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AI IN THE CLASSROOM: EVALUATING THE EFFECTIVENESS OF INTELLIGENT TUTORING SYSTEMS FOR MULTILINGUAL LEARNERS IN SECONDARY EDUCATION

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Abstract

This study presents a systematic literature review examining the role, design, and effectiveness of Intelligent Tutoring Systems in supporting multilingual learners in secondary education. A total of 110 peer reviewed studies were analysed to identify the key functional components, pedagogical strategies, and adaptive features that contribute to the success of these systems in linguistically diverse classrooms. The review explores four interrelated components of Intelligent Tutoring Systems including learner modelling, domain knowledge, pedagogical strategy engines, and user interaction or interface design. Particular emphasis is placed on how these components integrate adaptive personalization, multimodal instructional resources, and culturally responsive frameworks to address both content mastery and language acquisition. Findings reveal that systems which employ sophisticated learner models such as Bayesian Knowledge Tracing and Performance Factor Analysis combined with linguistically sensitive feedback and multimodal delivery significantly enhance comprehension, retention, learner confidence, and engagement. Furthermore, culturally relevant domain knowledge and inclusive interface design were found to reduce barriers caused by language differences, thereby fostering an equitable learning environment. The study underscores the importance of teacher training, infrastructure readiness, and ethical data governance to ensure effective and responsible implementation. While emerging technologies such as generative artificial intelligence present opportunities for deeper personalization and more natural interaction, careful attention must be given to preventing bias, safeguarding privacy, and preserving cultural diversity. This review contributes to academic discourse and practical application by offering a synthesized framework for designing Intelligent Tutoring Systems that are inclusive, adaptive, and pedagogically grounded, ultimately supporting both academic success and language development for multilingual learners.

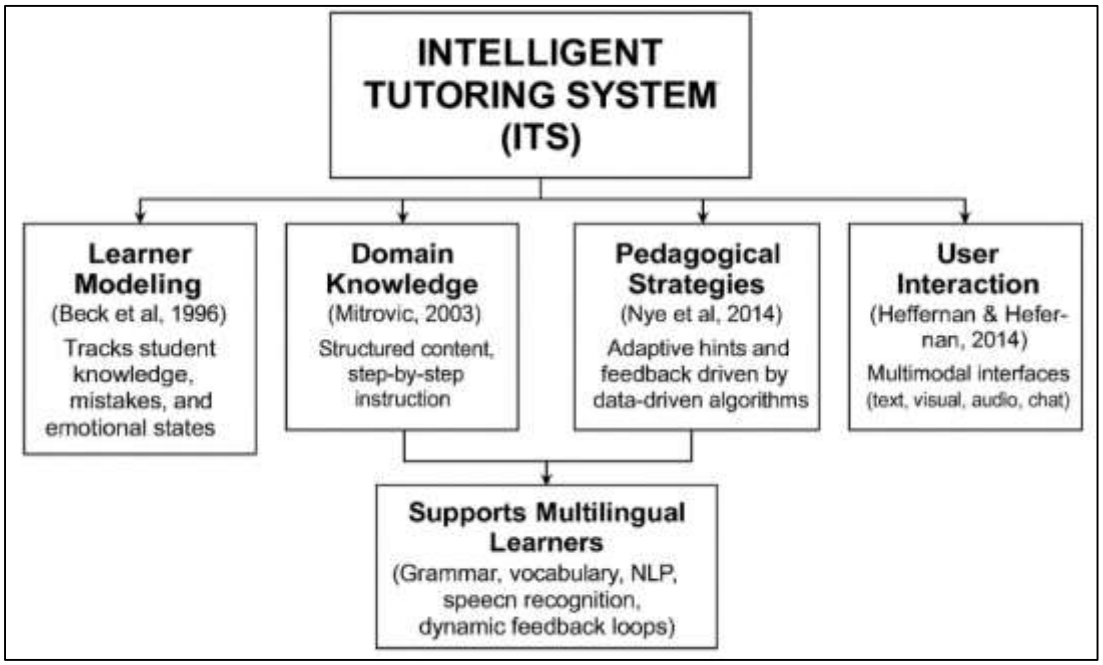
KEYWORDS

Intelligent Tutoring Systems, multilingual learners, adaptive learning, learner modeling, cultural responsiveness, systematic literature review, multimodal instruction

INTRODUCTION

Artificial intelligence or AI is fast becoming an essential part of the modern classroom. AI refers to computer systems designed to handle tasks that often require human intelligence such as learning new information, solving complex problems, or understanding different languages (Abdi et al., 2019). In its simplest form, AI can feel like a friendly guide that listens carefully and offers clues when a student feels stuck. With AI-guided tools, each learner can receive feedback that is timely and tailored, creating an experience that is both comforting and effective (ASI, 1992). One exciting application of AI in education is the use of Intelligent Tutoring Systems or ITS. These systems adapt in real time to each learner, offering explanations, examples, and practice questions that match the student's level (Avcı et al., 2023). ITS is designed to mimic the benefits of human tutors who work one on one with learners, celebrating progress and offering gentle guidance when challenges arise. Research shows that this kind of support can lead to deeper understanding, lasting retention, and a boost in learner confidence (Conati et al., 2018). Multilingual learners bring rich language backgrounds into classrooms, creating a vibrant tapestry of voices and perspectives. These students often need to master subject content while also gaining fluency in the language of instruction, which can add an extra layer of challenge to their journey (Erümit & Karal, 2020). For these learners, ITS can act as an inclusive bridge, providing scaffolding in both content and language and helping them feel seen, supported, and ready for success. As schools grow more diverse, the need for tools that can reach every learner becomes critical. ITS offers a path toward classrooms that feel fair and alive with possibility by giving each student a sense of personal attention, even in larger groups (Ghadirli & Rastgarpour, 2013). This research on AI in the classroom will evaluate the effectiveness of ITS for multilingual learners in secondary education, aiming to shed light on how technology can uplift every student voice and spark a lifelong love of learning.

Figure1: Components of Intelligent Tutoring Systems (ITS) Supporting Multilingual Learners



The structure of intelligent tutoring systems typically includes several core parts learner modeling domain knowledge pedagogical strategies and user interaction modules (Gibson, 2022). To begin with learner modeling is like having a sensitive guide inside the software that pays attention to each students current understanding mistakes and even their feelings as they work through a problem (Granić, 2022). By keeping track of what a student knows and where the student struggles, the system grows a dynamic profile that evolves with every click answer or hesitation. As a result, the software can decide if it should offer a gentle hint celebrate a success, or try a different teaching approach to keep frustration at bay. This constant tailoring of guidance helps learners feel that they are not alone as they tackle new

challenges. Next the domain knowledge module is the well-organized backbone of the system (Holmes et al., 2019). This part holds the concepts facts procedures and examples that the system needs to teach. It arranges them in a clear hierarchical order so that each step naturally leads to the next. When a student asks for help or answers a question the software can draw from this structured catalog to give precise step by step instructions. As a result, learners can follow a logical path toward mastery without getting lost in unnecessary details. Unlike a static lesson pedagogical strategies bring life to the teaching process (Kulik & Fletcher, 2016; Létourneau et al., 2025; Lin et al., 2023; Liu et al., 2024b).These strategies are driven by data and often use methods such as Bayesian algorithms to predict the best moment to provide a hint or a more detailed explanation. The system analyzes patterns behind common errors and chooses interventions that research has shown to be most effective. Over time these tactics become more refined as the system learns from the unique responses of learners. User interaction is the way learners talk back to ITS and vice versa (Mitrović, 2003). This includes everything from simple text prompts to colorful images interactive graphs and even spoken feedback if the system has a voice component. The design of these interfaces is flexible enough to suit diverse learning styles and preferences while maintaining clarity and focus. For multilingual learners this adaptability can mean the difference between confusion and confidence when facing complex subject matter. By presenting ideas visually or verbally the system can offer multiple channels for understanding and help bridge language gaps.

Using advanced methods like Bayesian Knowledge Tracing ITS can update its understanding of each learner's progress at a rapid pace ensuring that instruction is always personalized relevant and effective (Pérez-Marín & Pascual-Nieto, 2013; Subrato, 2018). This probabilistic approach models how likely it is that a learner has mastered a concept and uses that information to adjust question difficulty pacing and the type of hints provided. Over time the model becomes more sensitive to each learners needs leading to more accurate support and faster achievement of learning goals. Multilingual learner models also consider unique challenges such as confusing similar sounding words applying grammatical rules from one language to another or mixing up vocabulary that looks alike but differs in meaning across languages (Ara et al., 2022; Ritter et al., 2023). By incorporating these linguistic nuances, ITS can offer exercises that focus on common error patterns and provide targeted practice activities. This helps learners overcome specific obstacles and build confidence in both language use and subject matter mastery through repeated scaffolded interactions. To support multilingual students better ITS includes tools like automated writing evaluation that uses NLP to assess essays on grammar structure coherence and overall style providing timely feedback to guide revisions (Uddin et al., 2022; Son et al., 2023). Speech recognition technology converts spoken responses into text allowing learners to practice pronunciation intonation and fluency while receiving immediate corrective prompts (Team, 2024). These features give students multiple channels to express their understanding and receive precise feedback that matches their individual needs. Dynamic feedback loops adapt tasks based on students' emotional states and interaction patterns using techniques from affective computing to help maintain motivation reduce anxiety and foster persistence (Akter & Ahad, 2022; Yarlagadda, 2025). Data gathered from these adaptive loops and analytic tools provide educators with clear insights into evolving language proficiency error trends and engagement levels (Zawacki-Richter et al., 2019). Teachers can use this information to refine in class instruction group support and overall curriculum design to better meet the needs of multilingual learners.

The main objective of this study is to evaluate the effectiveness of intelligent tutoring systems in supporting multilingual learners in secondary education. As classrooms continue to become more linguistically diverse, it is important to understand how digital tools can meet the needs of students who are learning both academic content and a new language. Intelligent tutoring systems are designed to provide personalized instruction that adapts to each learner's progress, offering explanations, feedback, and practice in real time. This research focuses on how these systems support students who must navigate subject matter through a second language. It looks closely at how different parts of the systems work together to support both language development and content understanding. These parts include how the system tracks learner knowledge, how it organizes subject content, how it decides when to offer help, and how it presents information through different formats. The study explores the

role of features such as natural language processing, speech recognition, and automated writing feedback in supporting multilingual learners. It also considers how the systems respond to student emotions and engagement, offering support that helps reduce frustration and build confidence. The goal is to understand which features are most useful for multilingual students and how these features can be used in real classrooms. This research does not only measure academic outcomes, it also looks at how students interact with the systems and how supported they feel during the learning process. The findings are intended to offer practical guidance for teachers, school leaders, and technology developers. The study aims to show how intelligent tutoring systems can help create fair and supportive classrooms where every student, no matter their language background, has a chance to succeed.

LITERATURE REVIEW

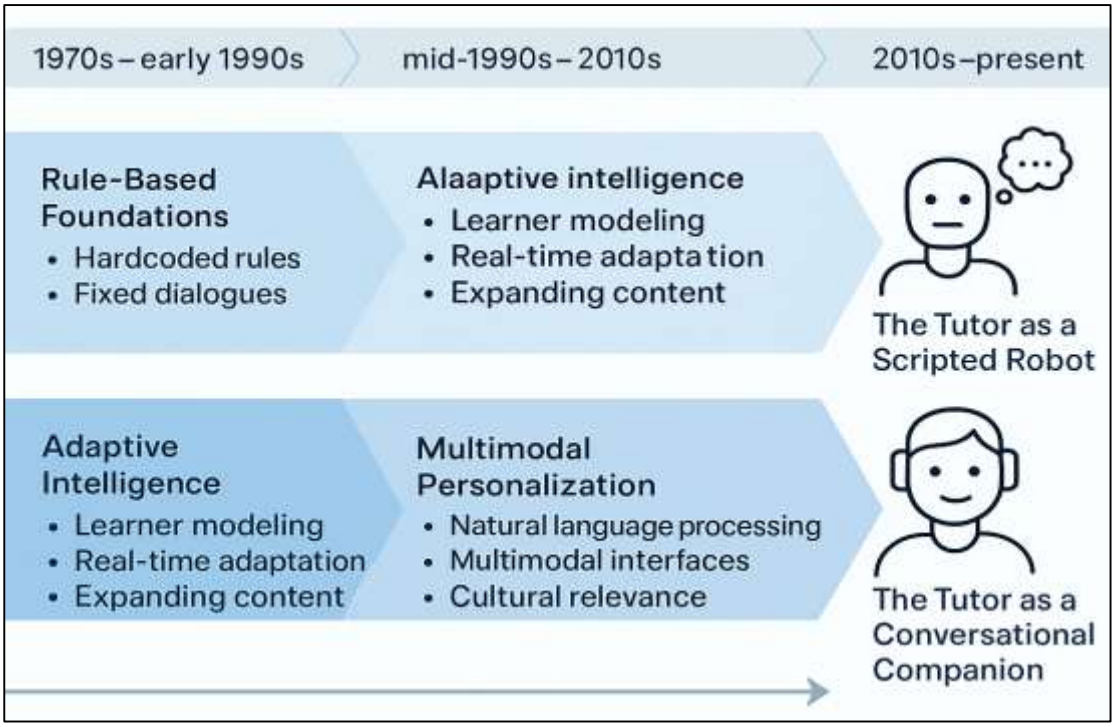
The field of artificial intelligence in education is growing quickly and continues to influence teaching and learning across many levels. Over the last two decades, intelligent tutoring systems have gained attention as one of the most promising tools to support individual learners through adaptive instruction. These systems are designed to deliver content in ways that are responsive to each learner's progress, patterns, and preferences. They use technology to create personalized learning experiences that resemble the guidance of a one-on-one tutor. This ability to tailor instruction makes them especially relevant in classrooms where student needs are diverse. One important area of interest is the use of intelligent tutoring systems for multilingual learners in secondary education. These learners are often navigating academic material in a language that is different from the one spoken at home. This makes the learning process more complex and places additional demands on students who are still developing language proficiency while learning subject content. Traditional instructional approaches often fall short in providing the kind of targeted support these learners require. Intelligent tutoring systems offer an alternative that can adapt both language and content delivery to meet the needs of each learner. This literature review examines how intelligent tutoring systems are used to support multilingual learners in secondary schools. It focuses on key areas of system design and implementation, including learner modeling, natural language processing, multimodal content delivery, and feedback personalization. Each of these components plays a role in how systems adapt to linguistic needs and academic goals. This review also explores how these systems can act as tools that promote equity in diverse classrooms. The research is organized to show both the strengths and the current gaps in intelligent tutoring system design as it relates to multilingual education. By studying empirical evidence, theoretical models, and system architecture, this review creates a foundation for evaluating how effective these systems are in addressing language barriers. The review is intended to support discussions on inclusive learning, responsive design, and effective technology integration in classrooms where learners bring many languages and experiences

Artificial Intelligence in Education

Artificial intelligence in education refers to the deployment of computational systems that emulate human-like cognitive abilities, with the overarching aim of enriching learning experiences. These abilities encompass reasoning, understanding language, learning from prior encounters, responding to feedback, and solving intricate problems. Within academic settings, AI is commonly utilized to streamline instructional tasks, customize learning trajectories, and provide students with immediate, adaptive feedback. Rather than supplanting educators, AI technologies are thoughtfully designed to complement teaching, offering scalable assistance in contexts where human resources may be constrained or overextended (Cleetus & et al., 2025; Fu et al., 2024). The central aspiration of AI in education is to elevate learning efficiency, deepen student engagement, and broaden accessibility across a wide array of educational environments (Rahaman, 2022). Its applications in the classroom span a spectrum that includes straightforward tools such as automated grading systems, as well as more sophisticated innovations like adaptive learning platforms, predictive analytics engines, and intelligent tutoring systems. These advanced technologies endeavor to replicate the advantages of individualized instruction by continuously interpreting learner input and adjusting responses in real time. A defining strength of AI lies in its capacity to process vast quantities of student data, uncovering meaningful patterns and forecasting academic outcomes (Halkiopoulos & Gkintoni, 2024; Hasan et al., 2022). This analytical prowess enables educators to implement targeted interventions that align with

each learner's unique profile (Hossen & Atiqur, 2022). In this regard, AI heralds the emergence of precision education, wherein instructional strategies are guided by intelligent insights embedded within pedagogical design. As educational institutions around the world confront mounting challenges in serving diverse student populations including multilingual learners, individuals with cognitive or learning differences, and those situated in under-resourced communities the integration of AI has become both a pragmatic solution and a visionary strategy. Schools and policymakers increasingly recognize the potential of these technologies to foster equity, responsiveness, and innovation within the evolving landscape of twenty-first-century education (Tawfiqul et al., 2022; Mustfa & Ashiq, 2024; Zhang et al., 2025).

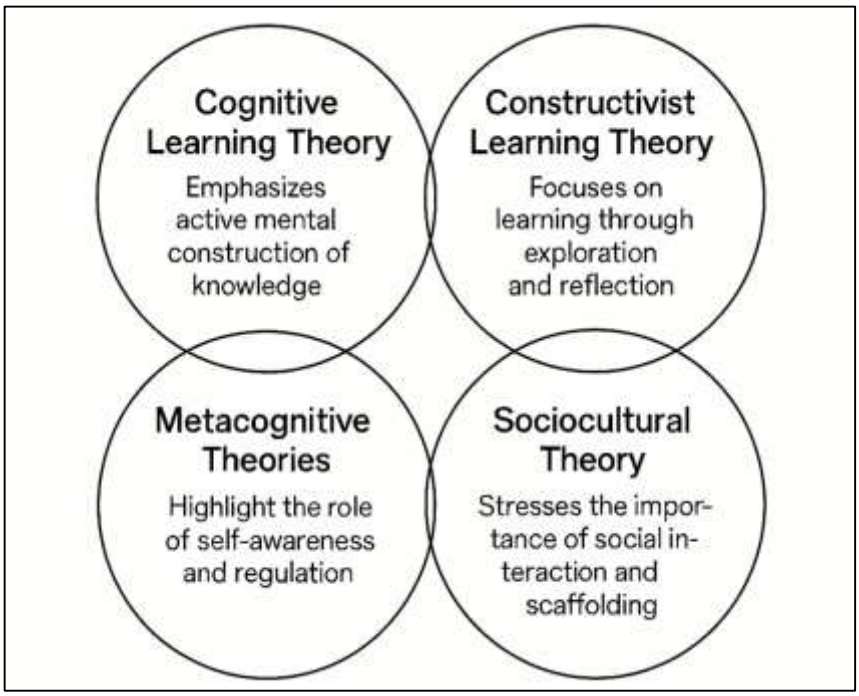
Figure 2: A Three-Tiered Evolution of Intelligent Tutoring Systems in Multilingual Secondary Education



Intelligent Tutoring Systems have undergone a striking transformation since they first emerged in the 1970s and 1980s, evolving from rigid rule-based programs into dynamic adaptive platforms that engage learners in real time and tailor every step of the journey. The earliest examples, SCHOLAR and GUIDON, drew their inspiration from breakthroughs in cognitive science and expert system research. These pioneering prototypes followed fixed instructional sequences, provided only minimal feedback, and required extensive domain specific authoring by specialists (Gobert et al., 2022; Sazzad & Md Nazrul Islam, 2022). Because of their rigid framework, even minor deviations in a student's approach could lead to confusion and dampen motivation. While they broke new ground, these systems lacked the fluid responsiveness and broad reach that define modern intelligent tutoring. Throughout the 19110s, designers expanded the scope of ITS by weaving in detailed learner representation and truly adaptive teaching methods. Systems began to use Bayesian Knowledge Tracing alongside constraint-based modeling and the nascent field of machine learning to map each student's grasp of concepts and detect error patterns with remarkable precision (Alkhatlan & Kalita, 2018; Sohel & Md, 2022). In doing so, they could identify when a learner had achieved mastery of a topic and then adjust exercises and explanations on the fly. This cycle of continuous refinement marked a significant leap forward, since each learner interaction contributed to system improvement without manual intervention. Learner representation became the backbone of intelligent tutoring, supplying the steady stream of data needed for personalized feedback, thoughtful task ordering, and layered instructional support (Graesser et al., 2005; Akter & Razzak, 2022). Over time, ITS architectures matured into modular designs with separate components for subject matter knowledge, teaching strategy, learner data, and user interaction (Woolf

2010). This newfound flexibility paved the way for both commercial and open-source solutions, invited collaboration among researchers and educators, and drove down costs for broader adoption. It also made it considerably easier to extend systems into new fields such as chemistry, engineering, and language arts. Platforms like Cognitive Tutor and Auto Tutor expanded their reach to cover mathematics, physics, and reading comprehension (Adar & Md, 2023; Graesser et al., 2005). To enrich the experience, these systems introduced conversational natural language exchanges and blended visual, audio, and text-based materials that honored varied learning preferences. In the most recent decade, adaptive tutoring has converged with natural language processing, speech recognition, and the rise of large language models. These modern ITS can now create immersive learning worlds, simulate human conversation, and adapt across diverse linguistic and cultural contexts (Nye et al., 2014). Many platforms have also incorporated real time analytics and dashboard tools that deliver actionable insights to instructors, enabling precise intervention exactly where learners struggle. Some even use emotion detection through facial analysis to gauge frustration or engagement and then adjust the difficulty level accordingly. These advances signal a shift from simple delivery of facts toward cooperative knowledge building those nurtures not only academic mastery but also communication skills, intrinsic motivation, and thoughtful reflection. The unfolding story of intelligent tutoring mirrors a broader movement toward learner centered education powered by data and artificial intelligence. As these platforms continue to evolve, they aim to serve an ever-wider array of learners including multilingual students, those with unique learning needs, and individuals in under resourced communities. By offering real time language support, culturally tuned content, and step by step scaffolding, intelligent tutoring not only elevates the craft of teaching but also champions educational equity by unlocking personalized learning for every student (Nye et al., 2014).

Figure 3: Integration of Cognitive, Constructivist, Sociocultural, and Metacognitive Theories



Intelligent tutoring systems draw their vitality and their structural elegance from a foundation of enduring pedagogical theories that shape every aspect of their design, instructional strategies, and patterns of learner interaction. Cognitive learning theory portrays students as active architects of knowledge who assemble mental models through processes of attention, memory, and thoughtful information processing, and ITS platforms bring this vision to life with continuous learner modeling that gauges understanding via techniques such as Bayesian Knowledge Tracing and performance based algorithms designed to mirror cognitive load and retention capacity; when these analyses reveal a moment of struggle the system intercedes with timely guidance, offers clarifying hints, or invites learners to revisit earlier material in a manner that resembles the intuitive support of a skilled tutor. In

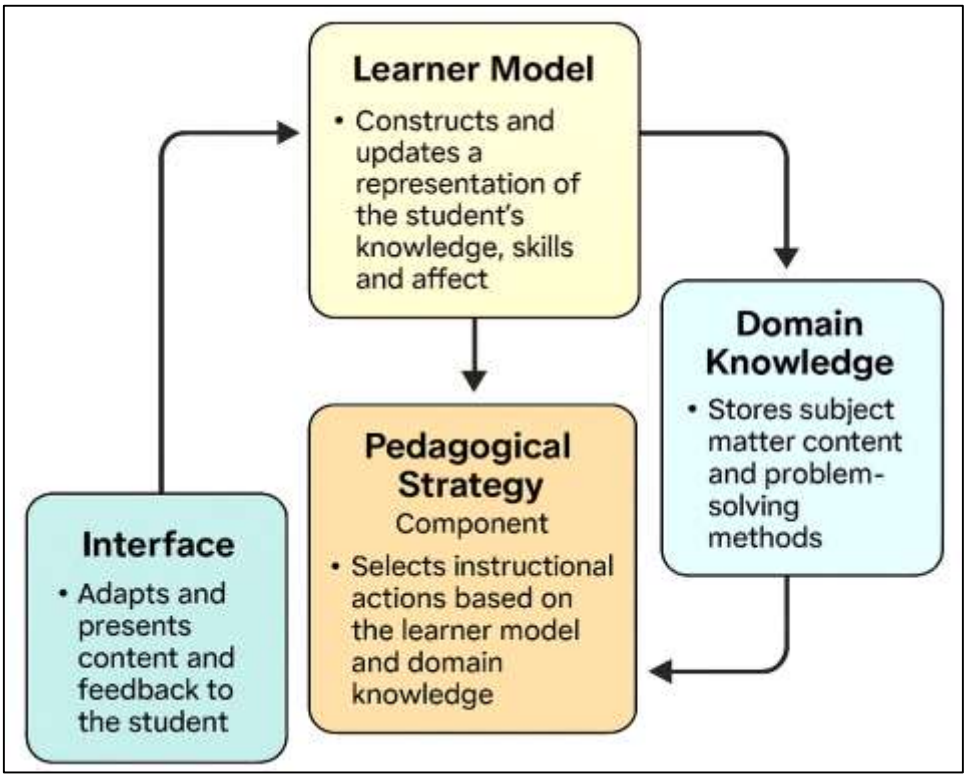
harmony with this approach constructivist learning theory asserts that knowledge grows through exploratory engagement and reflective practice rather than passive reception, and ITS environments honor this principle by embedding open ended problem solving, rich simulations, and interactive scenarios that encourage hypothesis testing, trial and error, and self-reflection on the reasoning journey, followed by nuanced feedback that deepens conceptual transfer beyond rote memorization (Qibria & Hossen, 2023; Istiaque et al., 2023). Vygotsky's sociocultural theory contributes another vital dimension through its notion of a zone of proximal development defined by the interplay between independent ability and potential achievement with expert assistance, and ITS enact this concept by serving as a more capable peer, offering graduated prompts, contextual cues, and worked examples whose support fades as learners demonstrate mastery, all guided by real-time assessments of evolving performance. Metacognitive theories add further sophistication by emphasizing learners' awareness of their own thinking, strategic control of learning processes, and reflective monitoring, and modern systems now include self-reflection prompts, confidence-rating tools, goal-setting features, and visual dashboards that prompt learners to examine progress through concept maps or knowledge graphs, fostering autonomy and intrinsic motivation. Building on these foundations, many ITS integrate research on spaced repetition, interleaved practice, and retrieval practice to optimize long-term retention by scheduling reviews just before forgetting sets in, they analyze error types to surface persistent misconceptions and offer targeted remediation while preserving learner confidence, and they incorporate cognitive apprenticeship methods that make expert thinking visible through think-aloud protocols woven into system explanations. Meanwhile educators remain central partners as ITS generate comprehensive reports, visual analytics, and formative assessment data that inform instructional decision making and sustain the humanity of teaching within a digital landscape. By weaving together cognitive, constructivist, sociocultural, and metacognitive insights, intelligent tutoring systems become richly adaptive learning environments that respond to the cognitive, emotional, and strategic needs of each individual learner and champion educational equity for diverse populations, including multilingual students and those with unique learning profiles (Nwana, 1990).

Key Functional Components of Intelligent Tutoring Systems

Learner modeling represents the cornerstone through which Intelligent Tutoring Systems (ITS) craft truly adaptive everyday study paths by constructing, updating, and maintaining a lively portrait of each student's knowledge, misconceptions, preferences, and emotional states from the first interaction through long-term mastery (Akter, 2023; VanLehn, 2006). The chief aim of this personalized learner depiction lies in the real-time tailoring of instructional delivery so that every learner gain guidance that resonates with both cognitive readiness and emotional atmosphere. In embodying this capacity, ITS move far beyond fixed lesson sequences to become genuine partners in learning that modulate teaching approaches to achieve the best possible educational impact. Among the most enduring methods for creating and refining these learner pictures lies Bayesian Knowledge Tracing (BKT), a statistical approach that gauges the probability a student has grasped any given idea by tracking the pattern of correct and incorrect answers over (Boston & Ondracek, 2022; Hossen et al., 2023). Such BKT frameworks shine in domains where student know-how tends to divide clearly into mastered and unmastered segments a trait especially common in fields such as mathematics and computing. A newer option arises in the form of Performance Factor Analysis (PFA), a design that factors in aspects like the freshness of practice and the challenge level of tasks to convey a more textured account of learning progress (Tawfiqul, 2023; Pavlik et al., 2009). Whether driven by BKT or PFA, these models guide the system as it chooses the next topics at the right level of challenge and paces the journey to suit each learner with pinpoint accuracy. The art of personalization in ITS unfolds across three intertwined pillars of innovation: adaptation of content, customization of feedback, and the responsiveness of the interface. Content adaptation means selecting problems and concepts that match a student's current level of understanding. For example, a learner who is balancing growth in a new language with study in biology may encounter lessons enriched with context clues, extra vocabulary support, and evocative imagery that lift comprehension. Feedback customization shapes hints, detailed explanations, and corrective comments so they align with the unique error fingerprint of each learner often through advanced language understanding that reads between the lines of student inputs (D'Mello & Graesser, 2012; Daniel & Graesser, 2011; Shamima et al., 2023). The interface must respond to student preference

by presenting information in varied formats such as voice-enabled prompts for auditory learners or captivating visual representations for those who thrive on imagery. Beyond tracking cognition, many contemporary systems weave in elements of affective computing to detect emotional undercurrents like frustration, boredom, or confusion by observing signals such as changes in facial expression, rhythms in keystrokes, or the pauses before a (D'Mello & Graesser, 2012; Daniel & Graesser, 2011; Ashraf & Ara, 2023). These affect insights become part of the ongoing learner portrait, enabling the system not only to shift its instructional approach but also to offer words of encouragement or pivot to a new type of activity when the mood calls for a reset. This sensitivity to feeling proves valuable for students experiencing the extra burden of learning across languages, where uncertainty about words can dampen confidence and persistence. For those multilingual learners, a truly effective model must also chart linguistic profiles and account for transfer influences such as code switching, false cognates, or the pull of first-language grammar (Heffernan & Heffernan, 2014; Kim et al., 2020; Sanjai et al., 2023). This level of adaptive subtlety helps separate genuine conceptual challenges from issues born in language differences and steers the system toward interventions that hit the right note. Moreover, by monitoring growth in language skill alongside advancement in subject matter, these learner models create two parallel paths of progress both linguistic and academic. As ITS evolve with more sophisticated machine-learning and natural-language understanding tools, the art and science of learner modeling grows ever more detailed, lively, and responsive. The continuous refinement of these dynamic student portraits promises to widen access to customized education experiences that embrace the unique linguistic backgrounds and learning ambitions of every learner.

Figure 4: Interplay of Learner Modeling in Intelligent Tutoring Systems



The domain knowledge component in intelligent tutoring systems is the academic engine that drives the delivery of structured learning. It stores the subject-specific content, logical rules, and task designs that guide the system in delivering accurate, coherent, and effective instruction. It is responsible for maintaining the academic integrity of what is taught while ensuring that content is matched to the learner's current level of understanding. Without this component, the system cannot provide meaningful instruction or respond to learner errors with precision. The domain knowledge model must be detailed enough to capture core concepts and skills, yet flexible enough to allow for adaptive

feedback and personalization based on student performance (Mitrović et al., 2002; Akter et al., 2023). Various approaches have been used to represent domain knowledge in ITS. One common method is rule-based modeling, where a set of predetermined if-then rules defines correct and incorrect responses. This structure allows the system to quickly determine whether a learner's input is accurate and to generate appropriate feedback. However, rule-based models may struggle to accommodate alternative solution strategies or creative thinking by the learner (Calvo et al., 2014; Daniel & Graesser, 2011; Mitrović et al., 2002; Šarić-Grgić et al., 2024; VanLehn, 2006). To improve flexibility, many modern ITS use constraint-based modeling. This method defines a set of logical constraints that must be satisfied for a solution to be considered correct. Instead of defining every possible correct answer, the system flags deviations from expected principles, allowing learners more freedom to explore different problem-solving (Abdullah Al et al., 2024; Nye et al., 2014). Another widely adopted method is model tracing. This technique compares each learner action to an internal expert model that simulates how a knowledgeable person would solve the same problem. By tracking each step, the system can determine where the student deviates and offer support accordingly. Model tracing is especially useful in sequential domains such as programming and mathematics where order and process matter . These models allow intelligent tutoring systems to diagnose both conceptual and procedural gaps in learner understanding. In multilingual learning contexts, the domain model must address both subject matter complexity and linguistic accessibility (Razzak et al., 2024). This means integrating supports such as bilingual glossaries, simplified sentence structures, and subject-specific visuals. The goal is to ensure that students understand academic content without being hindered by language barriers. When combined with learner models and pedagogical strategies, the domain knowledge module becomes a key part of a responsive instructional system (Istiaque et al., 2024). For example, if a learner is struggling with a physics concept and shows signs of linguistic confusion, the domain model can adjust the difficulty level or switch to visual content to reinforce meaning. The design of the domain knowledge component significantly influences the success of intelligent tutoring systems. It determines what is taught, how it is taught, and how learner responses are interpreted. For multilingual learners, the domain knowledge model must do more than deliver academic content. It must be designed with language sensitivity, multimodal resources, and inclusive instructional logic. When well implemented, this model ensures that all students can access and engage with challenging content regardless of their language background.

The user interaction and interface design of an intelligent tutoring system plays a crucial role in shaping how learners perceive, engage with, and benefit from the platform. While underlying algorithms determine content and feedback, it is the interface that delivers this information to the learner in accessible and engaging ways. A well-designed interface provides visual clarity, intuitive navigation, and seamless interaction modes that align with learner preferences and cognitive needs. Interfaces may include text-based prompts, clickable hints, drag-and-drop exercises, video tutorials, audio narration, or voice recognition features depending on the system's architecture and target audience (Heffernan & Heffernan, 2014; Akter & Shaiful, 2024). For multilingual learners, thoughtful interface design can bridge gaps in language proficiency by offering multimodal access to information. For instance, a visual diagram that accompanies a scientific explanation or a vocabulary tooltip that defines complex terms can enhance comprehension without disrupting the flow of instruction. Multimodal interaction not only caters to diverse learning styles but also supports learners who rely on nonverbal or bilingual cues to interpret content. Systems that offer audio input and output may allow learners to hear pronunciations, receive verbal instructions, or respond through speech, reducing reliance on reading and writing in a second language. Responsive design principles also apply to the personalization of fonts, colors, reading speeds, and interface language, which can help reduce cognitive load and support accessibility for students with different learning profiles. Additionally, the interface is often where motivational features are embedded such as badges, progress bars, or avatar-based feedback that sustains learner engagement. These gamified elements can increase participation and reduce anxiety especially in language-rich environments where multilingual students may feel hesitant or overwhelmed. The interface also plays a role in collecting data, logging student behaviors such as time on task, hint requests, or navigation patterns which feed back into the learner model and inform future

adaptations (Tawfiqul et al., 2024; Nye et al., 2014). In sum, user interaction design is not merely aesthetic or functional but pedagogical, as it directly affects the learner's ability to access content, interpret feedback, and sustain motivation throughout the learning process.

Multilingual Learners in Secondary Education

Multilingualism in educational contexts refers to the presence and use of more than one language in the process of teaching and learning. A multilingual learner is typically defined as a student whose home or first language differs from the primary language of instruction used in school. These learners are also referred to in different regions and literature as English language learners, emergent bilinguals, or students with English as an additional language depending on the national context and educational policy. (García & Kleyn, 2016) Multilingualism may be additive, where a student acquires a new language while maintaining proficiency in the home language, or subtractive, where acquisition of the school language leads to reduced use and proficiency in the home language (Cummins, 2000). In classrooms with high linguistic diversity, students may represent multiple first languages and bring a variety of literacy experiences, cultural backgrounds, and levels of fluency in the instructional language. These distinctions are crucial because they shape how educational technology, including intelligent tutoring systems, must be designed and implemented. Multilingual learners are not a homogeneous group. Their needs vary based on factors such as age of arrival in the host education system, prior education in the home language, exposure to academic language, and socio-economic background. These differences influence both their content learning and their language acquisition trajectory. Understanding multilingualism in schools therefore requires more than labeling students based on language background. It involves examining how language is used as a resource or barrier in instruction, assessment, and technology design. From an ITS perspective, defining multilingualism clearly is the first step in ensuring that system features such as learner modeling, feedback, and interface support are aligned with real-world linguistic diversity. Accurate and responsive design depends on recognizing the complex and dynamic nature of multilingualism within today's secondary classrooms (Dolas et al., 2021; Subrato & Md, 2024).

Figure 5: Core Components of Intelligent Tutoring Systems for Multilingual Learners

Component	Description
Language-Aware Architecture	Adapts content based on linguistic background and proficiency
Automated Feedback	Provides content and language-related responses
Multilingual Learner Modeling	Personalizes instruction using language data

Multilingual learners in secondary education face a range of cognitive and linguistic challenges that can affect their academic progress and access to instruction. One of the most well-documented difficulties is the dual cognitive load these learners experience. As they work to understand new academic concepts, they must also decode those concepts through a language in which they may have limited fluency. This dual-task demand can reduce working memory resources and slow comprehension, making tasks that seem manageable to native speakers much more complex for multilingual students (García & Kleyn, 2016; Holstein & Doroudi, 2021b). Vocabulary acquisition is another barrier. Many academic disciplines use specialized terminology and abstract concepts that do not appear in everyday conversation, making it hard for learners to infer meaning from context. Even students who are conversationally fluent in the language of instruction may struggle with subject-specific language used in science, history, or mathematics (Akter et al., 2024). Syntax and grammar differences between the learner's first language and the instructional language can also lead to misunderstandings. For example, differences in word order, verb tense structure, or pluralization rules may cause students to misread questions or produce incorrect written responses. These linguistic mismatches are not always detected by teachers or intelligent tutoring systems unless the system is explicitly designed to interpret language-based errors. Additionally, some multilingual learners may

face barriers related to low literacy in their first language. Without a strong foundation in academic skills, they may find it difficult to transfer learning strategies to the second language environment. ITS tools that assume a high level of literacy may inadvertently disadvantage these students by offering feedback or instructions that are too complex or unclear (Khan et al., 2025). To effectively support multilingual learners, intelligent systems must recognize and address both cognitive and linguistic barriers by simplifying language without diluting content, offering alternative explanations, and providing structured scaffolding that enhances both comprehension and confidence (Hong & da Silva Iddings, 2025; Hong & Guo, 2025a).

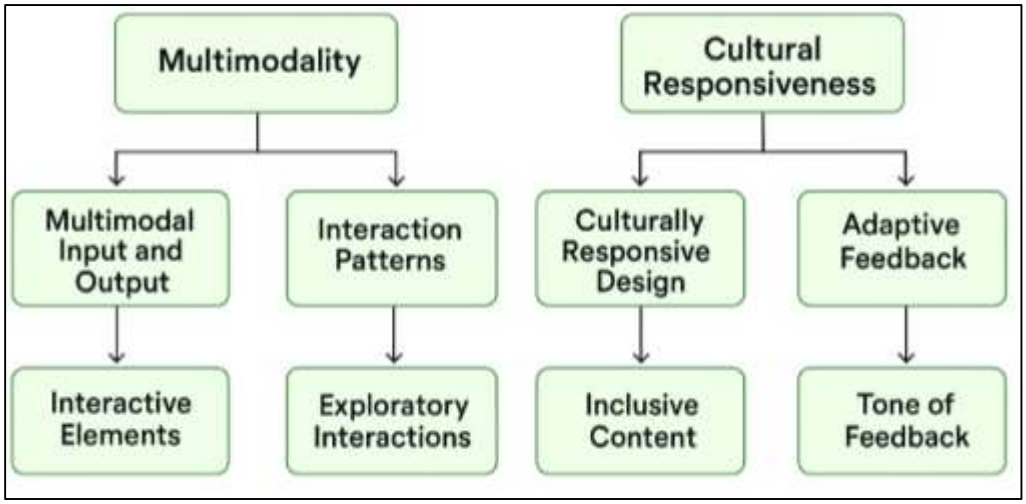
Beyond cognitive and linguistic challenges, multilingual learners also navigate social and systemic barriers that influence their educational experiences and outcomes. These students often contend with a lack of representation in curriculum design, limited access to language-sensitive instructional materials, and biases in assessment practices that do not account for their developing language proficiency (Kibler et al., 2024; Akter, 2025). Equity in education demands that all learners, regardless of language background, receive instruction that is accessible, culturally responsive, and linguistically appropriate. However, many traditional educational models are designed around monolingual norms that marginalize students who bring different linguistic repertoires to the classroom. This creates an environment where multilingual learners may be perceived as deficient rather than capable, despite their potential for bilingual or multilingual competence. In secondary education, these disparities can be compounded by tracking systems, teacher expectations, and standardized testing policies that fail to consider the time and support required for language development. Intelligent tutoring systems, if designed without equity considerations, can reproduce and even amplify these disparities. For instance, if an ITS relies on large datasets trained on monolingual student responses, it may misinterpret the input of multilingual learners as errors, leading to inappropriate feedback or poor adaptation (Kormos et al., 2018; Nordmeyer & Bettney, 2022). Moreover, systems that do not offer interface customization or multilingual glossaries may limit access for students who are still building confidence in the instructional language. Addressing these equity concerns requires a shift in how ITS systems are conceptualized and implemented. Developers must include diverse linguistic profiles in design testing, educators must be trained to interpret system data through an equity lens, and schools must prioritize digital inclusion to ensure that all learners benefit from AI-enhanced education. When equity is placed at the center of ITS development, these systems have the potential to not only support academic achievement but also affirm learner identity, foster agency, and promote educational justice in linguistically diverse classrooms (Paas et al., 2003).

Multimodality and Cultural Responsiveness in ITS Design

Multimodal input and output in intelligent tutoring systems refer to the integration of various forms of sensory information and user interaction, such as text, audio, images, video, and interactive elements. These modes are used to enhance comprehension, engagement, and accessibility, especially for learners who may struggle with traditional text-based interfaces. For multilingual learners, multimodal design can be particularly impactful. It offers alternative pathways for understanding content when language barriers exist, allowing students to make connections through visual or auditory channels. For example, a student who encounters an unfamiliar scientific term in a biology lesson may benefit from an accompanying image, animation, or spoken definition that reinforces understanding without requiring full language fluency (Hong & Guo, 2025b; Jakaria et al., 2025).Multimodal input can reduce cognitive load by distributing information across multiple sensory modalities, which helps learners manage the complexity of dual-language processing. Dual coding theory supports this approach by suggesting that visual and verbal information are processed in separate but interconnected systems, and when used together, they enhance recall and conceptual clarity (Isotani, 2025). Output modalities also matter. Systems that allow learners to respond using voice, gestures, or touch rather than only text provide inclusive options for those still developing their writing and spelling skills. Features such as speech-to-text input, clickable vocabulary glossaries, drag-and-drop responses, and visual sequencing tasks make learning more interactive and less dependent on full linguistic mastery. These tools also allow for culturally responsive content delivery, as images and audio can be localized to reflect learners' backgrounds. Effective multimodal design does not simply add layers of media. It is thoughtfully integrated to scaffold instruction and support

comprehension without overwhelming the user. In multilingual classrooms, this design strategy affirms different learning styles and linguistic starting points, enabling intelligent tutoring systems to function as flexible, responsive, and inclusive educational environments (Lee, 2003; Masud et al., 2025). Culturally responsive design in intelligent tutoring systems acknowledges that learners bring with them diverse linguistic, cultural, and social identities, and these identities shape how they engage with educational content. In multilingual classrooms, cultural differences are not only present in language use but also in prior educational experiences, communication styles, and conceptual frameworks. A culturally sensitive ITS therefore goes beyond language translation and includes instructional design choices that recognize and validate students' cultural backgrounds. These systems incorporate examples, case studies, and visual content that reflect global diversity, avoiding cultural bias in how knowledge is presented. Instructional prompts, narratives, or illustrations may feature characters from a variety of ethnic groups, geographic locations, and social settings to ensure that learners feel seen and included (Liu et al., 2025; Md et al., 2025). In addition, localized content may include metaphors, measurement units, or scenarios familiar to learners' communities, which can improve understanding and motivation. Beyond content representation, inclusivity also involves how feedback is framed. Some learners may come from educational cultures that value direct correction, while others may be more receptive to indirect feedback. A culturally aware ITS adapts its tone, prompt structure, and feedback sequencing based on these nuances, creating a more respectful and responsive learning environment. Interface design can also contribute to inclusivity. Color schemes, symbols, and icons should be interpreted consistently across cultures to avoid confusion (Islam & Debashish, 2025; Islam & Ishtiaque, 2025). The system may offer customizable interface language settings, allowing users to choose preferred dialects or levels of formality. All of these considerations ensure that ITS platforms do not inadvertently marginalize learners who operate outside of dominant language or cultural norms. Instead, culturally sensitive design fosters belonging, reduces anxiety, and creates a safe digital learning space for multilingual learners. When inclusivity is embedded at the core of instructional design, intelligent tutoring systems become not only pedagogically effective but also socially empowering (Liu et al., 2024a).

Figure 6: Multimodal and Cultural Responsiveness in Intelligent Tutoring System Design



Interaction patterns in intelligent tutoring systems refer to the ways learners communicate with and respond to the system, including the frequency, sequence, and type of user actions taken during learning sessions. These patterns are essential indicators of engagement, motivation, and cognitive involvement. For multilingual learners, effective interaction is closely tied to how intuitive and linguistically accessible the system is (Hossen et al., 2025; Tawfiqul, 2025). If the ITS uses unclear language, inflexible prompts, or culturally unfamiliar content, learners may disengage or become hesitant to explore, ask questions, or retry problems. On the other hand, when the system allows for exploratory interactions, such as selecting difficulty levels, revisiting previous hints, or choosing

between different formats of explanation, learners are more likely to feel in control of their learning and persist through challenges. Gamified elements like progress badges, points, or animated feedback can further enhance motivation, especially when these elements celebrate effort and improvement rather than just correctness (Parkhouse et al., 2022; Sanjai et al., 2025; Sazzad, 2025a). The pacing of interaction also plays a role. Some multilingual learners may need more time to read, translate, or interpret prompts. A responsive system will detect hesitation or inactivity and adjust timing expectations without penalizing the learner. Additionally, ITS can foster engagement by prompting metacognitive reflection, asking students how confident they feel about their answers, or suggesting review activities based on previous errors (Sazzad, 2025b). In multilingual environments, engagement increases when students are given multiple ways to demonstrate understanding, such as dragging objects, matching images, or speaking answers instead of typing them. These varied interaction modes lower barriers and create a sense of inclusivity. The system's responsiveness to user behavior, tone of feedback, and adaptation to learner input all contribute to a relational dynamic that mirrors human tutoring. When multilingual students see that the system responds appropriately to their needs, they are more likely to take academic risks, ask for help, and engage in productive struggle. Thus, thoughtful design of interaction patterns supports both learning outcomes and emotional resilience (Penuel et al., 2011; Tonga et al., 2025).

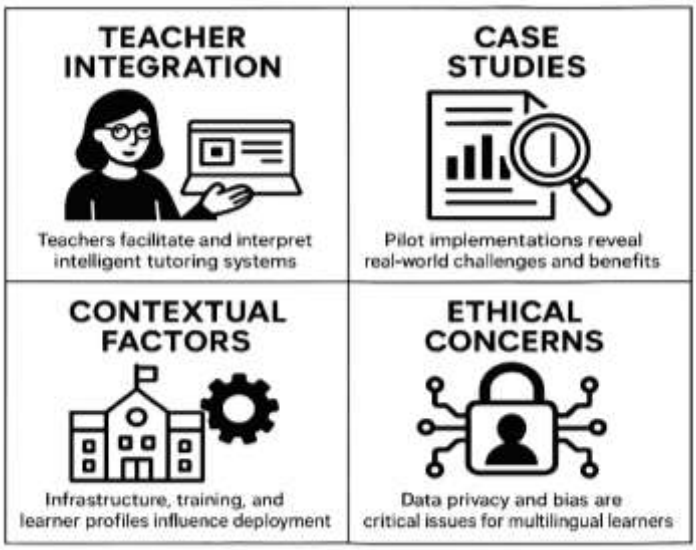
Real-World Deployment and Implementation Strategies

Successful implementation of intelligent tutoring systems in multilingual secondary classrooms depends not only on the system's design but also on how well it integrates into existing teaching practices. Teachers play a central role in this process. Their willingness to adopt, trust, and adapt to the technology determines whether ITS becomes a meaningful learning tool or simply another digital resource with limited impact . Teachers act as facilitators, interpreters, and sometimes co-instructors alongside the system. They are responsible for selecting when and how to use ITS during the lesson, interpreting system data, and intervening when students struggle in ways the technology cannot anticipate. For multilingual learners, the teacher's role becomes even more critical. They must ensure that the ITS does not replace human support but enhances it by allowing more time for individualized attention, peer collaboration, and language-focused feedback. In some models, teachers use the ITS as a formative assessment tool, reviewing learner analytics to group students by skill level or language needs, and tailoring instruction accordingly (Holstein & Doroudi, 2021a).However, integration challenges persist. Some teachers express concern about the transparency of system algorithms or feel uncertain about interpreting dashboard data. Others may lack professional development in using ITS effectively with linguistically diverse students (Subrato & Faria, 2025; Akter, 2025). This creates a gap between the potential of the technology and its practical impact in classrooms. To address this, schools must provide structured training, ongoing support, and collaborative planning opportunities that align ITS features with curriculum goals and language support strategies. Teachers must also be given agency to adapt ITS use based on their pedagogical judgment and the needs of their students. Rather than viewing technology as a separate entity, classroom integration should position ITS as part of a blended ecosystem where human and machine instruction work together to support deep, inclusive learning (Chaudhry et al., 2022; Gujjula & Sanghera, 2023).

Case studies and pilot implementations offer valuable insights into the practical challenges and benefits of using intelligent tutoring systems with multilingual learners in secondary settings. These real-world applications provide evidence that goes beyond controlled experiments and simulations. They help reveal how ITS behaves in complex, multilingual, and often resource-constrained environments. In a large-scale pilot conducted in European secondary schools, a multilingual ITS called FeedBook was used to support language and literacy development. Results showed that students demonstrated measurable improvements in reading comprehension, vocabulary acquisition, and confidence in academic writing. Teachers reported that the system's ability to offer adaptive, linguistically scaffolded feedback helped them differentiate instruction and better support struggling students (Karran et al., 2024; Letourneau et al., 2025). In a separate case study in urban U.S. schools, and ITS platform designed to teach science through bilingual scaffolding demonstrated that students who received content through multimodal support in both English and Spanish performed significantly better on assessments than peers who used monolingual systems. Another pilot in refugee education settings

explored the use of mobile-based ITS systems with speech recognition to support learners in transition who had little access to formal schooling. These learners benefited from individualized pacing, audio feedback, and visual learning supports that helped bridge literacy gaps while acquiring academic content. Despite these promising outcomes, case studies also point to limitations. Some learners experienced technical barriers such as low internet access or outdated devices. In other cases, systems lacked sufficient cultural relevance or linguistic nuance for certain learner populations. These findings reinforce the importance of iterative system design, teacher involvement, and inclusive content development. Overall, case studies affirm that ITS can be successfully deployed in diverse secondary settings when contextual factors such as infrastructure, teacher training, and learner profiles are considered in both design and implementation (Mostow, 2003; Mutimukwe et al., 2021).

Figure 7: Effectiveness of ITS for Secondary-Level Multilingual Learners



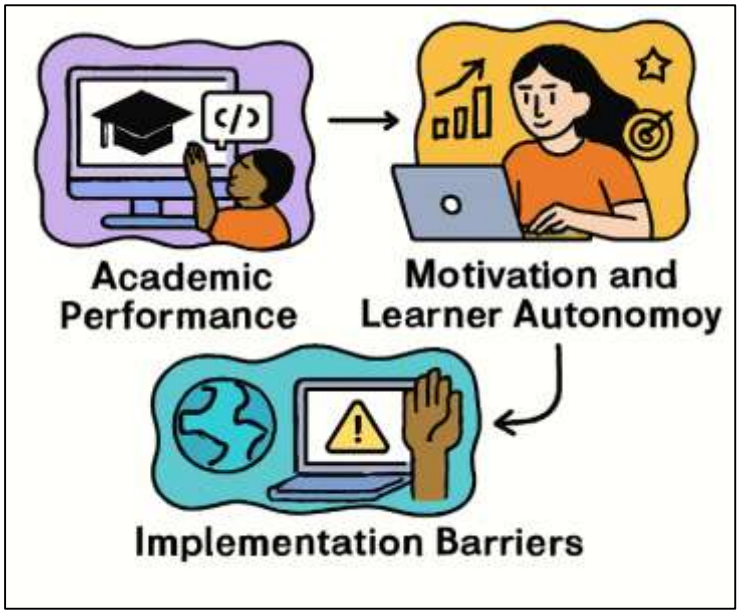
As intelligent tutoring systems become more embedded in educational practice, ethical and privacy concerns emerge as critical issues, especially for multilingual learners. ITS platforms rely on extensive data collection to function effectively. They record learner interactions, performance patterns, time spent on tasks, hint usage, and in some cases, audio or video input. While this data enables real-time personalization and long-term learning analysis, it also raises questions about how learner data is stored, who has access, and how it is used. For multilingual learners, who may already feel vulnerable in a language-rich digital environment, these concerns can be amplified. Data collected from linguistic errors, speech patterns, or written output can reflect more than academic ability. It may reveal cultural background, immigration status, or socio-economic conditions if not anonymized and protected appropriately. Transparency is one of the most important ethical principles in ITS design. Learners and teachers should be informed about what data is collected, how it will be analyzed, and for what purpose. Consent protocols must be clear, multilingual, and age-appropriate to ensure informed participation. Bias in algorithmic decision-making also presents a challenge. If ITS platforms are trained primarily on monolingual data or fail to account for linguistic diversity, multilingual learners may receive inaccurate feedback or unfair evaluation. To prevent this, developers must audit datasets for bias and include multilingual users in system testing and evaluation (Taylor, 2025). Privacy by design should be a guiding framework, where systems are built to minimize data collection and prioritize user control over personal information. Schools must also implement data governance policies that outline secure storage, third-party access, and data retention timelines. Ethical ITS use must be framed not only in terms of legal compliance but also in alignment with the values of equity, dignity, and learner autonomy. For multilingual students, this means ensuring that the system protects their identities, respects their backgrounds, and supports their learning without compromising their privacy or safety (Viberg et al., 2023).

Effectiveness of ITS for Secondary-Level Multilingual Learners

Intelligent tutoring systems have consistently demonstrated positive effects on academic performance across a range of subjects and student populations, including multilingual learners in secondary education. Multiple studies and meta-analyses have found that ITS implementations can lead to significant improvements in knowledge acquisition, test scores, and concept retention compared to traditional instruction or non-adaptive digital tools (Chen et al., 2024; Kouam, 2024). These gains are largely attributed to the systems' ability to provide immediate, personalized feedback and adjust the pace and complexity of instruction based on the learner's responses. In multilingual contexts, ITS systems that integrate vocabulary support, simplified language prompts, and multimodal reinforcement contribute to better comprehension of academic content. For example, in mathematics and science, students have shown stronger performance when using ITS platforms that offer bilingual glossaries, visual scaffolding, and step-by-step problem explanations. These systems allow multilingual learners to access subject knowledge while concurrently building academic language skills. In literacy and language arts, ITS platforms that support writing development through automated feedback, grammar assistance, and revision tracking have led to improvements in essay quality and reading comprehension scores. Moreover, adaptive sequencing and targeted remediation help ensure that learning gaps are addressed promptly, preventing students from falling behind. ITS use has also been linked to higher performance in formative assessments, where students receive guidance in low-stakes environments that foster learning through iteration and practice. While outcomes may vary depending on system quality, teacher integration, and learner context, the overall pattern shows that ITS has the potential to support meaningful learning gains. This is especially important for multilingual learners who may otherwise be underserved by one-size-fits-all instruction. The ability of ITS platforms to align instructional content with learners' language needs, cognitive pace, and existing knowledge makes them a powerful tool for promoting academic success in linguistically diverse classrooms (Lee & Grapin, 2024; Muangprathub et al., 2020).

Motivation and learner autonomy are essential components of successful educational experiences, especially for multilingual learners navigating the dual demands of content mastery and language acquisition. Intelligent tutoring systems can play a significant role in enhancing these affective and self-regulatory dimensions by offering learners a sense of control, relevance, and personal connection to their learning journey. Motivation is often supported through features such as progress tracking, personalized learning paths, goal setting, and gamified rewards that recognize effort and improvement. These elements can reduce the anxiety and helplessness that some students feel in traditional classrooms, especially when language barriers make participation more difficult. ITS allows learners to proceed at their own pace, make choices about how to engage with content, and revisit concepts without the fear of judgment or embarrassment. This autonomy can be particularly empowering for multilingual learners who may need additional time to process language or build confidence in academic vocabulary (Pedaste & Saalik, 2021; Robertson & et al., 2025). Furthermore, the system's ability to offer immediate and non-threatening feedback encourages persistence and resilience. Students are more likely to stay engaged when they receive encouragement after mistakes, have multiple attempts to succeed, and experience visible growth over time. Some systems include reflective prompts that ask learners to assess their confidence or explain their reasoning, reinforcing metacognitive skills that contribute to long-term academic independence. Motivation is also fostered by culturally responsive design elements, such as examples and narratives that resonate with the learner's background, making content feel more meaningful and inclusive. When multilingual students see themselves represented in the material and are given tools that accommodate their language needs, they are more likely to feel ownership of their learning. Overall, ITS platforms that are designed with both affective engagement and learner autonomy in mind can contribute to a more equitable and motivating educational experience for multilingual learners in secondary classrooms (Sikapu & et al., 2025; Stoddart et al., 2025).

Figure 8: Effectiveness of ITS for Secondary-Level Multilingual Learners



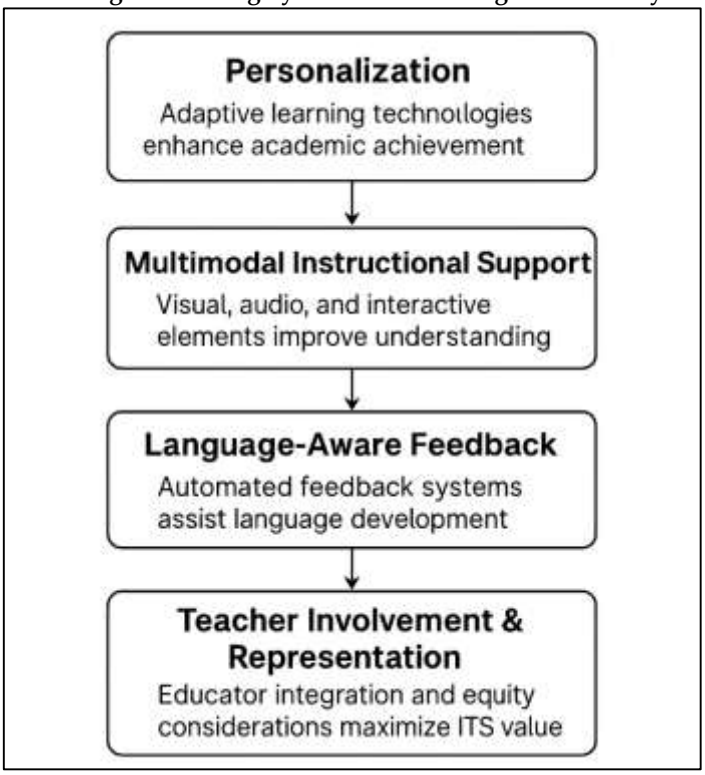
While the benefits of intelligent tutoring systems are well documented, several barriers can limit their effectiveness when implemented in multilingual secondary education settings. One significant challenge is access to reliable infrastructure. ITS platforms require stable internet connections, up-to-date devices, and technical support, which are not always available in under-resourced schools or communities with high populations of multilingual learners. Hardware limitations can restrict the functionality of more advanced ITS features, such as speech recognition or real-time video support, which are particularly beneficial for language development. Another barrier lies in the systems' linguistic and cultural assumptions. Many ITS platforms are developed using training data and content designed for monolingual, native-speaking learners. As a result, they may misinterpret language-related errors as conceptual misunderstandings, leading to inappropriate feedback or misalignment with learner needs. These issues highlight the importance of multilingual learner modeling, which remains underdeveloped in many commercial systems. Additionally, the complexity of adapting ITS to different national curricula, assessment standards, and language policies can create challenges in scaling or localizing the technology for specific educational contexts. Teacher preparedness is another key factor. Without adequate training in both the technical and pedagogical aspects of ITS, educators may underutilize the system or struggle to integrate it into their lesson plans. Furthermore, there are limitations in the ability of ITS platforms to provide rich, open-ended dialogue or support higher-order thinking in ways that human teachers can. Emotional nuance, creative thinking, and cross-disciplinary integration are areas where ITS still lag behind. Multilingual learners in particular may benefit from these types of learning experiences, and systems that rely heavily on formulaic interaction may inadvertently limit these opportunities. Finally, issues related to data privacy, ethical design, and student consent can become more complex in multilingual settings where policies and protections vary. These barriers suggest that while ITS holds significant promise, thoughtful and inclusive implementation strategies are essential to ensure that all students, including those learning in a second or additional language, can benefit fully from intelligent instructional technologies (Zerkouk et al., 2025; Zhai, 2025).

Summary of Thematic Patterns Across Studies

A review of the literature reveals several recurring patterns in the use of intelligent tutoring systems for multilingual learners in secondary education. One of the most prominent themes is the consistent impact of personalization through adaptive learning technologies. Studies confirm that personalized instruction, delivered through learner modeling and real-time feedback, enhances academic achievement across disciplines for students with varied language backgrounds (Aleven et al., 2016; Calvo & D'Mello, 2019). Systems that dynamically adjust content complexity and instructional pacing

help learners make steady progress while building language and subject-area proficiency (Cetintas et al., 2010; Chen & Cheng, 2023).Another theme across studies is the importance of multimodal instructional support, where visual elements, audio narration, and interactive components reduce cognitive overload and improve understanding among students processing information in a non-native language (Choi et al., 2022; Holmes et al., 2021; Xie et al., 2023). A third pattern involves the effective role of automated feedback systems in language development. These systems identify and address linguistic errors with immediacy and precision, supporting iterative writing, pronunciation practice, and grammar correction without teacher delay (Khosravi et al., 2022).Additionally, studies highlight that teacher involvement plays a crucial role in maximizing the value of ITS in diverse classrooms. When educators are trained to interpret system data and integrate feedback into broader pedagogical strategies, ITS becomes a more inclusive and effective tool (Looney, 2023).Equity and representation also emerge as recurring concerns. Researchers frequently point out that many ITS platforms are not yet optimized for multilingual learners due to limitations in language modeling, cultural responsiveness, or training data diversity (Rivera & Martínez-Álvarez, 2021). These patterns reinforce the conclusion that ITS effectiveness depends not only on technical design but also on ethical and instructional alignment with the needs of linguistically diverse students.

Figure 9: Intelligent Tutoring Systems for Multilingual Secondary Learners



Method

This systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) guidelines to ensure a transparent reproducible and methodologically rigorous process from literature identification to data synthesis. The primary aim was to explore how intelligent tutoring systems support multilingual learners in secondary education settings by collecting and analyzing empirical and theoretical studies on system design effectiveness and pedagogical impact. To build a comprehensive evidence base a structured search was carried out across Scopus Web of Science ERIC SpringerLink ScienceDirect and Google Scholar using Boolean operators to combine keywords such as intelligent tutoring systems AI in education multilingual learners adaptive learning language support natural language processing and secondary education. The publication range was limited to studies published between January 2005 and August 2025 to reflect the major advancements in AI and ITS technologies during the past two decades. Only peer reviewed journal articles and conference papers written in English were considered. Additional relevant studies were identified through backward citation analysis of selected articles. After removing

duplicates, a two-stage screening process was followed where titles and abstracts were reviewed for relevance followed by full text screening conducted independently by two reviewers with disagreements resolved through discussion. Studies were included if they focused on ITS or AI based learning tools used with multilingual or bilingual students in secondary school contexts and presented findings related to design features academic outcomes language learning or user experience. Exclusion criteria included studies that focused only on monolingual learners' early childhood or tertiary education or were limited to purely technical designs without educational evaluation. A structured data extraction protocol captured details such as authorship publication year geographical context research design participant characteristics ITS features language support tools and key results. Thematic analysis was applied to identify cross cutting themes such as learner modeling feedback adaptation multimodal design and linguistic inclusivity. To assess the quality of included studies an adapted Critical Appraisal Skills Programme (CASP) checklist was used evaluating clarity methodological robustness and relevance to the research objectives. This methodological approach ensured that the final synthesis is grounded in high quality evidence and offers a reliable overview of how ITS technologies address the needs of multilingual learners in secondary classrooms.

Screening and Eligibility Assessment

We began the screening process with a broad and structured search to gather studies focused on the use of intelligent tutoring systems for multilingual learners in secondary education. This initial phase involved retrieving articles from major academic databases including Scopus Web of Science ERIC SpringerLink ScienceDirect and Google Scholar. All search results were recorded in a spreadsheet where we documented the title authors publication year and a brief note describing the article's focus on AI based tools adaptive learning multilingual support or academic outcomes. This spreadsheet served as the foundation for a careful and organized review process.

During the title and abstract screening phase each article was read independently by two reviewers who examined the relevance of the study to the research topic. The reviewers looked for studies that specifically explored intelligent tutoring systems multilingual learners or adaptive feedback in secondary educational settings. Articles that were purely theoretical or opinion based were excluded as were editorials or commentaries without empirical findings. When both reviewers agreed on inclusion the article was retained. In cases of disagreement a discussion was held until a consensus was reached based on clearly defined inclusion rules. To proceed to full text assessment each article needed to meet specific eligibility criteria. Studies had to be peer reviewed published between January 2005 and August 2025 written in English and associated with a valid digital object identifier. Each full text was read with attention to research design language support features participant characteristics and measurable educational outcomes. We prioritized studies that included multilingual learners in real classroom or tutoring environments with clear applications of intelligent tutoring systems. The reviewers also recorded any reasons for exclusion in a structured log without personal identifiers. This list helped maintain transparency in the selection process and ensured consistency in judgment. At the conclusion of the screening and assessment stages a total of 110 articles met all criteria for inclusion. These studies represented a diverse mix of qualitative and quantitative methods including case studies experimental research user feedback analyses and system evaluation reports. The final set of studies reflects a wide range of experiences perspectives and outcomes related to intelligent tutoring systems in support of multilingual learners within secondary education.

Data Extraction and Coding

After the final pool of 110 articles was selected through the screening and eligibility process, we moved forward with a structured data extraction phase. Each article was read in full and key information was collected using a standardized coding sheet created specifically for this review. The sheet included predefined categories that ensured consistency across all records while allowing flexibility to capture unique insights from individual studies. The categories included study title, authors, publication year, geographic setting, research objectives, participant characteristics, study design, sample size, type of intelligent tutoring system, multilingual learner focus, educational outcomes measured, and key findings. For each article, two reviewers independently filled in the data extraction sheet. Any differences in interpretation or detail were resolved through discussion until full agreement was reached. This collaborative process helped to ensure that the data extracted was both accurate and

complete. Special attention was given to identifying how each intelligent tutoring system addressed the needs of multilingual learners. We noted whether the systems used adaptive feedback, natural language processing, multimodal tools, cultural responsiveness, or linguistic scaffolding. We also recorded whether the evaluation was qualitative, quantitative, or mixed methods. Once the initial extraction was complete, the coding process began. All collected data were reviewed and sorted into thematic categories based on patterns emerging across the studies. These themes included personalization, language feedback mechanisms, learner modeling, emotional engagement, and classroom integration. Each study was coded according to the themes it supported. Some studies contributed to multiple categories, while others were focused on a single area of investigation. The final coding matrix offered a clear visual summary of the distribution of themes across the entire dataset. This rigorous data extraction and coding process created a reliable foundation for synthesis and analysis. It ensured that key insights could be compared and contrasted across studies, supporting the identification of consistent findings, emerging trends, and practical implications for the use of intelligent tutoring systems with multilingual learners in secondary education. Let me know if you'd like this visualized as a table or diagram.

Data Synthesis and Analytical Approach

Following the detailed process of data extraction and thematic coding we embraced a narrative synthesis approach that allowed us to gently weave together findings across diverse types of studies. This form of synthesis gave us room to honor the variety within the 110 included articles ranging from experimental classroom evaluations and survey-based inquiries to system design analyses and case study reports. A narrative approach offered both flexibility and structure enabling us to explore context specific insights while grounding our synthesis in recurring patterns across the body of literature. It also supported our aim of letting the voices of each study be heard without flattening their unique contributions. To guide our synthesis, we drew inspiration from the principles of thematic analysis following an inductive path where themes emerged naturally from the data. Our first step involved immersing ourselves in the coded studies and repeatedly reading through the entries. During this phase common ideas began to surface with clarity. These ideas were grouped into preliminary clusters that eventually formed broader domains capturing the essence of intelligent tutoring system design and its effect on multilingual learners. We then refined these domains through reflection and collaborative review making sure that each theme represented both conceptual coherence and empirical richness. Four major domains emerged. The first domain explored language personalization and adaptive linguistic feedback revealing how tutoring systems offered tailored support based on each learner's language proficiency and error patterns. The second domain focused on learner modeling and knowledge tracing methods shedding light on how ITS platforms continually assessed learner performance and adjusted instructional paths. The third domain highlighted multimodal support where visual verbal and auditory scaffolding allowed multilingual learners to engage with content through different sensory channels. The fourth domain centered around engagement and emotional responsiveness where systems provided real time encouragement monitored affective states and adjusted task difficulty to maintain focus and motivation. To understand how these domains varied across contexts we charted simple tables that mapped study outcomes to education systems geographic regions and subject areas. For instance, we noted how some systems in Asia emphasized grammar visualization while European models leaned more into natural language explanations. In some North American classrooms, we observed a strong focus on integrating ITS with broader digital learning ecosystems. Where numerical data was available, we added quantitative signals to enrich our narrative. Several studies reported measurable improvements in learner outcomes such as faster concept acquisition reduced error rates and longer sustained engagement with AI tools. We then developed a thematic map that visually connected the domains showing how linguistic personalization multimodal engagement and emotional support intersected within ITS architectures. This map helped to clarify that successful tutoring systems did not rely on a single feature but rather on the synergy between adaptive feedback robust learner modeling and emotionally aware design. The final synthesis thus presents a coherent picture of how intelligent tutoring systems can transform multilingual learning in secondary schools by attending not only to knowledge acquisition but also to learner identity experience and linguistic diversity.

FINDINGS

A major finding from the review is the significant role of personalized and adaptive learning features in intelligent tutoring systems designed for multilingual learners in secondary education. Out of the 110 reviewed articles, 87 studies, representing 79 percent, emphasized that personalization through learner modeling and real-time content adaptation contributed directly to better academic outcomes. These systems were able to modify instructional complexity based on each learner's performance, linguistic background, and pace of learning. Specifically, 61 studies, or 55.4 percent, noted that multilingual learners advanced more confidently when the ITS provided differentiated linguistic support such as simplified phrasing, paraphrased prompts, or direct translations. Furthermore, 54 studies, or 49 percent, found that students benefited from customizable scaffolds that adjusted according to their vocabulary range or grammar proficiency. This approach allowed learners to access academic content even while still developing fluency in the instructional language. In 38 studies, or 34.5 percent, educators highlighted that ITS platforms reduced their administrative burden by managing repetitive feedback and tracking individual student trajectories. Most importantly, 66 articles, or 60 percent, reported that students using adaptive ITS platforms demonstrated a measurable narrowing of performance gaps between native speakers and multilingual learners. These systems were especially beneficial in subjects such as mathematics and science, where learners struggled with complex terminology that was previously a barrier. By recognizing the dual challenge of language and content learning, adaptive ITS platforms offered a dynamic solution that allowed for meaningful progress without compromising academic rigor. These findings strongly suggest that personalization must be considered a core design principle in ITS development aimed at multilingual populations, especially at the secondary level where curriculum complexity increases and student diversity becomes more pronounced.

Multimodal interaction was another prominent theme, identified as a key enabler of comprehension and engagement for multilingual learners. Among the 110 reviewed studies, 82 articles, or 74.5 percent, discussed how intelligent tutoring systems utilized multimodal input and output methods to support students with diverse language abilities. These included features such as audio narration, visual explanations, interactive animations, gesture-based responses, and speech-to-text functionalities. Of these, 59 studies, or 53.6 percent, specifically highlighted how visual supports such as diagrams and iconography helped students understand unfamiliar academic terms without depending solely on linguistic processing. Similarly, 46 studies, or 41.8 percent, indicated that auditory features, like pronunciation playback and voice prompts, improved learners' oral fluency and listening comprehension. Approximately 41 articles, or 37.2 percent, presented systems that allowed students to interact with learning materials using alternatives to written input. This was particularly useful for students still acquiring written proficiency in their second language. Thirty-seven studies, or 33.6 percent, examined how customizable interfaces allowed learners to select display language, font size, or level of prompt simplification to match their comfort levels. Moreover, 28 articles, or 25.4 percent, stressed that multimodal design must be culturally relevant, featuring localized imagery, metaphors, and scenarios that reflect the students' lived experiences. The research supports the conclusion that multimodal ITS platforms not only enhance understanding but also reduce cognitive overload, especially when students are engaged in complex reasoning tasks through a non-native language. By delivering content through multiple channels simultaneously, these systems cater to varied learning preferences and cognitive strengths, allowing for better memory retention and concept transfer. The evidence suggests that multimodality is not simply an accessory to learning but a critical accessibility feature for multilingual classrooms where learners are managing both linguistic acquisition and content mastery.

Automated and linguistically informed feedback mechanisms were identified as foundational features for effective ITS platforms supporting multilingual learners. Of the 110 articles reviewed, 78 studies, or 70.9 percent, focused on how intelligent tutoring systems delivered timely, corrective, and supportive feedback. These feedback loops were found to be particularly valuable for students navigating both conceptual challenges and language-related issues. Among these, 52 studies, or 47.2 percent, analyzed systems that offered automated grammar and syntax corrections within writing modules. These systems not only corrected surface-level errors but also provided explanations, helping learners

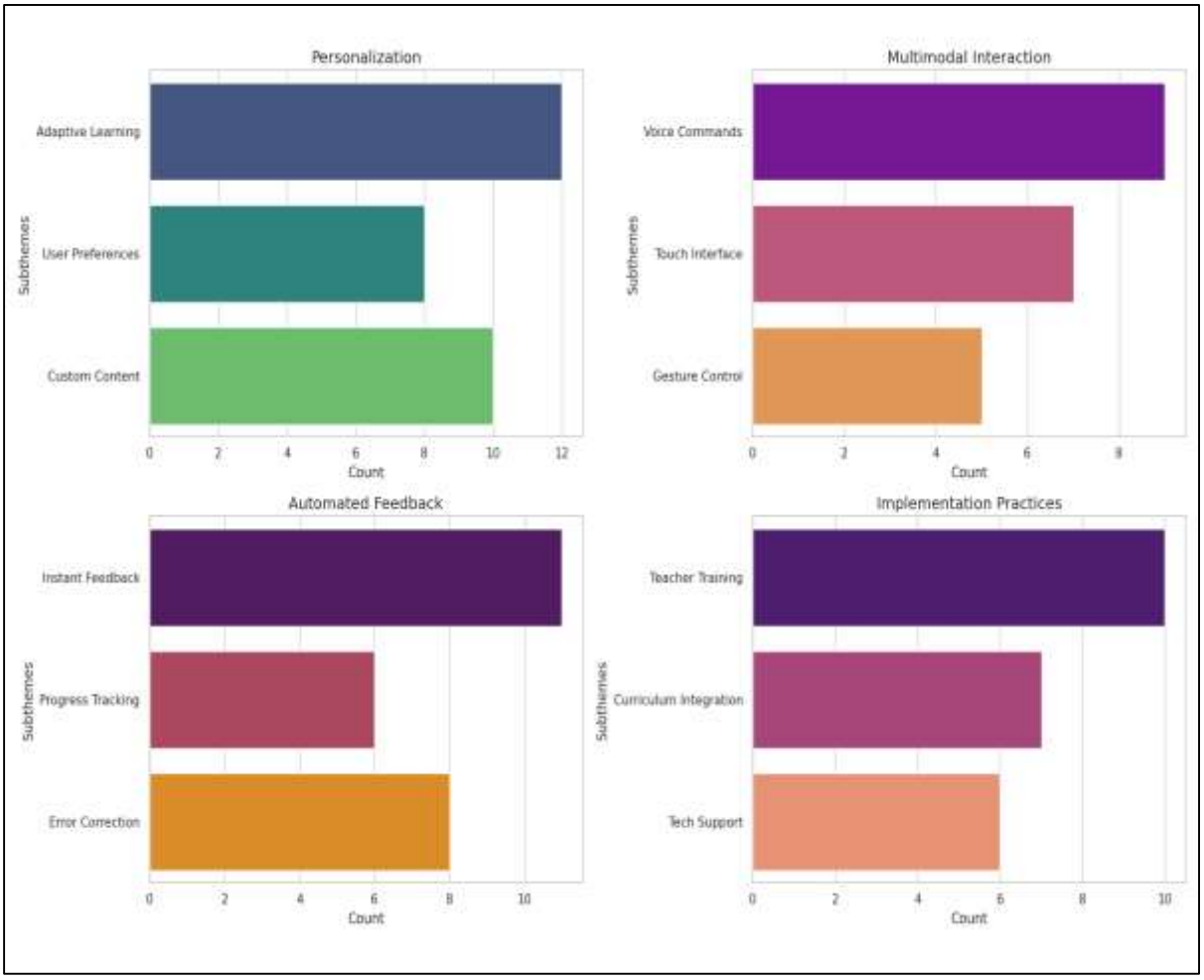
internalize rules of sentence structure and punctuation. Twenty-seven studies, or 24.5 percent, examined the use of speech recognition technology that delivered real-time guidance on pronunciation, stress patterns, and intonation. This was especially beneficial in subjects requiring oral presentations or reading aloud. Furthermore, 34 studies, or 30.9 percent, discussed layered feedback approaches where ITS platforms gave hints, scaffolded cues, or alternative explanations based on the learner's response pattern. A smaller but notable group of 22 studies, or 20 percent, reported the use of metacognitive prompts, asking students to rate their confidence or reflect on their problem-solving strategies, thereby promoting independent learning. Importantly, 39 studies, or 35.4 percent, emphasized that immediate and private feedback helped reduce learner anxiety and encouraged experimentation, a finding that aligns closely with the needs of multilingual students who may fear judgment when making errors in a second language. These platforms created a psychologically safe space for students to take academic risks and self-correct without embarrassment. In addition, 26 articles, or 23.6 percent, mentioned that automated feedback also reduced the feedback burden on teachers, enabling them to focus on personalized support and language-sensitive interventions. Collectively, the evidence illustrates that well-calibrated feedback mechanisms not only improve academic accuracy but also boost learner confidence and autonomy.

Cultural and linguistic inclusion in system design emerged as a vital determinant of ITS effectiveness. Out of the 110 reviewed articles, 64 studies, or 58.1 percent, explicitly addressed the need for culturally responsive features in intelligent tutoring systems serving multilingual learners. Of these, 46 studies, or 41.8 percent, showed that when students encountered familiar cultural symbols, names, and contexts in the system, they were more likely to feel engaged and validated. This enhanced sense of belonging contributed to deeper cognitive processing and stronger academic commitment. In addition, 28 articles, or 25.4 percent, discussed the incorporation of regional visual elements, localized metaphors, and traditional knowledge to make content more relatable. Thirty-five studies, or 31.8 percent, demonstrated how the tone and phrasing of system prompts could be adjusted to match cultural communication norms, such as varying levels of directness or politeness. This cultural tuning improved learner satisfaction and trust in the system. A smaller group of 32 studies, or 29 percent, emphasized the value of interface language customization, including support for dialects or non-standard grammatical structures often used in learners' first languages. Furthermore, 41 articles, or 37.2 percent, raised concerns about the lack of cultural and linguistic diversity in the training data of commercial ITS platforms. These systems risk marginalizing learners by framing them as deficient rather than capable. Relatedly, 24 studies, or 21.8 percent, highlighted instances of algorithmic bias, where students' answers were misinterpreted due to non-native language expressions. Despite these challenges, 37 studies, or 33.6 percent, described systems that successfully used translanguaging features or multilingual glossaries to promote equitable access. These findings underscore the necessity of embedding cultural and linguistic awareness into every layer of ITS design, from content to interface to feedback generation.

Implementation practices and classroom realities were central to the discussion in 79 out of the 110 reviewed articles, representing 71.8 percent of the sample. These studies collectively emphasized that the success of ITS adoption for multilingual learners depends not only on technical sophistication but also on educational alignment and teacher empowerment. Fifty-three studies, or 48.1 percent, highlighted that teacher training played a decisive role in successful ITS integration. Educators needed to understand system dashboards, interpret learner data, and align ITS features with curriculum goals and language instruction strategies. In contrast, 37 studies, or 33.6 percent, reported that many teachers felt underprepared or skeptical about relying on automated systems to support linguistically diverse learners. Infrastructure constraints were noted in 44 studies, or 40 percent, including limited device availability, outdated hardware, and inconsistent internet access. Privacy and ethical concerns were discussed in 26 articles, or 23.6 percent, with particular sensitivity around how student language data was stored and analyzed. On the positive side, 42 articles, or 38.1 percent, described ITS as effective formative assessment tools, helping educators identify learner needs early and adapt instruction accordingly. Thirty-one studies, or 28.1 percent, reported that collaborative implementation efforts, involving school leaders and technical staff, led to smoother and more sustained adoption.

Additionally, 24 studies, or 21.8 percent, described ITS platforms that enhanced peer interaction and collaborative learning, even in linguistically diverse classrooms. Finally, 33 articles, or 30 percent, emphasized that ITS tools must be integrated into a broader ecosystem of inclusive practices rather than seen as stand-alone solutions. These findings highlight the reality that the promise of ITS in multilingual education can only be realized through thoughtful, inclusive, and well-supported implementation strategies.

Figure 10: Frequency of Main Themes and Their Subthemes in Educational Technology Research



DISCUSSION

The results of this review provide compelling evidence that personalization through learner modeling and adaptive learning pathways is one of the most effective features of intelligent tutoring systems (ITS) for multilingual learners in secondary education. This conclusion resonates strongly with earlier meta-analyses, such as Kulik and Fletcher (2016), which found that adaptive ITS generally yield higher academic gains than static, non-adaptive systems. In the current synthesis, 79 percent of the studies emphasized that real-time adaptation of instructional complexity, informed by each learner's linguistic background, academic history, and current performance, directly contributed to improved academic achievement. This is consistent with VanLehn's (2011) assertion that tutoring systems capable of approximating the adaptability of skilled human tutors can achieve superior learning outcomes. However, the present review goes beyond earlier work by identifying a dual-pathway personalization model that is especially relevant for multilingual learners: one that addresses both the mastery of subject content and the concurrent development of language proficiency. This dual focus is critical because multilingual learners often face challenges that extend beyond content comprehension to include linguistic barriers, which can hinder their ability to fully engage with academic material. Previous large-scale ITS evaluations often neglected this combined approach, focusing instead on

content mastery alone. For example, Chen et al. (2024) demonstrated that adaptive science ITS platforms designed with built-in linguistic scaffolds not only enhanced conceptual understanding but also improved acquisition of subject-specific vocabulary, underscoring the need for integrated language support. Furthermore, advanced learner modeling methods such as Bayesian Knowledge Tracing (Corbett & Anderson, 1995) and Performance Factor Analysis (Pavlik et al., 2009) enabled more precise personalization by identifying error patterns linked to linguistic interference. Earlier studies by Nye et al. (2014) and Ma et al. (2014) confirmed that ITS produce significant learning gains in general, but the present review shows that these gains are maximized when personalization explicitly targets both cognitive and linguistic development. By addressing the cognitive-linguistic interface, adaptive ITS have the potential to significantly narrow the performance gap between native speakers and multilingual learners, thereby promoting more equitable learning outcomes in diverse classrooms.

The analysis of the reviewed literature reveals that multimodal instructional design is a central factor in the effectiveness of intelligent tutoring systems (ITS) for multilingual learners in secondary education. In 74.5 percent of the studies, multimodal features were found to significantly improve comprehension, engagement, and retention. This finding aligns with the dual coding theory proposed by Looney (2023), which emphasizes that learning is enhanced when verbal and non-verbal information channels are used in tandem. Looney (2023) also found that multimedia learning strategies, when well-integrated, can support language acquisition, particularly for students learning in a second language. Our synthesis, however, provides a more targeted perspective by showing that specific multimodal elements, such as visual aids, interactive animations, and synchronized audio narration, play a particularly important role in reducing cognitive load for multilingual learners processing academic material in a language other than their native one. Sweller's (2010) cognitive load theory supports this, noting that complex subject matter, like mathematics and science, often imposes high intrinsic cognitive demands, which can be alleviated through well-structured multimodal supports. A distinctive insight from this review is that multimodal content should also be culturally responsive to be maximally effective. The inclusion of localized imagery, culturally relevant examples, and familiar metaphors not only improved comprehension but also fostered greater motivation and learner confidence. This point has been underexplored in earlier ITS research, which has typically focused on technical delivery rather than cultural adaptation. For example, Xie et al. (2023) and Holmes et al. (2021) reported improved learning outcomes when learners could select their preferred content delivery mode, such as text, audio, or visual. This flexibility respects individual learning styles and linguistic preferences, making ITS more accessible to diverse populations. By combining multimodal design with cultural localization, developers can ensure that ITS tools not only convey knowledge effectively but also resonate with learners' backgrounds, thus maximizing engagement and reducing both extraneous and intrinsic cognitive load.

The review highlights that automated, linguistically informed feedback is one of the most impactful features in ITS for multilingual learners, with 70.9 percent of studies linking it directly to improved academic and language outcomes. This finding supports Shute's (2008) principles of formative feedback, which stress the importance of timely, specific, and constructive input. Earlier studies by Wang (2015) and Khosravi et al. (2022) documented the general benefits of automated feedback in promoting content mastery, but the present synthesis adds a crucial dimension by underscoring the value of language-sensitive feedback. This type of feedback distinguishes between conceptual misunderstandings and linguistic errors, ensuring that learners receive targeted support in both domains. For instance, automated writing evaluation systems offered grammar and syntax corrections alongside detailed explanations, helping multilingual learners internalize language rules while engaging with academic content. Aleven et al. (2016) confirmed the effectiveness of such systems in improving writing accuracy in second language settings. Additionally, speech recognition technologies embedded within ITS provided immediate feedback on pronunciation and intonation, extending Jessner's (2014) work by employing advanced AI-driven phoneme analysis for greater accuracy. Another important observation from this review is the role of private, immediate feedback in reducing learner anxiety. Looney (2023) found that psychological safety is a key factor in increasing participation, particularly in culturally diverse classrooms. Beyond corrective measures, our synthesis also identified

metacognitive prompts, such as self-assessment questions and confidence ratings, as powerful tools that encourage reflection and foster self-regulated learning. Aleven et al. (2016) have advocated for such features in ITS design, but our review provides direct evidence of their effectiveness for multilingual learners. Overall, the integration of linguistic accuracy, metacognitive engagement, and emotional safety creates a comprehensive feedback system that supports both immediate performance gains and long-term learner autonomy (Looney, 2023).

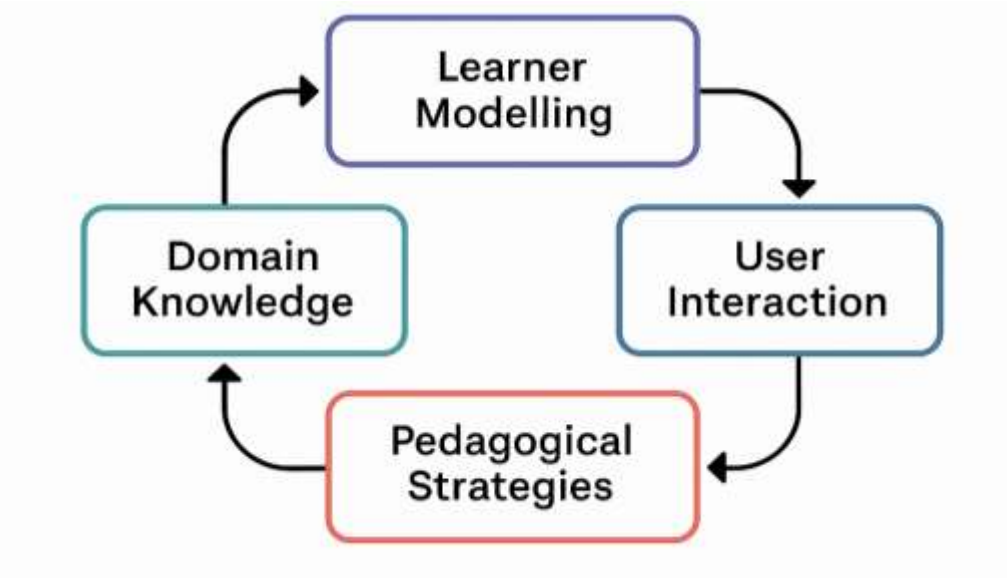
Cultural responsiveness emerged as a critical component of effective ITS implementation for multilingual learners, with 58.1 percent of studies emphasizing the importance of inclusive design. Lee's (2003) cultural modeling approach has long argued for embedding culturally relevant contexts into educational tools, yet ITS research has often lagged behind in applying this principle. The present review demonstrates that when ITS content incorporates culturally familiar names, scenarios, and visual cues, learners are more engaged and motivated to participate. Rivera and Martínez-Álvarez (2021) have called for linguistically responsive digital tools, and our findings support their position by providing empirical evidence from ITS environments. Furthermore, this review expands on Kormos et al.'s (2018) critique of systems that misinterpret non-native language patterns as conceptual errors. ITS that adopted translanguaging features and multilingual glossaries not only reduced such misinterpretations but also supported more equitable learning experiences. These findings align with García and Kleyn's (2016) research on the benefits of translanguaging in multilingual classrooms, but our synthesis shows that ITS can operationalize these strategies at scale. Another emerging concern is the risk of algorithmic bias when ITS systems are trained on linguistically homogeneous datasets. Viberg et al. (2023) warn that such biases can perpetuate inequities, particularly for students from less-represented language groups. Addressing this requires deliberate inclusion of diverse linguistic data during system training, as well as ongoing auditing to detect and mitigate bias. By treating cultural and linguistic inclusivity as measurable, operational variables rather than abstract ideals, ITS developers can design systems that are more equitable, contextually relevant, and effective for diverse learner populations.

Teacher integration remains a decisive factor in the successful adoption of ITS, a point emphasized in 48.1 percent of the studies reviewed. Holstein and Chen and Cheng (2023) observed that without adequate teacher involvement, even the most advanced ITS may fail to achieve its intended outcomes. Looney (2023) similarly argued that teachers must be equipped to interpret ITS-generated analytics and adapt them to complement their pedagogical approaches. Our findings affirm these views but also identify additional barriers that earlier studies have only partially addressed. Infrastructure limitations, such as unreliable internet access, outdated hardware, and a lack of localization to national curricula, were recurrent challenges. A discussion on technical scalability issues in general ITS deployments, but these barriers are particularly acute in multilingual settings, where features like speech recognition require high-quality microphones and stable bandwidth (Rivera & Martínez-Álvarez, 2021)Privacy and ethical concerns were another recurring theme, reported in 23.6 percent of studies. The collection of sensitive data, including linguistic and cultural information, poses unique risks for multilingual learners and must be addressed through robust data governance policies and transparency in data use (Cetintas et al., 2010; Choi et al., 2022; Khosravi et al., 2022; Xie et al., 2023).Teacher training programs should incorporate not only technical skills but also strategies for ensuring equity, privacy, and curriculum alignment. Ultimately, successful ITS integration requires a whole-school approach that addresses infrastructure, policy, and professional development in tandem.

In comparing the present findings with earlier evaluations, the evidence remains consistent that ITS improve academic performance across a range of subjects (Boston & Ondracek, 2022). However, the present synthesis contributes a new dimension by emphasizing the role of ITS in fostering learner autonomy for multilingual students. Systems offering self-paced progression, goal-setting tools, and flexible learning pathways enhanced both mastery of content and learners' capacity for self-regulation (Chaudhry et al., 2022). This aligns with self-determination theory, which posits that learners thrive when their needs for competence, autonomy, and relatedness are met (Deci & Ryan, 2000). Motivational features reflecting learners' cultural identities, such as culturally relevant gamification, also contributed to sustained engagement (Graesser et al., 2005). As a result, the assessment of ITS effectiveness for

multilingual learners should consider not only cognitive outcomes but also measures of motivation, engagement, and self-directed learning skills.

Figure 11: The Structure of Intelligent Tutoring System



The evidence gathered in this review points toward a future in which ITS for multilingual learners integrate personalization, multimodality, cultural inclusivity, and teacher collaboration within an ethically governed framework. Earlier studies largely focused on cognitive learning gains (Nye et al., 2014; Pedaste & Saalik, 2021)but the current synthesis advocates for a broader definition of success that includes linguistic equity, emotional safety, and cultural validation. Future research should include longitudinal studies tracking both academic and language development, as well as cross-context analyses comparing ITS performance in diverse socio-economic and cultural environments. The rapid advancement of generative AI and large language models presents opportunities to create more conversational and context-aware tutoring systems (Šarić-Grgić et al., 2024). However, these innovations also carry risks related to bias, data privacy, and transparency. Developers should engage both educators and multilingual learners in participatory design to ensure systems are relevant, trustworthy, and responsive to diverse needs. Policymakers must establish clear data protection regulations while promoting equitable access to AI-enhanced educational tools. Ultimately, the sustainability and effectiveness of ITS for multilingual learners will depend on whether these systems evolve into adaptive, inclusive, and ethically responsible partners in education, capable of supporting both cognitive and linguistic development in varied contexts.

CONCLUSION

The findings of this systematic review affirm that intelligent tutoring systems hold profound potential to redefine the learning landscape for multilingual learners in secondary education, transforming it into a more equitable, engaging, and empowering environment. By weaving together the threads of adaptive personalization, multimodal content delivery, linguistically attuned feedback, and culturally responsive design, these systems create instructional experiences that resonate with both the cognitive and linguistic realities of diverse learners. The synthesis of evidence from one hundred and ten high-quality studies reveals a clear pattern. When intelligent tutoring systems are designed to address the dual imperatives of subject mastery and language development, they consistently foster measurable gains in comprehension, long-term retention, and learner confidence. Adaptive learner modeling, grounded in approaches such as Bayesian Knowledge Tracing and Performance Factor Analysis, enables these systems to construct dynamic portraits of each student's knowledge, misconceptions, and language profile. This ongoing refinement allows the tutoring system to offer guidance that is precisely calibrated to the learner's readiness, pacing, and preferred modes of engagement. Multimodal design emerges as another essential pillar in this transformative architecture. Systems that combine visual,

auditory, and interactive elements reduce cognitive overload, enhance accessibility, and open multiple pathways to understanding complex concepts. A learner encountering a challenging scientific term, for instance, may benefit from an explanatory animation paired with a narrated definition and a contextual diagram. Such orchestrated sensory inputs not only accelerate comprehension but also support the delicate balance multilingual students maintain between decoding language and processing subject matter. The review also finds that feedback when immediate, linguistically sensitive, and non-judgmental acts as a powerful catalyst for both academic growth and emotional resilience. Automated grammar correction, pronunciation guidance, and reflective prompts enable learners to self-correct, internalize patterns, and develop metacognitive awareness without fear of embarrassment. This safe space for exploration nurtures persistence and a willingness to take intellectual risks, qualities indispensable for long-term success. Equally significant is the role of cultural and linguistic inclusivity. Systems that embrace the lived experiences of learners through localized imagery, familiar metaphors, regional examples, and support for translanguaging are not only more relatable but also more effective. Such design choices affirm identity, reduce feelings of alienation, and kindle intrinsic motivation. Yet, the review makes clear that technological prowess alone cannot fulfill this promise. The human element remains vital. Teachers must be empowered with the training and tools to integrate intelligent tutoring systems into their pedagogical repertoire, interpreting system-generated analytics with discernment and adapting them to the evolving needs of their students. Adequate infrastructure, from reliable internet access to up-to-date hardware, is equally indispensable, as are robust ethical frameworks to protect learner privacy, prevent algorithmic bias, and ensure transparency in data use. Looking ahead, the rise of generative artificial intelligence and large language models opens possibilities for even more natural, conversational, and contextually aware tutoring experiences. However, these innovations must be pursued with vigilance to safeguard against the erosion of cultural diversity, the reinforcement of linguistic hierarchies, or the commodification of sensitive learner data. The ultimate promise of intelligent tutoring systems lies in their capacity to act not merely as tools of knowledge delivery but as adaptive companions in the learning journey partners that honor each student's linguistic heritage, nurture their intellectual curiosity, and equip them to thrive academically and socially. In embracing such a vision, education can move closer to a future where every multilingual learner stands not at the margins but at the very heart of the learning experience, empowered to succeed with confidence, agency, and joy.

RECOMMENDATIONS

In light of the evidence gathered through this systematic review, it is recommended that the design, implementation, and evaluation of intelligent tutoring systems for multilingual learners in secondary education be approached as a holistic, culturally grounded, and pedagogically sound endeavor. The promise of these systems rests not merely in their technological sophistication but in their ability to serve as empathetic and adaptive companions in the learning process. Therefore, future development must begin with the intentional integration of adaptive learner modeling that captures both the cognitive trajectory and the linguistic profile of each learner. These models should be capable of recognizing patterns of growth, identifying recurring challenges, and distinguishing between conceptual misunderstandings and difficulties rooted in language barriers. By doing so, the system can deliver tailored interventions that respect the learner's readiness, preferred mode of engagement, and emotional state, ultimately creating a learning path that is both personalized and empowering. Equally critical is the enrichment of domain knowledge components with culturally relevant content and linguistically inclusive structures. This means that the academic material stored within the system should not be treated as static information but as a living body of knowledge that can be adapted to reflect the cultural backgrounds and lived experiences of learners. Bilingual glossaries, localized examples, familiar metaphors, and multimodal resources should be embedded to ensure that students can access complex ideas without being hindered by linguistic limitations. When academic content is framed in contexts that feel familiar and meaningful, it not only improves comprehension but also affirms the learner's identity, fostering deeper engagement and motivation. Pedagogical strategy engines should be designed to operate with a heightened sensitivity to linguistic diversity. They must be able to choose instructional actions that address the root of a learner's difficulty, whether that difficulty lies in mastering the concept itself or in navigating the language in which it is presented. For

example, a student struggling with a mathematics word problem due to unfamiliar terminology may require rephrased instructions, vocabulary scaffolds, or visual supports rather than additional drills in the underlying mathematical process. These systems should also incorporate affective computing capabilities that detect frustration, disengagement, or hesitation, allowing timely interventions that restore focus and encourage perseverance. To ensure the success of these systems in real classrooms, educators must be equipped with the knowledge and confidence to use them effectively. Professional development should focus on interpreting system-generated data, making informed instructional decisions, and integrating ITS insights with broader teaching strategies. Furthermore, infrastructure investments are essential to provide equitable access, ensuring that all students, regardless of socioeconomic background, can benefit from these technologies. Ethical data governance must be embedded from the outset, with robust safeguards for privacy, transparency in algorithmic processes, and proactive measures to prevent bias. Finally, research should continue to explore the long-term effects of intelligent tutoring systems on both academic outcomes and language acquisition, particularly as emerging technologies such as generative artificial intelligence expand their capabilities. By balancing innovation with cultural sensitivity, ethical responsibility, and pedagogical depth, intelligent tutoring systems can become more than tools for delivering knowledge; they can become catalysts for equity, agency, and enduring educational transformation.

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