Higher Education and Practice Vol. 3 No. 9, 2026

The Application of Artificial Intelligence in Bilingual Education in Primary Schools in Ethnic Minority Areas of Qinghai: Technological Possibilities and Structural Constraints

Zeng Maotai
College of Nationalities Normal, Qinghai Normal University, Xining, Qinghai, China

Abstract: Artificial intelligence technology offers new tool possibilities for bilingual teaching in ethnic minority regions, but its actual effectiveness is constrained by the structural characteristics of the bilingual education system. Taking primary schools in ethnic minority areas of Qinghai as the object of analysis, this paper draws on the functional classification framework of AI in language teaching and, in combination with the differences in minority-language and Chinese bilingual education models, the teacher structure, and the language ecology in ethnic minority areas of Qinghai, examines the applicable conditions and limits of four types of applications: intelligent listening training, pronunciation detection, reading recommendation, and robot-assisted teaching. The analysis shows that AI can produce marginal improvements in the contextualization of oral training, the immediacy of pronunciation feedback, and the adaptation of reading resources, but it is difficult for AI to replace the cultural mediation function of bilingual teachers, nor can it resolve the deep-seated contradictions caused by the instrumental weakness of the minority language. The effective embedding of AI should be premised on supplementing rather than replacing bilingual teachers, and bounded by respect for the minority cultural context. Rather than treating AI as a substitute for teachers or as a solution to structural inequality, this paper argues that its most defensible role is a conditional, teacher-mediated, and culturally bounded supplement. The paper contributes to the discussion of educational technology in ethnic minority regions by connecting the functional promises of AI to the institutional, linguistic, and cultural conditions under which bilingual teaching actually takes place.

Keywords: Artificial Intelligence; Ethnic Minority Areas of Qinghai; Bilingual Education; Primary School; Technological Limits

1. Introduction

Bilingual education in primary schools in ethnic minority areas of Qinghai has long been situated within multiple tensions. The first tension concerns language policy and cultural inheritance[2][3]: schools must respond to the national requirement to improve students' proficiency in the national common language, while also sustaining minority mother-tongue culture and the educational value of the minority language as a living language. The second tension concerns regional heterogeneity: differences in language environments between pastoral areas and towns make it difficult for a unified teaching model to adapt to all schools. The third tension concerns human resources: the structural shortage of bilingual teachers constitutes the most direct practical bottleneck. These tensions do not merely form a background to technological innovation; they shape what any technological tool can actually do in the classroom.

Against this background, artificial intelligence technology has been expected to "alleviate the shortage of high-quality educational resources." Applications such as Chinese and minority language bilingual speech recognition, intelligent teaching-assistant robots, AI listening-and-speaking classrooms, and minority-language speech assessment have already been piloted in some primary and secondary schools in Qinghai. Policy discourse and public reporting often present these tools as evidence that digital technology can compensate for geographical remoteness, teacher shortage, and resource inequality. However, the introduction of technological tools does not automatically equate to an improvement in teaching quality. A tool may be technically functional yet pedagogically ineffective; it may

generate impressive demonstrations yet fail to be integrated into ordinary classroom routines; it may increase the quantity of language input yet reduce the quality of meaningful interaction. What AI can and cannot do in bilingual education therefore needs to be examined by returning to the specific scenarios and institutional conditions of bilingual teaching.

Existing studies have provided a preliminary review of the functions of AI in language teaching, covering dimensions such as listening training, pronunciation detection, reading recommendation, and robot-assisted education[1]. These studies help identify the technical affordances of AI: it can provide standard speech models, repeated practice opportunities, immediate feedback, personalized recommendations, and low-anxiety interaction. However, these discussions are mostly set against the background of general language teaching and rarely address the special conditions of bilingual education in ethnic minority regions. In ethnic minority areas of Qinghai, bilingual education involves the coexistence of mother tongue and common language, the structural imbalance in teacher capacity, the uneven density of language contact across urban and pastoral settings, and the inseparability of cultural context from language learning. These conditions are not marginal complications; they are central to whether AI can be meaningfully used.

This paper attempts to place the functional framework of AI-assisted language teaching under the realistic constraints of bilingual education in primary schools in ethnic minority areas of Qinghai. It analyzes the possible contributions and inherent limits of each application and thereby discusses the reasonable positioning of AI in bilingual education in ethnic minority regions. The paper does not propose a new empirical survey or claim to evaluate specific products. Rather, it is a conceptual and contextual analysis that synthesizes existing literature, reported cases, and policy observations. Its purpose is to clarify the conditions under which AI may serve as a supplementary tool and the boundaries beyond which technological enthusiasm becomes pedagogically and ethically problematic.

The central argument is that AI can produce marginal improvements in selected dimensions of bilingual teaching—especially oral practice, pronunciation feedback, and resource adaptation—but it cannot replace the cultural mediation function of bilingual teachers, nor can it resolve the deeper contradiction produced by the instrumental weakness of the minority language in the broader society. The effective embedding of AI should therefore be premised on supplementing rather than replacing bilingual teachers, and bounded by respect for the minority cultural context. In the conclusion, the paper suggests that the most valuable position for AI in bilingual classrooms in minority regions is beside the teacher, not in front of the teacher.

2. Analytical Framework and Method

This paper adopts a contextual and function-oriented analytical framework. The first dimension is functional: AI applications in language teaching are classified according to the pedagogical tasks they promise to support, namely listening training, pronunciation detection, reading recommendation, and robot-assisted teaching. The second dimension is structural: each function is examined against the institutional and linguistic conditions of bilingual education in ethnic minority areas of Qinghai, including bilingual models, teacher capacity, language ecology, and cultural context. The third dimension is normative: the analysis asks not only whether a tool works technically, but also what role it should play in a bilingual classroom and what it should not be expected to do.

This framework is deliberately cautious about technological determinism. It does not assume that the presence of a tool implies its pedagogical value. Instead, it treats technology as something that must be selected, embedded, interpreted, and evaluated by teachers within specific institutional settings. In this sense, the paper follows a teacher-mediated view of educational technology: the meaning of a tool is not located in the tool itself but in the pedagogical activity in which the tool is used. This view is particularly important in bilingual education, because the teacher's role is not merely to transmit language but to mediate between two language worlds, to explain cultural references, and to help students navigate the emotional and cognitive challenges of moving between the minority language and Chinese.

The analysis is also sensitive to the difference between technical possibility and structural feasibility. A speech recognition system may be

technically capable of scoring pronunciation, but its use may be limited by the availability of training data in a local dialect. A reading recommendation system may be algorithmically sophisticated, but its usefulness may be constrained by the scarcity of graded reading materials in the minority language. A robot may be engaging for children, but it may not be able to perform the cultural mediation that bilingual teaching requires. By distinguishing technical possibility from structural feasibility, the paper avoids both technological pessimism and technological optimism. It asks what AI can reasonably be expected to contribute under existing conditions, and what conditions would need to change before its contribution could be expanded.

3. The Structural Premises of Bilingual Education in Primary Schools in Ethnic Minority Areas of Qinghai

Before discussing technological applications, it is necessary to clarify the institutional configuration and resource conditions of bilingual education in primary schools in ethnic minority areas of Qinghai, because these constitute the basic constraints on the role of AI. Three premises are especially important: differences in bilingual models, the structural shortage of bilingual teachers, and the uneven language ecology across urban and pastoral areas.

3.1 Differences in Bilingual Models Determine Heterogeneous Technological Needs

Primary schools in ethnic minority areas of Qinghai can be roughly divided into two types of models. In the first type, most subjects other than Chinese language are taught in the minority language. In the second type, Chinese is the language of instruction for most subjects, and the minority language is offered as an independent course. These two models are not simply administrative variations; they create different language environments, different patterns of language input, and different pedagogical needs. Students in the first type are extensively exposed to academic registers of the minority language in subject learning, but they may have relatively limited opportunities for Chinese oral communication training. Students in the second type mainly use Chinese in subject learning, and their minority-language literacy and oral use depend more on the minority-language classroom.

This difference has direct implications for AI deployment. If the deployment of AI tools ignores the model difference and appears under a unified guise of "bilingual teaching assistance," it may produce unintended effects. In the first type, an AI tool that predominantly offers Chinese-language practice may intensify the encroachment of Chinese on the space of disciplinary language, especially if the tool is used across subjects. In the second type, an AI tool that treats the minority language as a supplementary or ceremonial language may weaken its training value as a living communicative language. The first step in technological application is therefore not to choose tools, but to determine what language skills the bilingual model of a specific school and a specific class actually requires support for. A tool that is appropriate for one model may be inappropriate for another.

This point also suggests that "bilingual" is not a single pedagogical target. In some classrooms, the priority may be Chinese oral fluency and confidence; in others, it may be minority-language academic literacy; in still others, it may be the ability to move between the two languages in subject learning. AI systems that are designed around a generic model of language learning may fail to capture these differentiated goals. Effective deployment therefore requires a preliminary diagnosis of the local bilingual model, the language background of students, the language of instruction in different subjects, and the specific skills that teachers find most difficult to support.

3.2 The Structural Shortage of Bilingual Teachers Constitutes the Core Bottleneck

The proportion of teachers in ethnic minority areas of Qinghai who are proficient in both the minority language and Chinese has long been low, and the professional structure is imbalanced. Bilingual teachers in science and subjects such as music, physical education, and art are especially scarce. This shortage is not only a matter of quantity but also a matter of capacity structure. Even if teachers are on staff, their minority-language academic ability and Chinese teaching conversion ability vary considerably. Some teachers may be fluent in everyday communication but less confident in academic language; others may be able to teach in Chinese but less able to explain concepts in the minority

language; still others may have the language ability but lack the pedagogical knowledge to support bilingual transfer[4].

AI is often expected to "make up for the teacher shortage." This expectation is understandable, but it needs to be qualified. Technology can reduce the cost of certain repetitive labor, such as providing repeated pronunciation models, marking simple oral responses, or offering additional practice opportunities. However, it cannot create out of thin air the bilingual teaching judgment that teachers do not possess. If teachers themselves lack a deep understanding of the conversion between the two languages in teaching, the content generated by intelligent tools will be difficult to effectively integrate into classroom teaching. A robot or an AI platform may present a sentence in two languages, but it may not know when to switch languages, how to explain a cultural reference, or how to respond to a student's confusion. These decisions require professional judgment that is situated in the classroom and in the relationship between teacher and students.

This is why the teacher shortage cannot be treated simply as a problem of "coverage." The issue is not only that there are too few teachers, but that the teachers who are present may not have the specific bilingual pedagogical capacities needed. AI can support teachers by providing resources and feedback, but it cannot substitute for the development of those capacities. In fact, if AI is introduced without adequate teacher preparation, it may increase rather than reduce the burden on teachers, because teachers must learn to operate the tool, evaluate its output, and integrate it into an already complex bilingual classroom.

3.3 The Uneven Language Ecology Constrains the Equalization of Technological Utility

Language use in ethnic minority areas of Qinghai shows significant regional differentiation. In urban environments, the frequency of contact with Chinese is relatively high, while in pastoral areas the minority language remains the most important language of daily communication. This means that the same intelligent speech assessment system may mainly serve refined training in standard Chinese pronunciation in urban schools, while in pastoral schools even the basic amount of Chinese speech input may be difficult to guarantee. The effectiveness of technological tools depends on the existing density of language contact, not the reverse.

This point is crucial for understanding the limits of AI as an equalizing tool. Technology is often promoted as a way to overcome geographical distance and resource inequality, but its effectiveness is not independent of the local language ecology. A tool that works well in a town school where students already have substantial Chinese exposure may not work well in a pastoral school where students have limited opportunities to hear and use Chinese outside the classroom. In the latter setting, the problem is not simply a lack of practice; it is a lack of comprehensible input, meaningful interaction, and communicative need. AI can increase the quantity of input, but it cannot by itself create the social conditions that make input comprehensible and meaningful.

Moreover, the language ecology affects not only students' language proficiency but also their motivation and identity. In pastoral areas, the minority language may be the language of family, community, and emotional life. Chinese may be perceived as the language of schooling, examinations, and future employment. AI tools that are designed around a monolingual model of language learning may inadvertently reinforce this hierarchy by treating the minority language as a subject to be practiced and Chinese as the language of educational success. A more sensitive approach would recognize that bilingual education is not only about language skills but also about the relationship between languages and the identities they carry.

4. Functional Analysis of Four Types of AI Applications in Bilingual Teaching

Under the above constraints, several functional directions of AI can produce improvements in a marginal sense, but each improvement is accompanied by conditions that require careful treatment. This section examines four applications: intelligent listening training, pronunciation detection, reading recommendation, and robot-assisted teaching.

4.1 Intelligent Listening Training: Contextualization and Immediacy Limited by Starting Points

Intelligent devices can provide standard speech models, original story audio, and interactive dialogue exercises. In areas lacking a native-speaker language environment, these functions

have supplementary value. Practice in county-level pilot schools shows that AI listening-and-speaking classrooms can provide students with accurate speech models for reading texts aloud[8][9] and extend the learning space when families lack tutoring capacity. For students who have little exposure to standard Chinese outside school, such tools can offer additional opportunities to hear and imitate fluent speech. They can also reduce the pressure on teachers to provide repeated demonstrations, allowing teachers to focus on more complex aspects of language use.

However, for pastoral students with weak Chinese listening and speaking foundations, a mere "increase in input" may not translate into comprehensible input. If the intelligent system cannot carry out difficulty stratification and semantic scaffolding according to students' actual listening levels, abundant speech resources may instead increase cognitive load. A student who does not understand the meaning of the input may simply learn to tolerate noise or to guess from superficial cues. The effectiveness of listening training therefore depends on whether the system can connect with the language groundwork already laid by teachers in class, rather than operating independently.

This point suggests that AI listening training should be designed as part of a pedagogical sequence, not as a standalone intervention. Before students listen to an AI-generated dialogue, the teacher may need to pre-teach vocabulary, activate background knowledge, and set a listening purpose. After listening, the teacher may need to check comprehension, clarify misunderstandings, and connect the dialogue to students' own experiences. Without these steps, the technology may increase time on task without increasing learning. In bilingual classrooms, the teacher's mediation is especially important because students may need to move between the minority language and Chinese to understand the content. An AI system that operates only in one language may not be able to provide the cross-linguistic support that students need.

4.2 Pronunciation Detection: Technical Rationality and Dialect Differences

The immediate feedback of pronunciation detection has clear technical rationality. Chinese pronunciation assessment technology is relatively mature and can provide quantitative feedback from dimensions such as the accuracy of initials and finals, fluency, and intonation. For students who need frequent practice and immediate correction, such feedback can be useful. It can help them notice errors that might otherwise go unnoticed and can provide a sense of progress. In large classes, where teachers cannot listen to every student individually, AI-based pronunciation detection can offer additional practice opportunities.

Research on pronunciation error detection for rural students in minority regions has attempted to convert speech signals into minority-language characters and information on initials and finals to help students locate pronunciation problems[6]. This work is technically promising, but it also reveals a fundamental challenge: the phonetic differences among regional varieties of the same minority language are significant. The variety spoken in the research area differs from the standard used to train mainstream acoustic models, and whether the training data of existing speech models sufficiently cover the phonetic features of that variety directly affects the reliability of the assessment[6][7]. If the model is trained mainly on another variety or on a standardized pronunciation, it may misrecognize legitimate local pronunciations as errors.

This raises a pedagogical and ethical issue. If the system uses a certain dialect or standard pronunciation as the benchmark to "correct" students' local pronunciation, technological feedback may slide from language training into the implicit depreciation of dialect variants. Students may learn that their family's way of speaking is "wrong" rather than "different." In bilingual education, this is not a trivial matter. Language is tied to identity, and the way a teacher or a machine responds to a student's pronunciation can affect the student's confidence and sense of belonging. The reasonable positioning of pronunciation detection in bilingual teaching should be to help students expand their phonetic repertoire, rather than replace dialect belonging with a single standard. The goal should be to add registers and contexts, not to erase the local voice.

4.3 Reading Recommendation: Personalized Logic and Resource Scarcity

There is a structural mismatch between the personalized logic of reading recommendation and the scarcity of bilingual reading resources. The core advantage of intelligent reading

recommendation lies in graded recommendation based on students' reading levels and interests. In a well-resourced environment, such systems can help students find materials that are neither too easy nor too difficult, and can support independent reading. However, in the minority-language and Chinese bilingual context, this logic faces a double difficulty.

First, the stock of graded reading resources in the minority language is far from sufficient to support refined difficulty stratification. Even if the AI recommendation system accurately identifies a student's reading ability, there may be no "material" to recommend. A recommendation engine cannot compensate for the absence of a library. In many schools, the problem is not that the algorithm is insufficiently personalized, but that there are too few appropriate books, especially books that are culturally relevant and linguistically accessible. Second, the development of bilingual reading ability is not a simple juxtaposition of reading levels in two languages. It involves conceptual transfer and cross-linguistic connections. A student may be able to read a Chinese text about a familiar topic but struggle with the same topic in the minority language because the vocabulary or discourse patterns are different. A system that evaluates and recommends books separately by language can hardly respond to the cognitive needs specific to bilingual readers.

The priority of reading recommendation in primary schools in ethnic minority areas of Qinghai may therefore not be the refinement of algorithms, but the foundational construction of bilingual parallel texts and culturally relevant materials. Before AI can recommend, there must be something worth recommending. This suggests a different order of intervention: invest first in the creation, translation, adaptation, and distribution of bilingual reading materials; then develop recommendation systems that can use those materials. Otherwise, AI may create a façade of personalization while leaving the underlying resource gap untouched.

4.4 Robot-Assisted Teaching: Instrumental Value and the Limits of Cultural Mediation

Robot-assisted education has instrumental value in classroom interaction and repetitive tasks, but it cannot assume the cultural mediation function of bilingual teaching. Intelligent teaching-assistant robots introduced in primary schools in several counties of Qinghai[5] can already achieve voice-guided reading, oral assessment, and simple classroom interaction. They have shown effects in stimulating lower-grade students' interest and reducing teachers' repetitive burden. A bilingual teaching-assistant robot developed by a Tianjin University team[5] has also been piloted in primary and secondary schools in Qinghai, serving nearly five thousand person-times. These practices are significant because they show that robots can provide a low-anxiety interactive entry point for oral practice and can partially alleviate the gap in individualized guidance caused by teacher shortages.

However, one of the core tasks of bilingual teaching is to transmit the meaning structures of two cultural worlds in language learning. This requires teachers to identify the cultural confusion students encounter in language conversion and to demonstrate by example the ways of thinking and emotional attitudes behind the two languages. A robot can repeat a phrase, score a pronunciation, or run a scripted dialogue, but it cannot easily recognize when a student's confusion is cultural rather than linguistic. It cannot share its own experience of moving between two languages. It cannot model the emotional labor of translation or the ethical responsibility of representing a culture. Robots can become practice partners, but it is difficult for them to become cultural mediators.

Positioning them as "assistance" rather than "replacement" is therefore not only a judgment of technological realism but also a requirement of educational ethics. If robots are presented as substitutes for teachers, there is a risk that the most relational and culturally embedded aspects of bilingual education will be marginalized. If they are presented as assistants, their value can be more accurately located: they can handle repetition, provide novelty, and offer additional practice, while teachers retain responsibility for meaning-making, cultural interpretation, and the formation of classroom relationships.

5. Discussion: the Conditions and Boundaries of AI as a Supplementary Tool

Based on the above analysis, the reasonable role of AI in bilingual education in primary schools in ethnic minority areas of Qinghai can be defined from three levels.

First, the release of AI's effectiveness depends on the "mediating use" of bilingual teachers. Technological tools themselves do not produce

teaching meaning; meaning is produced through teachers' selection, embedding, and interpretation of tools. Experience in county-level pilot areas shows that schools where smart education equipment plays a role are often also schools with stronger digital teaching capabilities among teachers[8][9]. Low information technology literacy among teachers and the lack of professional guidance are the main obstacles to deepening digital applications. In bilingual education scenarios, this requirement is even more demanding: teachers not only need to operate tools but also need to judge which content is suitable for presentation by AI and which must be explained and converted by themselves in two languages. What AI reduces is repetitive labor, but what it increases is the professional judgment burden on teachers in technology integration and language mediation.

Second, AI cannot resolve the deep-seated contradictions caused by the instrumental weakness of the minority language. A persistent structural fact in bilingual education in ethnic minority areas of Qinghai is that the instrumental value of Chinese in further education and employment is far higher than that of the minority language. Parents and students show a strong pragmatic orientation in language choice, while at the same time they do not deny the significance of the minority language in cultural inheritance and self-identity. If AI is positioned simply as a tool to "improve the efficiency of Chinese teaching," it may objectively accelerate the realization of this instrumental logic and push the minority language further back into a symbolic course. Technology cannot create social demand for the use of the minority language, nor can it replace the role of language policy and community language vitality in maintaining intergenerational transmission of the minority language. When introducing AI into bilingual education, it needs to be made clear that it does not assume the function of reversing the language ecology, nor should it use the name of "efficiency" to conceal the political-economic roots of this ecological problem.

Third, the non-computability of cultural context constitutes the boundary of AI assistance. A large amount of content in minority-language textbooks is translated from Chinese textbooks, lacking local cultural characteristics, and the translation of specialized terms is inconsistent. This long-standing problem cannot be solved by intelligent translation tools. Translation accuracy does not equal equivalence of cultural meaning. When AI deals with minority cultural concepts, distributional bias in its training data may cause generated content to be superficial or homogenized. A considerable part of bilingual teaching—helping students understand the life-world behind language and establishing meaningful connections between two cultural frames of reference—precisely lies in areas that algorithms can hardly reach.

These three conditions suggest a principle of "supplementarity" rather than "substitution." AI should be introduced where it can add practice, feedback, and access without displacing the relational and cultural work of the teacher. It should be evaluated not only by efficiency metrics but also by its effects on language vitality, student identity, and teacher professionalism. In this sense, the question is not simply "What can AI do?" but "What should AI be allowed to do in a bilingual classroom?"

6. Implications for Implementation and Research

Several practical implications follow from this analysis. First, deployment should begin with a local diagnosis of the bilingual model, the language ecology, and the teacher capacity of the school. A tool that is appropriate for an urban school with strong Chinese exposure may not be appropriate for a pastoral school with limited Chinese input. Second, teacher training should focus not only on operating technology but also on integrating technology into bilingual pedagogy. Teachers need opportunities to evaluate AI-generated content, adapt it to local cultural contexts, and decide when to use the tool and when to rely on their own explanation. Third, resource development should precede or accompany algorithmic refinement. Without graded reading materials in the minority language, bilingual parallel texts, and culturally relevant content, reading recommendation systems will have limited value.

Fourth, evaluation should be multidimensional. It should include language outcomes, but also classroom interaction, student confidence, teacher workload, and cultural relevance. A tool that improves pronunciation scores but reduces students' willingness to speak the minority language is not a success. Fifth, policy should avoid framing AI as a solution to structural inequality. Technology can support teachers, but

it cannot replace investment in teacher education, bilingual materials, community language vitality, and language policy. If AI is presented as a substitute for these investments, it may distract attention from the deeper conditions that shape bilingual education.

Future research could examine how teachers actually use AI in bilingual classrooms, how students respond to different types of AI feedback, and how AI affects the relationship between the minority language and Chinese in subject learning. Comparative studies across different bilingual models and different language ecologies would be especially valuable. Research is also needed on the ethical and cultural dimensions of AI-generated content in the minority language, including issues of dialect representation, translation equivalence, and cultural stereotyping.

7. Conclusion

What artificial intelligence offers to bilingual education in primary schools in ethnic minority areas of Qinghai is not a substitutive transformation but a set of conditional tools for marginal improvement. Intelligent listening training and pronunciation detection can make up for teacher shortages in the immediacy and accessibility of oral feedback; reading recommendation can assist personalized learning on the premise that resource construction is in place; and robot-assisted teaching can provide a low-anxiety interactive entry point for lower-grade students. However, the effectiveness of these tools depends on whether they are embedded in a design that respects differences in bilingual models, takes teacher mediation as the core, and takes the minority cultural context as the boundary.

Technology can shorten the delay of feedback, but it cannot shorten the distance in meaning between two language worlds; it can reduce the burden of repetitive labor, but it cannot replace teachers' professional judgment in moving between the two languages. In bilingual classrooms in ethnic minority areas of Qinghai, the most valuable position for artificial intelligence is to stand beside the teacher, not in front of the teacher. The task of the coming period is therefore not to ask how quickly AI can be expanded, but to ask under what conditions it can be used without weakening the relational, cultural, and pedagogical foundations of bilingual education.

References

[1] Qiu Tingting. Artificial Intelligence and Its Application in Early Childhood Bilingual Teaching[J]. Keji Feng, 2021(3).

[2] Salami L O. It is still "Double Take": mother tongue education and bilingual classroom practice in Nigeria[J]. Journal of Language, Identity and Education, 2008, 7(2): 91-112.

[3] Zhang L, Tsung L. Bilingual education and minority languages in China: prospects and challenges[M]. Singapore: Springer, 2019: 149-165.

[4] Pando M, Aguirre-Muñoz Z. Case-based instruction in science professional development: bilingual and ESL teachers reflect about science subject matter knowledge and pedagogy[J]. Journal of Science Teacher Education, 2020, 32(3): 286-305.

[5] Wei Jianguo Team. Intelligent Interactive Robot—AI Empowering National Common Language Teaching in Ethnic Minority Regions[R]. Case of the National Key Field Language Technology Empowerment Innovation Project, 2025.

[6] Tong R, Chen N F, Ma B, Li H. Context aware mispronunciation detection for Mandarin pronunciation training[C]. Proceedings of Interspeech 2016, 2016: 3112-3116.

[7] Lonergan L, Qian M, Ní Chiaráin N, Gobl C, Ní Chasaide A. Low-resource speech recognition and dialect identification of Irish in a multi-task framework[C]. Proceedings of the Speaker and Language Recognition Workshop (Odyssey 2024), 2024: 67-73.

[8] Wang Qingmei, Cheng Huanyu. Let Classrooms Have "Wisdom" and Growth Have "Roots"[N]. Qinghai Daily, 2025-12-20.

[9] Zhou W. Empowering high-quality development of rural teacher teams through smart education[M]. Singapore: Springer, 2025: 267-269.