expend excessive effort deciphering auditory information, allowing them to focus cognitive resources on understanding complex concepts. This effect is particularly pronounced when learning challenging content.

Second, enhanced teacher speech retains natural intonation and emotional expressiveness, making instruction more engaging. Advanced systems further optimize vocal quality, rendering speech more natural and pleasant. As a result, students experience less listening fatigue during extended sessions and are better able to maintain sustained attention.

4.3 Facilitating information assimilation and knowledge internalization

For the entire class, improved speech clarity reduces unnecessary cognitive load and increases learning efficiency. When all students can clearly hear every explanation regardless of seating position, they can devote full attention to conceptual understanding rather than compensating for poor audibility. This promotes deeper cognitive processing, stronger connections between new and existing knowledge, and more durable learning outcomes. Consequently, students can master core concepts during class, reducing the need for extensive post-class review and freeing time for practice, group discussions, and extended reading, thereby creating a positive learning cycle.

From a personalized learning perspective, intelligent speech technologies can collect and analyze learning data, such as response accuracy and time spent on specific concepts. These analytics are automatically fed back to teachers, enabling precise identification of students' strengths and weaknesses. Teachers can then adjust instructional focus and pacing, providing targeted support where needed. When learning content and methods align more closely with individual students' abilities and progress, learning becomes more efficient and less stressful.

5. Conclusion

In summary, intelligent speech enhancement technology constitutes a crucial component of modern educational technology. Its role in improving classroom acoustic environments and enhancing teaching effectiveness has become increasingly evident. With continued technological advancement and accumulated implementation experience, intelligent speech technologies are expected to become powerful drivers of educational modernization, supporting overall improvements in teaching quality and providing a solid foundation for pedagogical innovation.

Conflict of Interest

The author declares that he has no conflicts of interest in this work.

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