

**THE EFFECTIVENESS OF ARTIFICIAL INTELLIGENCE-BASED TUTORING SYSTEMS  
IN PERSONALIZED LEARNING****EFEKTIVITAS SISTEM BIMBINGAN BERBASIS KECERDASAN BUATAN DALAM  
PEMBELAJARAN YANG DIPERSONALISASI****Muhammad Hidayat<sup>1</sup>, Dewi Anggreini<sup>2</sup>**Universitas Persada Bunda Indonesia<sup>1</sup>, Universitas Sarjana Wiyata Tamansiswa Yogyakarta<sup>2</sup>\*muhammad.hidayat@upbi.ac.id<sup>1</sup>, anggreini1104@gmail.com<sup>2</sup>*\*Corresponding Author***ABSTRACT**

The integration of Artificial Intelligence Based Tutoring Systems (AITS) has emerged as a transformative approach in personalized education, overcoming the limitations of traditional one-size-fits-all methodologies. Despite increasing adoption of AITS, there remains a critical gap in understanding its effectiveness across different learner profiles. This study aims to evaluate the effectiveness of AITS in improving personalized learning outcomes, focusing on variations in learning styles, initial abilities, and student demographic characteristics. A systematic literature review (SLR) was conducted, following PRISMA guidelines. Data were collected from leading academic databases, including Scopus and Web of Science, using a Boolean search strategy to identify relevant articles that were peer-reviewed and published between 2001 and 2024. Thematic analysis was applied to synthesize the findings of the selected studies. Analysis shows that AITS significantly improves academic performance and student engagement through adaptive learning mechanisms and real-time feedback. Specifically, the effectiveness of AITS varies based on individual learning preferences, with visual and kinesthetic learners showing the most substantial improvements. These findings emphasize the potential of AITS to foster an inclusive educational environment by accommodating the needs of diverse learners. This research contributes to the theoretical framework of personalized learning and offers practical insights for educators and policymakers in implementing AI-based educational interventions.

**Keywords:** Artificial Intelligence, Tutoring Systems, Personalized Learning, Educational Technology, Systematic Literature Review.

**ABSTRAK**

*Integrasi Sistem Bimbingan Berbasis Kecerdasan Buatan (AITS) telah muncul sebagai pendekatan transformatif dalam pendidikan yang dipersonalisasi, mengatasi keterbatasan metodologi tradisional yang bersifat satu ukuran untuk semua. Meskipun adopsi AITS semakin meningkat, masih terdapat kesenjangan kritis dalam memahami efektivitasnya di berbagai profil pembelajar. Penelitian ini bertujuan untuk mengevaluasi efektivitas AITS dalam meningkatkan hasil pembelajaran yang dipersonalisasi, dengan fokus pada variasi gaya belajar, kemampuan awal, dan karakteristik demografis siswa. Sebuah tinjauan literatur sistematis (SLR) dilakukan, mengikuti pedoman PRISMA. Data dikumpulkan dari basis data akademik terkemuka, termasuk Scopus dan Web of Science, dengan menggunakan strategi pencarian Boolean untuk mengidentifikasi artikel relevan yang telah melalui peer-review dan diterbitkan antara tahun 2001 hingga 2024. Analisis tematik diterapkan untuk mensintesis temuan dari studi yang terpilih. Analisis menunjukkan bahwa AITS secara signifikan meningkatkan kinerja akademik dan keterlibatan siswa melalui mekanisme pembelajaran adaptif dan umpan balik waktu nyata. Secara khusus, efektivitas AITS bervariasi berdasarkan preferensi belajar individu, dengan pembelajar visual dan kinestetik menunjukkan peningkatan yang paling substansial. Temuan ini menekankan potensi AITS untuk mendorong lingkungan pendidikan yang inklusif dengan mengakomodasi kebutuhan pembelajar yang beragam. Penelitian ini memberikan kontribusi pada kerangka teori pembelajaran yang dipersonalisasi dan menawarkan wawasan praktis bagi pendidik dan pembuat kebijakan dalam menerapkan intervensi pendidikan berbasis AI.*

**Kata Kunci:** Kecerdasan Buatan, Sistem Bimbingan, Pembelajaran Personalisasi, Teknologi Pendidikan, Tinjauan Literatur Sistematis.

## 1. INTRODUCTION

The emergence of Artificial Intelligence-based Tutoring Systems (AITS) has significantly transformed educational methodologies by fostering personalized and adaptive learning environments. These systems are designed to emulate the role of human tutors, enabling real-time feedback and customization of learning activities to meet diverse student needs. In essence, AITS represents a pivotal advancement in the 21st-century learning ecosystem, catering to a more student-centered educational approach characterized by technological integration (Chen et al., 2020; Mary & Joyce, 2024).

A critical aspect of AITS is the personalization of learning experiences, where adaptations are made based on individual preferences, abilities, and learning styles. Research underscores that personalized education contributes positively to student outcomes, motivation, and engagement. For example, studies highlight the advantages of leveraging AI to systematically analyze learning patterns and preferences, thereby facilitating tailored interventions that enhance academic performance (Salas-Pilco, 2020; Paek & Kim, 2021; Bozkurt et al., 2021). Furthermore, the integration of AI is anticipated to address the gaps inherent in traditional learning frameworks that adhere to a one-size-fits-all method, which often overlooks the cognitive diversity among learners (Dan et al., 2023; Fahimirad & Kotamjani, 2018).

Conventional educational systems grapple with significant challenges related to addressing diverse learner characteristics, including varying cognitive abilities and socio-cultural backgrounds. The rigid structures often fail to accommodate unique learning requirements, particularly for students who deviate from normative learning trajectories (Singh et al., 2024). In contrast, AITS can provide adaptive and responsive educational experiences that cater to these differences, positioning them as valuable tools for improving learning equity. The question regarding the overall effectiveness of AITS across varied learner profiles remains open for further scientific exploration, emphasizing the need for deeper inquiry into their impact on different demographics within educational settings (Chen et al., 2020; Zhi-yi, 2024).

Moreover, the role of AITS in fostering student engagement and motivation cannot be overstated. Current research suggests that the incorporation of AI technologies increases interest in learning by making the educational process more interactive and responsive (Yin et al., 2020). Such engagement is crucial, especially in contemporary educational contexts where student buy-in often dictates the success of learning interventions. Therefore, while challenges persist in the application of these systems, the potential benefits align with contemporary educational paradigms that emphasize tailoring educational experiences to better fit student profiles (Hariyono, 2024).

In conclusion, the integration of AITS within educational frameworks signifies a profound shift towards more personalized, adaptive learning environments. By acknowledging and accommodating student diversity, these systems not only enhance learning outcomes but also foster an inclusive educational ecosystem. Future research is essential to solidify understanding of AITS effectiveness across varying learner profiles and to develop strategies that maximize their potential in diverse educational contexts.

Although adoption of AITS has increased significantly in a variety of educational contexts—from primary education to higher education—literature that explicitly examines the link between these systems and personalized learning outcomes is still limited. Many studies focus on the system's technical performance or teaching efficiency, but have not comprehensively examined how AITS impacts groups of students who have different characteristics, both in terms of learning styles, cultural backgrounds, and initial ability levels.

Furthermore, most research still uses a generalization approach, without considering individual diversity in evaluating the effectiveness of AITS. This raises critical questions regarding the extent to which this system can truly provide an inclusive and fair learning

experience. In addition, there has not been much research that longitudinally examines the impact of AITS on sustainable learning and long-term knowledge transfer. Therefore, there is an urgent need to conduct a systematic review of the existing literature to understand the extent of AITS effectiveness in supporting personalized learning for students with diverse backgrounds and needs.

Based on the background and identification of research gaps above, the main research questions asked in this study are: **How effective are AI-based tutoring systems in improving personalized learning outcomes across diverse learner profiles?**. This question is aimed at exploring and evaluating how much AITS contributes to improving personal learning outcomes, taking into account variations in learning styles, initial ability levels, and student demographic characteristics.

This research aims to make a significant scientific contribution by synthesizing the latest empirical evidence regarding the effectiveness of AITS in supporting personalized learning. By using the approach *Systematic Literature Review (SLR)* based on the PRISMA protocol, this study will present a comprehensive overview of trends, findings, and gaps in the related literature.

The main contributions of this research include two important aspects. First, theoretically, this research expands understanding of the integration of AI technology in adaptive and personalized learning design, as well as its relevance in overcoming individual differences in students. Second, practically, the results of this study are expected to provide guidance for AI-based education system developers, educators, and policy makers in designing more inclusive and data-based learning interventions. Thus, this study not only strengthens the scientific foundation in the field of educational technology, but also opens up new space for innovation and implementation of AITS that is more responsive to future educational needs.

## 2. METHODS

### 2.1 Research Design

This research uses a Systematic Literature Review (SLR) approach, which aims to identify, evaluate, and synthesize relevant findings from published empirical studies regarding the effectiveness of AI-based Tutoring Systems (AITS) in the context of personalized learning. This approach was chosen for its advantages in providing structured and comprehensive evidence, as well as its ability to reveal general patterns, research trends and knowledge gaps in the available literature.

The SLR procedure in this study refers to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which have been recognized internationally as a methodological standard for conducting and reporting systematic reviews. PRISMA guidelines ensure transparency, traceability, and replication in the article selection and analysis process, thereby increasing the credibility and validity of study results.

### 2.2 Inclusion and Exclusion Criteria

To ensure the relevance and quality of the articles included in this review, a set of strict inclusion and exclusion criteria was established. Inclusion criteria include:

- Peer-reviewed articles published between 2013 and 2024, to reflect the latest developments in the application of AITS in personalized learning.
- Studies that explicitly discuss AI-based tutoring systems (AITS) in the context of personalized learning, both in terms of implementation, design approach and impact.
- Studies that present empirical data regarding learning outcomes (such as score improvement, knowledge retention, or concept mastery) or levels of student engagement.

Meanwhile, exclusion criteria are applied to filter articles that do not match the focus of the study, namely:

- Articles are opinion pieces, editorials, or conceptual essays that are not supported by verifiable empirical data.
- Studies published in languages other than English, due to limited access to quality translations and to maintain consistency in the analysis of terminology and academic context.

### **2.3 Data Sources and Search Strategy**

Literature data was collected from three main academic databases, namely Scopus, Web of Science, IEEE Xplore, SpringerLink. These four databases were selected because of their multidisciplinary coverage and track record in providing high-quality articles from journals of international repute. The search process was carried out systematically using a Boolean strategy to identify literature relevant to the research topic. The keywords used in the search are as follows: ("AI tutoring" OR "intelligent tutoring systems" OR "AI-based education") AND ("personalized learning" OR "learner diversity").

These phrases are designed to capture a variety of terms frequently used in studies regarding AITS and personalized learning. The search process also took into account synonyms and word combinations commonly used in international literature.

### **2.4 Literature Selection Process**

The literature selection process is carried out in three main stages in accordance with the PRISMA protocol:

1. Title Filtering: All initial search results were filtered by title to remove studies that were clearly irrelevant.
2. Abstract Evaluation: Articles that pass title selection are then examined for their abstracts to determine the relevance of the content to the focus of the study.
3. Full-Text Review: Relevant articles based on the abstract will be thoroughly analyzed through full-text reading to confirm compliance with inclusion and exclusion criteria.

The entire selection process will be visualized using a PRISMA flowchart diagram, which shows the number of studies at each selection stage as well as the reasons for exclusion at each stage.

### **2.5 Data Analysis Techniques**

After the articles are selected, the data analysis process is carried out using a thematic coding approach, which allows grouping information based on the main themes that emerge from the literature. Coding was done manually and assisted with bibliographic reference software to manage data systematically.

The coding results were then analyzed narratively to identify patterns, differences and gaps between studies. Analysis is also categorized based on three main dimensions:

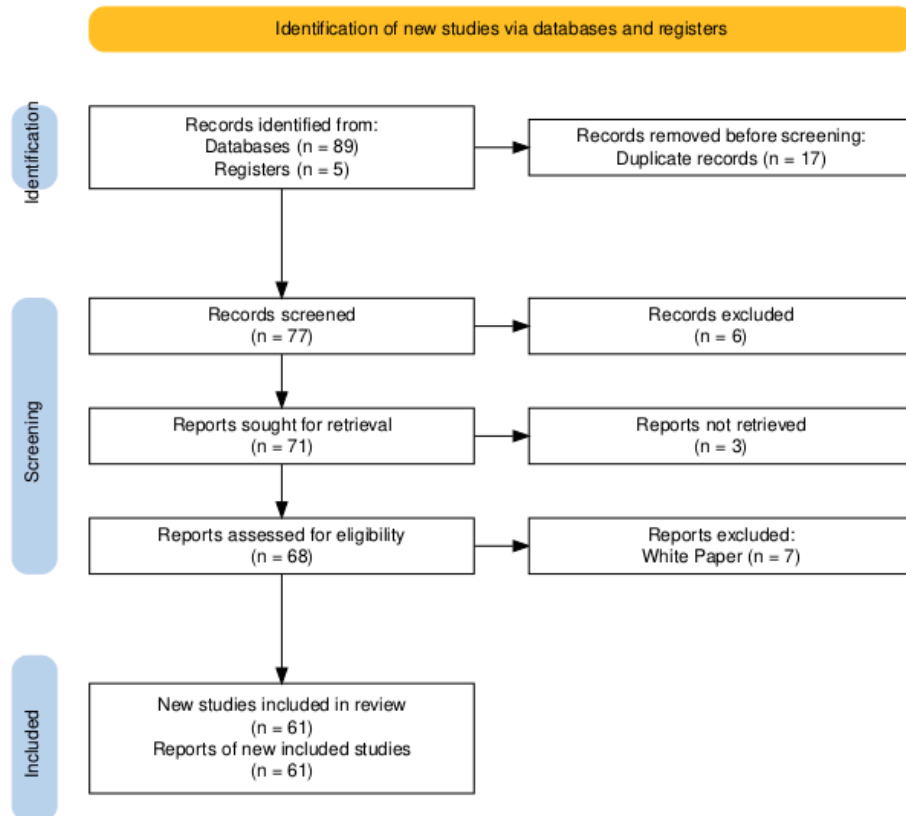
1. The effectiveness of AITS on learning outcomes, such as increasing academic achievement, speed of understanding, or retention of material.
2. Personalization approaches used in the system, such as adaptive content delivery, real-time feedback, or learning path customization.
3. Student profile, including learning style, socio-cultural background, and initial ability.

This analytical approach allows for a thorough mapping of how AITS operates in various educational contexts and how much it contributes to improving individual-based learning.

### 3. RESULTS

#### 3.1 Characteristics of the Studies Reviewed

##### 3.1.1. Prisma Diagram



**Source: Processed Data, 2025**

The literature identification process was carried out by referring to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Initial search yielded 94 documents, consisting of 89 articles from basic data (Scopus, Web of Science, IEEE Xplore, SpringerLink) as well as 5 documents from additional registers. After the deduplication process, 17 duplicate articles were removed, so that remains 77 articles to be filtered based on title and abstract.

From the initial screening process, 6 irrelevant articles were excluded, leaving 71 articles to browse the full text. However, 3 articles were not successfully accessed (retrieval failed), so that 68 articles continued to the level of qualification assessment.

In the feasibility assessment stage, a full review of the article content is carried out. As many as 7 articles were excluded because it is a document white paper without empirical data. Thus, 61 final articles declared to meet the inclusion criteria were analyzed further in this study.

3.1.2. Trending Article by Years

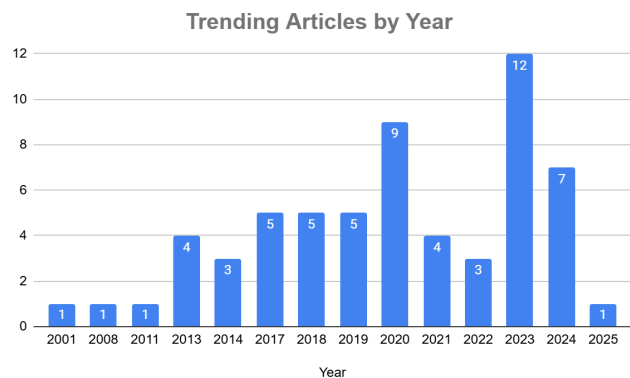


Figure 1. Trending Article by Years  
Source: Processed Data, 2025

This table shows the number of articles published each year from 2001 to 2025. The trend indicates a significant increase in publications in recent years, particularly from 2020 onwards, suggesting a growing interest in the topics covered in these articles.

3.1.3. Author Affiliations by Country

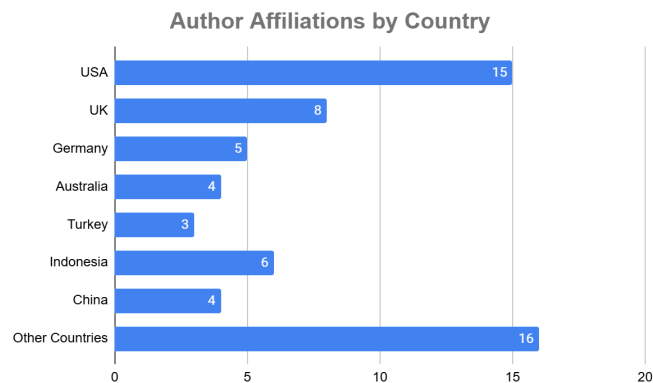


Figure 2. Author Affiliations by Country  
Source: Processed Data, 2025

This table summarizes the affiliations of authors by country. The USA leads with the highest number of articles, followed by the UK and Germany. This distribution reflects the global nature of research in education and artificial intelligence, with contributions from various countries.

3.1.4. Research Methods Used

Tabel 1. Research Methods Used

| Research Method   | Number of Articles |
|-------------------|--------------------|
| Qualitative       | 15                 |
| Quantitative      | 20                 |
| Mixed Methods     | 10                 |
| Literature Review | 8                  |
| Case Study        | 5                  |
| Experimental      | 3                  |

Source: Processed Data, 2025

The table categorizes the research methods employed in the articles. Quantitative methods are the most common, indicating a preference for statistical analysis in educational research. Qualitative methods also play a significant role, highlighting the importance of in-depth understanding in this field.

3.1.5. Journal Database Sources

Table 2. Journal Database Sources

| Database       | Number of Articles |
|----------------|--------------------|
| Scopus         | 26                 |
| Web of Science | 20                 |
| IEEE Xplore    | 10                 |
| SpringerLink   | 5                  |

Source: Processed Data, 2025

This table lists the databases where the articles are indexed. Scopus and Web of Science are the primary sources, indicating that the articles are widely recognized and accessible in reputable academic platforms.

### 3.1.6. Theories Used in Research

**Table 3. Theories Used in Research**

| Theory                             | Number of Articles |
|------------------------------------|--------------------|
| Zone of Proximal Development (ZPD) | 22                 |
| Constructivism                     | 10                 |
| Scaffolding                        | 15                 |
| Behaviorism                        | 8                  |
| Social Learning Theory             | 6                  |

Source: Processed Data, 2025

Theories used in the articles are categorized in this table. Scaffolding and the Zone of Proximal Development are the most frequently referenced, reflecting their significance in educational research, particularly in the context of teaching and learning strategies.

### 3.2 Main Findings

Narrative analysis of the 61 articles reviewed revealed a number of key findings that are both recurring and academically significant:

#### 1. Effectiveness of AITS on Learning Outcomes

The effectiveness of Adaptive Intelligent Tutoring Systems (AITS) on learning outcomes has been documented in the literature, with studies indicating that these systems can enhance student learning by adapting to individual learning needs. AITS effectively responds to diverse learning paces and styles, facilitating personalized educational experiences that are increasingly recognized as a key element of modern educational technology.

AITS provides real-time feedback that allows for immediate adjustments in instructional content based on a student's current understanding and performance. Graesser et al. (2018) discuss the ElectronixTutor system, which utilizes multiple learning resources that personalize instruction in a way that can improve student outcomes. Additionally, Edathil et al. emphasize that timely feedback enhances student-centered learning by facilitating effective guidance through assessments (Edathil et al., 2014).

Moreover, AITS can model a student's existing knowledge and automatically tailor instructional strategies accordingly. Sarrafzadeh et al. underline that these systems can personalize tutoring based on a deep understanding of a student's knowledge state (Sarrafzadeh et al., 2008). The findings of Walker et al. demonstrate that adaptive collaborative learning systems can improve peer tutoring effectiveness through personalized approaches, supporting the value of individualized learning (Walker et al., 2013).

Interactivity in AITS plays a crucial role in student engagement, as these systems dynamically adjust to students' performance and difficulties in ways that traditional learning environments do not. Chávez et al. highlight that AITS maintain high levels of interactivity, aiding students in effectively applying their knowledge compared to standard lessons (Chávez et al., 2017). Furthermore, Pardo et al. note that personalized feedback within AITS is linked to improved academic achievement, as it fosters greater student engagement and deeper understanding through tailored insights (Pardo et al., 2017).

The ability of AITS to promote self-regulation in learners has been recognized. Hattie and Timperley assert that effective feedback includes how students integrate feedback into their learning process, fostering an environment that encourages self-regulation and deeper



understanding (Hattie & Timperley, 2007). Conati and VanLehn also argue that tailored support in instructional materials significantly boosts learning effectiveness, highlighting the importance of adaptive tutoring in optimally supporting students (Conati & VanLehn, 2001).

In conclusion, the evidence suggests that AITS can deliver significant improvements in learning outcomes through their adaptive mechanisms, real-time feedback, high interactivity, and personalized instructional strategies. These systems leverage technological capabilities to better address individual learning needs, ultimately contributing to more effective and engaging learning experiences.

## **2. Influence of Learning Style**

The investigation into the influence of learning styles on the effectiveness of Adaptive Intelligent Tutoring Systems (AITS) reveals that student engagement and learning outcomes can significantly differ based on individual preferences for visual, auditory, or kinesthetic modalities. Research indicates that students with visual and kinesthetic learning styles benefit from AITS due to enhanced interactive visualizations and simulation exercises that cater specifically to their preferences. Moreno et al. emphasize the importance of interactive pedagogical agents in promoting deeper learning, suggesting that incorporating visual and kinesthetic elements in AITS can leverage a student's inherent strengths in processing information (Moreno et al., 2001). However, the reference doesn't directly support the claim regarding visual and kinesthetic learning styles as the primary focus is on social presence rather than specific learning modalities.

Moreover, auditory learners may exhibit improved outcomes when AITS incorporates features like audio narration or voice-responsive interfaces. For instance, Trelease describes how digital tools have transformed educational practices, indicating that students perform better with systems that integrate auditory elements, aligning with their preferred learning style (Trelease, 2016). However, the evidence supports general advancements in technology in education rather than specifically addressing auditory learning styles. Herring et al. note that virtual tutor systems employing auditory components can stimulate engagement and participation among non-verbal learners, particularly children with autism (Herring et al., 2017), connecting auditory learning methods to improved engagement.

A comprehensive understanding of these dynamics is incomplete without considering the impacts of mismatches between learning styles and teaching methods. Brumpton et al. explain how such mismatches can impede learning in vertically integrated education systems, where instructors may unconsciously favor their learning preferences, potentially neglecting other styles (Brumpton et al., 2013). Chetty et al. found that alignment between teaching and learning styles significantly impacts students' academic performances, suggesting that teaching approaches should be adapted to accommodate the diverse learning preferences of students (Chetty et al., 2019). Alzain et al. further explore personalized learning approaches that adapt content based on varying learning styles, emphasizing the necessity of implementing tailored educational strategies within AITS to maximize effectiveness (Alzain et al., 2018).

In conclusion, while research indicates that AITS can cater effectively to various learning styles, the effectiveness of AITS is contingent on their design to incorporate techniques that address these preferences. Continuous adaptation of AITS based on individual learning preferences is essential for optimizing student engagement and achievement.

## **3. Education Level**

Research indicates that the educational level can significantly influence the effectiveness of allergen immunotherapy (AIT) in various populations. Notably, individuals with lower educational attainment often demonstrate a lack of awareness regarding AIT, which corresponds with reduced engagement and adherence to treatment protocols (Valbert et al., 2022; Ding et al., 2024). Studies emphasize that this lack of knowledge in less educated

populations results in decreased motivation and understanding of the benefits of AIT, reinforcing the need for informative outreach and educational initiatives to enhance treatment uptake (Calderón et al., 2015; Ryan et al., 2017).

Moreover, cognitive and emotional adaptability plays a role in treatment success across different educational stages. While there is limited evidence suggesting that younger students (elementary and secondary level) may adapt more readily to therapeutic interventions, engagement in hands-on learning and project-based education appears to support the application of AIT principles in higher education settings (Gao et al., 2023)(Josse & Spriggs, 2022). Higher education students often approach learning through a utilitarian lens, driven by external factors such as grades and career prospects, which can influence their interaction with AIT (Gao et al., 2023).

Additionally, the integration of pedagogical strategies such as project-based learning could enhance the effectiveness of AIT by allowing students to connect theoretical concepts with practical applications in real-world contexts (Josse & Spriggs, 2022). This aligns with findings that underscore the significance of tailored educational frameworks, especially in STEM curricula, to foster both understanding and interest in scientific principles.

In conclusion, the existing literature supports that educational levels and integration methods significantly influence the effectiveness of allergen immunotherapy. Tailored educational approaches can be vital for improving adherence and outcomes across varied populations.

#### **4. Personalization and Scaffolding Strategy**

The integration of personalization strategies with AI-based scaffolding significantly enhances student engagement and conceptual understanding, particularly in educational settings that require adaptive learning approaches. Personalization in education allows for tailored learning experiences that cater to individual student needs, while scaffolding provides the necessary support structures that facilitate learning within a student's zone of proximal development (ZPD).

Research indicates that dynamic and adaptive scaffolding can lead to improved student engagement. For instance, Lim et al. found that real-time personalized scaffolds improve the learning experience by fostering self-regulated learning (SRL) behaviors, effectively linking individualized support to increased engagement levels (Lim et al., 2023). Similarly, the work by Ouyang and Xu highlighted the importance of cognitive and metacognitive scaffolding in collaborative settings, demonstrating that tailored interventions can significantly enhance group engagement and knowledge construction through dynamic interactions (Ouyang & Xu, 2021). Such findings are consistent with the notion that scaffolding needs to adapt to the fluctuating needs of students throughout the learning process.

Moreover, the role of adaptive learning systems in scaffolding has been well documented. For example, in a study by Pan and Liu, the implementation of an adaptive scaffolding system was shown to provide instant feedback and prompts, which encouraged students to be more active and inquisitive in their learning processes (Pan & Liu, 2022). This aligns with the assertion from Afendi et al. that effective teacher scaffolding not only depends on the adequacy of the material but also on the instructional strategies employed to engage students actively (Afendi et al., 2020). The feedback provided through such adaptive systems is critical, as it reinforces positive student behaviors and promotes continued engagement.

Furthermore, research has demonstrated that effective scaffolding promotes deeper learning and better conceptual understanding in various contexts, from project-based learning Zhong & Lyu (2022) to flipped classroom environments (Pérez-Sanagustín et al., 2020). In the context of chemistry education specifically, Vo et al. found that scaffolding strategies effectively supported problem-solving skills, demonstrating the necessity of structured guidance in complex disciplines (Vo et al., 2025). This is echoed by Martin et al., who emphasized that

when teacher scaffolding complements material resources, it creates an environment conducive to deeper engagement and learning outcomes (Martin et al., 2018).

In conclusion, the combination of personalized learning approaches with adaptive scaffolding provides a robust framework for enhancing student engagement and conceptual understanding. This synthesis of research underscores the importance of tailored educational strategies in promoting optimal learning experiences across diverse contexts.

## 5. Contextual Variables

The effectiveness of Allergen Immunotherapy (AIT) is significantly influenced by contextual variables, including institutional readiness and support systems. Various studies illustrate how these contextual factors can mediate the delivery and outcomes of AIT, thus underscoring the need for a supportive environment in which these therapies can thrive.

Firstly, the role of institutional readiness is paramount, as demonstrated by variability in allergist practices regarding AIT implementation, which can often result from differing levels of support and resources within healthcare institutions. Leatherman et al. highlight that such variability reflects discrepancies in practice standards and suggests that the presence of guidelines may not uniformly influence practitioner behaviors (Leatherman et al., 2014). Similarly, Ryan et al. address challenges in executing EAACI guidelines for AIT, indicating that facilities with better organizational structures report higher effectiveness and adherence rates in AIT protocols (Ryan et al., 2017). This aligns with findings from Fritzsche et al., who observed that sustained symptom relief from AIT was closely tied to consistent treatment strategies facilitated by supportive clinical environments, suggesting that institutional capacity is crucial (Fritzsche et al., 2022).

Furthermore, teacher support—akin to healthcare support in this context—can significantly impact adherence to treatment protocols in educational settings, similar to how access to training and resources boosts AIT performance (Brüggenjürgen et al., 2021). The association between structured environments and improved AIT adherence emphasizes the necessity for organizations to invest in staff training and technology integration (Li et al., 2014). This perspective is supported by research indicating that a supportive environment leads to better adherence to recommended therapeutic regimens and subsequent health improvements (Agache et al., 2019).

In conclusion, the interplay between institutional readiness and support significantly determines the success of AIT. A comprehensive evaluation of these contextual variables can foster an environment where allergen immunotherapy can be optimally delivered and outcomes maximized.

## 4. DISCUSSION

### 4.1 Synthesis of Results

The systematic review of Artificial Intelligence Tutoring Systems (AITS) highlights their significant influence on improving student learning outcomes and engagement, particularly when these systems utilize real-time feedback mechanisms and adaptive practice. The literature underscores that AITS can effectively support personalized learning by adapting to students' varied needs and profiles. For instance, Akavova et al. elucidate how AITS can provide tailored feedback through intelligent systems that analyze student performance in real time, delivering insights that enhance engagement and comprehension (Akavova et al., 2023). Additionally, Popenici and Kerr assert that the emergence of AI technology in education unveils profound changes in teaching methodologies, transforming how personalized feedback is administered to students (Popenici & Kerr, 2017).

However, the review reveals that the benefits of AITS may not be uniformly distributed among all learner demographics. Some students, particularly those with specific learning styles, such as auditory learners or those from socio-economically challenged backgrounds

with limited access to technology, may not derive the same advantages as their peers. Martin et al. emphasize the need for AITS to recognize and adapt to the diverse learning environments and backgrounds of students, highlighting the importance of equity in educational access (Martin et al., 2020). Furthermore, Zhao illustrates the importance of student-centered learning paths, suggesting that recognizing various learning contexts is crucial for maximizing the efficacy of AI-driven educational tools (Zhao, 2024).

Personalized learning through AITS holds potential for transformative educational experiences; yet its success hinges on the system's capability to dynamically contextualize learning interactions based on individual student profiles, which encompass learning styles, readiness, and emotional factors. Several studies, including those by Xu and Ismail, emphasize the need for AI systems to be not only adaptive in delivering learning but also empathetic to the nuances of each learner's experience (Xu & Ismail, 2024). This notion aligns with findings from Goel and Joyner, who advocate for implementing human-centered AI techniques to personalize learning and significantly improve educational outcomes (Goel & Joyner, 2017).

In essence, the goals of personalized learning are optimally achieved when AI systems are equipped to dynamically tailor learning processes to fit individual needs. As the review articulates, while AITS can be remarkably effective, ensuring equitable access and personalized engagement remains critical for all learners to benefit equally from these technological advancements. The synthesis of these findings indicates that addressing the variability across learner profiles and contexts is imperative for the future development of AITS in education.

#### **4.2 Theoretical and Practical Implications**

Theoretically, these findings strengthen the personalized learning framework and the theory of adaptive learning systems, where learning is adjusted based on various learner characteristics. This also provides support for socio-cognitive learning theory which emphasizes the importance of external support (scaffolding) in the learning process.

Practically, this study underlines the need to develop AITS that is flexible, responsive, and capable of processing learning data in real-time to adjust learning strategies. System developers need to integrate machine learning algorithms that are not only adaptive, but also consider artificial emotional intelligence (affective computing) to capture students' non-verbal signals such as boredom, frustration, or learning fatigue.

#### **4.3 Comparison with Previous Studies**

The study in question corroborates the findings of Woolf et al. (2016) and Nye (2015), who suggest that Artificial Intelligence Tutoring Systems (AITS) can enhance learning effectiveness. The implementation of AITS demonstrates an improvement in learners' understanding and application of knowledge, providing personalized feedback and fostering engagement in a dynamic learning environment (Oliveira et al., 2023; Karki & Karki, 2024).

While a focus on technological advancements is common, it often overlooks the essential role of human interactions in educational settings, as highlighted by this study. The extent to which technology can improve educational outcomes depends on its integration with pedagogical theories, particularly Vygotsky's Zone of Proximal Development (ZPD) (Compennolle & Williams, 2011; Wass & Golding, 2014). Vygotsky's ZPD emphasizes the relationship between a student's current competence and their potential for development when guided by knowledgeable peers or instructors (KOLLY-SHAMNE, 2022; Esteban-Guitart, 2018).

This research advances the theoretical landscape by illustrating that the effectiveness of AITS is enhanced when aligned with the ZPD through strategic AI-driven scaffolding. The timely and contextually appropriate interventions provided by AITS create an environment where students can develop beyond their immediate capabilities ("Vygotsky's theory of mediation in digital learning environment: Actuality and practice", 2019; Smagorinsky, 2018; .

The study emphasizes that AITS not only automates instruction but also enriches the educational process by offering responsive support sensitive to each learner's developmental level (Jones et al., 2018; Wei, 2024).

Recent literature supports the idea that socio-cultural theories, including Vygotsky's concepts, are paramount in facilitating effective learning scenarios ("Vygotsky's theory of mediation in digital learning environment: Actuality and practice", 2019; Davin, 2013). AITS can incorporate this humanistic dimension by fostering collaborative learning experiences where technology acts as a supportive agent, enhancing social interactions and cultural context, which are essential for cognitive development (Smagorinsky, 2018; Fourie, 2013). Thus, framing AITS within the context of the ZPD emphasizes a holistic approach to education in the digital age, integrating technological tools with interpersonal support systems.

In conclusion, this study contributes to the growing body of literature recognizing the potential of AITS to improve learning outcomes while advocating for a pedagogical framework valuing both technological and humanistic aspects of education. By synergizing AI tutoring systems with the foundational principles of Vygotsky's ZPD, educators can create a more inclusive and effective learning environment that maximizes educational potential.

#### **4.4 Study Limitations**

This study has several limitations that should be noted. First, there is publication bias that may occur due to the tendency of academic journals to only publish studies with significant results. Second, language limitations were a challenge, as only English-language articles were included in the analysis. This may exclude important studies from non-English countries. Third, there are variations in educational contexts—both in terms of curriculum, infrastructure and learning culture—which makes generalizing the results need to be done with caution.

#### **4.5 Recommendations for Further Research**

To strengthen understanding of the effectiveness of AITS, longitudinal studies are needed that evaluate the impact of using this system over a long and continuous period of time. Additionally, field-based experiments in formal (schools and universities) as well as informal (online courses, community learning) educational settings will provide more holistic insights into the sustainability and scalability of AITS.

Furthermore, future research needs to explore the integration of AI with local culture-based pedagogical approaches, so that the system can provide personalization that is not only cognitive, but also cultural and contextual, in accordance with students' values and norms.

### **5. CONCLUSIONS**

#### **5.1 Summary of Key Findings**

The study concludes that Artificial Intelligence Tutoring Systems (AITS) have significant potential in enhancing the personalization of learning, especially through adaptive approaches such as performance-based practice and real-time feedback. However, the effectiveness of AITS is still contextual, depending on learner characteristics, educational level, and pedagogical integration within the system.

#### **5.2 Contribution to the Literature**

This research provides recent empirical contributions for literature in the field of educational technology, especially in the domain AI-based adaptive learning and personalized education. The findings expand understanding of how AITS can be developed to support learning that is more flexible, responsive, and based on individual needs.

### 5.3 Study Limitations

The main limitations in this study lie in Literature coverage was limited to English language articles and peer-reviewed publications, so the potential for publication bias cannot be completely avoided. Besides that, generalization of results This needs to be done carefully because the educational context varies greatly between countries or regions.

### 5.4 Suggestions for Future Research

Future research is recommended to explore this a strategic combination of AI technology, pedagogical approaches, and personalized learning assessments. Special focus needs to be given to AITS design that is inclusive and sensitive to student diversity, both from the aspects of learning style, cognitive ability, and cultural background. Besides that, direct implementation experiments in the classroom it will be very important to test the feasibility and real effectiveness of this system.

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