A Review of Artificial Intelligence-Based Educational Interventions for Students with ADHD

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Students with Attention-Deficit/Hyperactivity Disorder (ADHD) face challenges such as inattention, executive dysfunction, and emotional regulation difficulties that hinder academic success. Artificial intelligence (AI) offers promising support through adaptive learning platforms, intelligent tutoring systems, and real-time feedback tools that personalize instruction and provide immediate guidance. This paper explores how AI can be responsibly leveraged to improve both academic and emotional outcomes for students with ADHD. A structured qualitative review of recent literature was conducted to evaluate AI-based educational interventions relevant to ADHD-specific challenges. Findings show that AI can enhance focus, task completion, and content mastery by tailoring instruction to each student's needs and pacing. Emotional support features (such as affect-sensitive feedback and nonjudgmental learning environments) also improve self-confidence and reduce frustration. However, these benefits depend on ethical deployment, including taking precautions for algorithmic bias, data privacy, and equitable access. A conceptual framework linking ADHD symptom domains with AI intervention strategies and outcomes is proposed. When aligned with evidence-based practices and implemented with teacher oversight, AI can meaningfully augment existing support for neurodiverse learners. Responsible integration of AI holds strong potential to create more inclusive and effective learning environments for students with ADHD.

Keywords: ADHD, Education Technology, Artificial Intelligence (AI), Personalized Learning, Real-time Feedback, Machine Learning (ML), Executive Functioning, Large Language Model (LLM), Educational Equity, Data Privacy, Algorithmic Bias, Adaptive Learning Systems, Student Engagement, Emotional Regulation

Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) affects approximately 5–7% of school-aged children worldwide and is associated with inattention, hyperactivity, and impulsivity that hinder academic and social success [1]. Traditional school-based supports, such as behavioral classroom management, IEPs, and teacher-delivered accommodations, can improve outcomes, especially when paired with clear structure and immediate feedback [2,3]. However, these interventions are resource-intensive and inconsistently applied. Studies show that only one-third of students with ADHD receive evidence-based behavioral support in school [3], revealing a significant gap in access to consistent and personalized care. Figure 1 provides a visual summary of these traditional interventions and their associated implementation challenges.

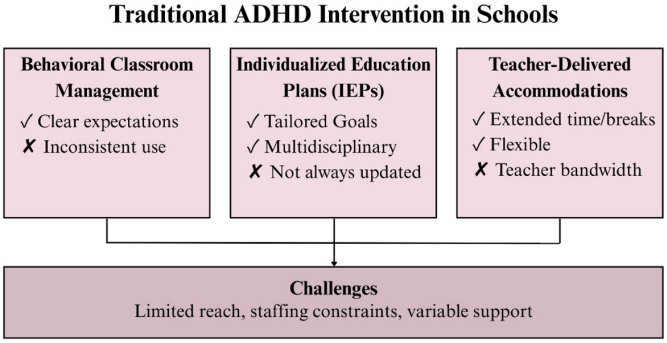

Fig. 1 A Simplified Schematic of Traditional School-Based ADHD Interventions and Their Limitations

Recent advances in artificial intelligence (AI) offer promising ways to augment and scale ADHD supports. AI-powered systems, such as intelligent tutoring platforms, emotion-sensitive agents, and adaptive scheduling tools, can provide real-time feedback and personalized instruction based on a student's individual needs [4]. While promising, these tools also raise concerns about data privacy, algorithmic bias, and equitable access [5,6].

This paper explores how AI can be responsibly leveraged to improve academic and emotional outcomes for students with ADHD. A structured qualitative literature review of peer-reviewed and select authoritative sources from 2014 to 2024 was conducted, focusing on empirical findings, ethical risks, and real-world case study insights related to AI use in ADHD

education. Guided by a neurodiversity-informed perspective and the FATML (Fairness, Accountability, Transparency in Machine Learning) framework, a conceptual model linking ADHD symptoms to specific AI interventions is proposed. The goal is to inform educators, developers, and policymakers seeking inclusive, effective tools for neurodiverse learners.

Methods

Search Strategy and Selection Criteria

This study employed a qualitative literature review to synthesize recent developments in the application of artificial intelligence (AI) to support students with Attention-Deficit/Hyperactivity Disorder (ADHD). The review focused on literature published between 2014 and 2024, drawing primarily from peer-reviewed sources. Search was conducted using academic databases including PubMed, ERIC, SpringerLink, IEEE Xplore, and Google Scholar. Search terms included combinations of: *"AI education ADHD," "adaptive learning ADHD," "real-time feedback education ADHD," "AI ethics education," and "intelligent tutoring ADHD."*

An initial corpus of 90+ sources was identified. Titles and abstracts were screened for relevance based on inclusion criteria: (1) the study examined AI tools or systems applied in educational settings, (2) it reported findings directly relevant to students with ADHD or features aligned with ADHD-related needs (e.g., executive functioning, emotional regulation), and (3) it provided empirical data or meaningful analysis. Exclusion criteria removed studies that lacked methodological detail or were tangential to the educational domain. After removing duplication and screening, 35 sources were assessed for full-text eligibility. Twenty-five studies were ultimately included, comprising 20 peer-reviewed articles and five high-quality gray literature sources (e.g., institutional reports, conference proceedings).

While peer-reviewed sources formed the backbone of the review, select non-peer-reviewed materials were included to provide additional context, particularly where peer-reviewed data was limited or unavailable. The following non-peer-reviewed sources were included and are marked in the reference list:

- Bulut, O., Cutumisu, M., & Singh, C. (2024). Research Square preprint – used for contextual discussion of AI evaluation frameworks.
- Baillifard, A. et al. (2023). arXiv preprint – used to illustrate a prototype AI tutoring system.
- Choksi, P. et al. (2024). arXiv preprint – referenced for innovative wearable affective computing design.
- Future of Privacy Forum & ConnectSafely (2021). Policy white paper – provided background on privacy frameworks for student data.

Data Extraction and Thematic Synthesis

Each selected article was systematically coded using a structured template. Extracted data included the publication year, study type (quantitative, qualitative, mixed methods), participant demographics (including age and ADHD diagnosis), type of AI tool (e.g., writing assistant, behavior monitoring system, adaptive tutor), key intervention components, outcomes (academic, behavioral, or emotional), and implementation context (e.g., classroom, remote, pilot). Studies were also coded for methodological robustness and noted for limitations or contextual factors such as teacher facilitation, digital access, or cultural setting.

A thematic synthesis was performed to identify recurring patterns and cluster findings under four domains aligned with ADHD-specific challenges:

1. AI for personalized learning and academic support
2. AI for real-time feedback and cognitive scaffolding
3. AI for executive functioning and organizational skills
4. AI for emotional regulation and social engagement

Cross-cutting themes such as ethical risk, accessibility, and user trust were also noted. The synthesis prioritized triangulation of evidence across study types, experimental designs, case studies, and qualitative interviews, to ensure a balanced perspective. Table 1 provides a sample of representative studies from the final dataset, detailing participants, AI tools, methodologies, and ADHD-specific outcomes.

Quality Appraisal and Use of Gray Literature

To ensure rigor, included studies were assessed for sample size, replicability, clarity of intervention, and use of validated outcome measures. The review acknowledges potential publication bias toward positive findings in emerging technologies. To counterbalance this, limited use was made of high-quality gray literature, such as industry white papers and government-funded pilots, which often provide implementation challenges underreported in academic publications. These were used for contextual grounding and are clearly cited.

At least five included documents were identified as non-peer-reviewed (e.g., arXiv preprints, policy reports, or public-facing project summaries). These were used with discretion and flagged accordingly to maintain academic transparency. Overall, the review integrates empirical rigor with real-world application insights, offering a narrative synthesis rather than a statistical meta-analysis due to heterogeneity across study designs.

Table 1 Summary of Selected Studies on AI-Based Interventions for Students with ADHD

Study (Year)	Participants / Context	AI Intervention	Key Findings	ADHD Challenges Addressed
Sharma & Solis (2024)	60 high school students with ADHD (randomized trial)	AI writing assistant providing real-time feedback and grammar support	Improved writing speed and organization; reduced stress and cognitive load	Executive functioning; attention; emotional regulation
Herrera & Solis (2024)	K–12 students with ADHD in Lima, Peru (pilot study)	Adaptive learning app adjusting difficulty based on real-time performance	Increased engagement and task completion; reduced frustration	Sustained attention; persistence
Brancaccio et al. (2023)	Students using a wearable device targeting executive function	Wearable with feedback for attention and self-regulation support	Improved executive function and academic performance	Inattention; executive function deficits
Aoki et al. (2022)	Students with ADHD using AI reading applications	Animated feedback via AI to enhance reading comprehension	Improved comprehension and student motivation	Reading focus; engagement
Chevalère et al. (2023)	Students in an AI-based open-ended learning environment	Instructional strategy using AI to adapt to student emotional states	Reduced boredom; improved emotional regulation and learning outcomes	Emotional regulation; engagement

Results

AI for Personalized Learning and Academic Skill Improvement

One of the biggest benefits of AI in education is its ability to support personalized learning. Traditional teaching methods often do not engage students with ADHD. These students may have varying skill levels and need content that matches their attention spans and interests. AI-driven personalized learning systems help by adjusting what is taught, how it is taught, and the pace of teaching based on each student's needs. The review shows that several studies indicate this kind of personalization can lead to significant academic gains for ADHD learners.

Adaptive Content and Pacing

AI-based adaptive learning platforms continuously assess a student's performance and adjust lesson difficulty and pace in real time. For example, if a student masters a math concept quickly, the system will advance to a more challenging topic; if the student struggles, the AI might provide additional practice on prerequisite skills or present the material in a different format. This approach aligns well with the learning needs of students with ADHD, who often benefit from just-right challenge levels, which are tasks that are not so easy that they become boring, but not so difficult that they provoke frustration. By keeping students in this optimal zone of proximal development, AI tutors can sustain engagement. In a controlled trial at a Pakistani university involving 300 students across four courses, the group using an AI-powered adaptive learning platform demonstrated a 25% improvement in grades, test scores, and engagement compared to the control group, with results reaching statistical significance ($p<0.001$)[7]. Although that study was on a general student sample, the results are especially pertinent for ADHD students, who often have inconsistent work output. The AI system's moment-to-moment adjustments smoothed out the learning curve, helping students remain steadily productive rather than oscillating between high and low performance. Another case from the review, focused specifically on ADHD, comes from a pilot program in Lima: an AI-powered adaptive learning app was introduced to several classrooms to support students with ADHD in core subjects. Teachers observed that the app's real-time tailoring of task difficulty improved students' focus and persistence, leading to a 25% increase in task completion rates over the term[8]. Students who previously would abandon assignments when they became too hard were now continuing with guided support. This suggests that adaptivity can effectively mitigate one of the classic ADHD issues, a low threshold for frustration, by ensuring that tasks remain attainable yet stimulating.

Multimodal Instruction and Engagement

AI tutoring systems often incorporate multiple representations and modalities to cater to different learning styles. For example, an Intelligent Tutoring System (ITS) for math might use visual diagrams, interactive widgets, and verbal explanations interchangeably to teach a concept. For students with ADHD, who may have difficulty sustaining attention through long lectures or dense text, this variety can re-capture attention and reinforce understanding. The Cognitive Tutor system (an AI-based tutoring program originally developed at Carnegie Mellon University) is one notable example that has been used in schools for subjects like algebra. It tracks each student's problem-solving process and provides tailored hints; if a student is stuck factoring a polynomial, the system may switch to a graphical representation or a relevant sub-problem to unblock their thinking. Studies on Cognitive Tutor and similar systems have shown improved mastery of math skills in middle and high school students, including those with learning difficulties[9]. By presenting information in diverse ways and giving instant feedback, AI tutors leverage the high stimulation threshold of many ADHD learners; in essence, keeping them engaged through interactive and gamified elements. In a supervised study at UniDistance Suisse[10], 51 undergraduate psychology students used a personal AI tutor app over a semester. The app generated microlearning questions and quizzes tailored to each student via GPT 3 and delivered spaced-retrieval practice during study sessions. Compared with peers not using the tutor, the AI-supported group demonstrated significantly higher exam scores, on average about 15 percentile points higher, and reported increased engagement and enjoyment. This suggests that structured, interactive micro quizzes and immediate feedback via AI can improve content retention and sustain attention in learners with executive function vulnerabilities akin to ADHD.

Real-Time Feedback and Error Correction

Immediate feedback is crucial for effective learning and is particularly beneficial for students with ADHD, who might not sustain attention long enough to benefit from feedback given hours or days later. AI systems excel at providing real-time feedback because they can instantly analyze student input. For example, an AI-based grammar and writing tool like Grammarly can immediately underline an awkward sentence or spelling mistake and suggest corrections, rather than a student waiting a week for a teacher to mark their essay. In the review, it was found that real-time feedback not only improves academic skills but also helps ADHD students stay on task by continuously guiding them. A study on an AI writing assistant4 demonstrated that high-school students with ADHD were able to write essays more efficiently, completing assignments 40% faster, when they received instantaneous feedback on their writing. The tool would, for instance, prompt a student with "Your introduction is missing a clear thesis statement" or highlight that their attention to detail was slipping (e.g. multiple spelling errors), allowing the student to correct the course immediately. This prevented small issues from accumulating and becoming overwhelming by the end of the task. As a result, students spent less total time writing and editing, and they experienced less frustration because they didn't get stuck as often wondering what to do next. Teachers also noted improvements in the coherence of final drafts, indicating that the iterative feedback loops helped students organize their thoughts better, which is a challenge for many with ADHD.

Support for Executive Functions and Study Skills

Beyond subject-matter instruction, several AI tools aim to bolster executive functioning skills that are critical for academic success. For instance, AI-powered scheduling apps and digital planners can help students with ADHD manage their time and responsibilities. These tools use algorithms to prioritize tasks and send reminders for upcoming deadlines or break big projects into smaller subtasks. One promising investigation was an open-label pilot study involving a wearable digital intervention designed to enhance on-task behavior in children with ADHD[11]. In this four-week classroom-based trial, 38 children aged 8–12 wore a wrist-worn device that vibrated intermittently and prompted them to self-assess their attention by tapping the device and parent-reported measures collected before and after the intervention showed statistically significant improvements in attention, executive functioning (including organization and planning), and academic performance, with moderate effect sizes. The device's coaching-like reminders appeared to reinforce self-monitoring habits at the point of performance, reducing off-task behavior and indirectly improving classroom readiness and assignment completion. By encouraging students to actively check and sustain their focus, this wearable intervention underscores the potential of AI-augmented tools to support executive functioning, and thus academic outcomes, in real-world school environments.

In summary, AI-based personalized learning interventions show considerable promise in improving academic outcomes for students with ADHD. By tailoring instruction to individual needs and providing timely feedback, these technologies tackle core academic challenges faced by ADHD learners: maintaining attention, managing appropriate levels of difficulty, and staying organized. It is worth noting, however, that successful implementation requires thoughtful integration with classroom practices. AI is most effective as a complement to, not a replacement for, skilled teachers and evidence-based pedagogical techniques. In the studies reviewed, the best outcomes occurred when teachers

actively monitored the AI interventions and provided human support and motivation alongside the technology [7,8]. This human-AI synergy ensured that personalization did not lead to isolation; instead, it freed teachers to give more individualized attention where needed (for example, focusing on students' creative expression or higher-order thinking skills, while the AI handled repetitive skill practice). The next section delves more deeply into one of the critical components of personalized learning, real-time feedback, and examines how it particularly benefits ADHD students by creating a responsive learning loop.

Real-Time Feedback and Cognitive Support

Real-time feedback refers to the process of providing instantaneous responses or guidance to students based on their current actions or performance. For learners with ADHD, who may be prone to losing focus or making impulsive errors, real-time feedback serves as an immediate corrective mechanism and motivator. Instead of waiting for a quiz to be graded or for a teacher to notice a mistake, the student can adjust their approach instantly. AI systems delivering live feedback significantly help in maintaining student engagement, improving accuracy, and preventing minor misunderstandings from turning into major learning gaps. This section highlights how AI-enabled real-time feedback impacts ADHD students' learning experiences and outcomes.

Maintaining Focus and Correcting Errors through Instant Responses

One challenge in a typical classroom is that a student might go off-task or disengage without the teacher noticing right away, especially in larger classes. An AI-driven program, however, can detect inactivity or off-task behavior and respond immediately. For example, if a student is working on an online math platform and stops interacting for a certain period (perhaps their attention drifted), the system can play a sound, flash a notification, or present a more engaging problem to regain the student's attention. This kind of immediate nudge is particularly valuable for students with ADHD, whose attention can fluctuate frequently. In a 2023 case study by Dahnoun (University of Bristol), a real-time feedback system was implemented in a digital learning platform. Teachers using the system could see live analytics on student engagement; if a student's activity stalled, the teacher's tablet would alert them, allowing timely intervention. For the students, the system itself gave immediate hints when it detected repeated errors. The result was that students with ADHD in the trial spent more time actively engaged in the learning task and less time "stuck" or daydreaming, compared to classes without the real-time feedback system. Both teacher-led and AI-generated feedback in the moment helped keep the momentum of the class, benefiting not only ADHD learners but the entire group by minimizing downtime.

Immediate correction of mistakes is another strength of AI tutors and tools. Children with ADHD can sometimes develop misconceptions in subjects like math or grammar if errors aren't addressed promptly; and once a misconception forms, it can be harder to unlearn. AI systems like Knewton Alta (an adaptive learning platform) or intelligent math tutors continuously analyze each answer a student submits. If an error is made, the system doesn't just mark it wrong; it often provides an explanation or a hint toward the right answer straight away. This approach prevents the student from practicing something incorrectly over and over. For instance, if a student with ADHD is solving equations and keeps distributing multiplication incorrectly, an AI tutor can catch this pattern after the first or second occurrence and remind the student of the distribution rule immediately, before they cement the wrong procedure. Such predictive analytics in AI tutoring software can identify the likely source of a student's mistake and offer a tailored prompt to address it. By catching errors early, real-time feedback ensures that students with ADHD practice skills correctly, leading to more confidence and mastery.

Positive Reinforcement and Motivation

Immediate feedback in AI systems isn't only about correction; it's also about reinforcement of positive behaviors. Educational AI programs frequently incorporate gamification elements like points, badges, or simple congratulatory messages to reward students for effort and progress. This kind of instant positive reinforcement can be very encouraging for students with ADHD, who might otherwise receive disproportionate negative feedback in traditional settings (e.g., being frequently told "pay attention" or getting poor grades on tests long after the fact). In the studies reviewed, it was found that AI tools providing real-time encouragement helped improve students' emotional engagement with learning. For example, a reading app using AI would display an animated character that smiles or gives a thumbs-up when the student completes a paragraph, or it might say "Great job! You've answered 5 in a row correctly." These small rewards can accumulate significant motivational effects. One experimental study [12] with an adaptive learning platform showed that students with ADHD were more likely to persist through challenging material when the system gave frequent micro-rewards and feedback, compared to a version of the software that only gave final scores at the end of an activity. The immediate praise tapped into the reward-seeking tendencies of ADHD brains; research has shown that individuals with ADHD often have a reward deficiency in the dopamine pathway, making immediate rewards more effective for them than delayed ones. Thus, AI's capability to deliver instantaneous reward stimuli (even as simple as a digital badge or a progress bar filling up) plays to this neurocognitive profile, sustaining

motivation and effort.

Preventing Small Problems from Escalating

A notable advantage observed is that real-time feedback can prevent minor lapses from turning into major setbacks. In a conventional scenario, if a student with ADHD misunderstands a concept early in a lesson, they might become frustrated or disengaged, and by the time the teacher notices, the student could be far off-track or emotionally upset. AI interventions short-circuit this sequence. For instance, consider a student getting frustrated by a multi-step physics problem: a real-time hint at step 2 can alleviate the frustration and get them through step 3, whereas without it, the student might give up entirely by step 4 and perhaps start acting out due to frustration. Herrera & Solis (2024)[8] reported exactly this in their adaptive app trial; the real-time adjustments and feedback "reduced frustration" in students, which in turn led to better task persistence. By addressing confusion or off-task behavior immediately, the AI system helped maintain a positive learning trajectory. Another example is an AI-based classroom attention tracking system studied by Chen et al. (2023, as cited in a summary[13]). Cameras and AI would analyze when a student's gaze wandered or when they started fidgeting excessively (potentially losing focus), and then the system would either alert the teacher or flash a gentle cue on the student's device. This early intervention mechanism was found to significantly increase the time ADHD students stayed on-task in class, as measured by independent observers. Teachers in that study noted that the AI alerts often caught disengagement before a student became disruptive to others, thereby also improving overall class management.

Grammarly and Writing Feedback

As a concrete illustration, one tool mentioned in several sources is Grammarly, an AI-driven writing assistant widely used to check grammar and style. While not designed exclusively for ADHD, it provides a clear example of real-time feedback in action. For students with ADHD, writing assignments can be daunting because they require sustained attention, organization, and attention to detail. Grammarly helps by underlining mistakes or unclear phrasing instantly and explaining why it might be a problem ("Consider splitting this long sentence" or "This word is repeated; consider a synonym"). By doing so, it externalizes some of the executive functions (planning, error-monitoring) that ADHD students struggle with. One recent quasi-experimental study[13] involving high school students found that those using Grammarly Premium showed significant improvements in both writing accuracy and confidence. The experimental group demonstrated a greater reduction in grammatical errors and reported higher self-efficacy scores compared to a control group that did not use the tool. Students described Grammarly as a "personal editor," noting that real-time corrections turned the revision process into an engaging task of "spot the error" rather than a tedious chore and helped alleviate anxiety about making mistakes. This example underscores how real-time feedback tools can act as a supportive scaffold, giving ADHD students the chance to correct and learn from their mistakes in the moment, rather than feeling defeated by a paper full of red marks returned days later.

In conclusion, real-time feedback mechanisms enabled by AI significantly benefit students with ADHD by keeping them engaged, guiding them through difficulties, and reinforcing their efforts immediately. These systems function like teaching aides that are always present and provide the kind of individualized, on-demand attention that a human teacher in a busy classroom might wish to offer but often cannot. It is important to note, however, that the quality of feedback matters; it must be clear, constructive, and appropriately tuned. Overly frequent feedback can become distracting rather than helpful (a known issue if systems are not calibrated correctly, sometimes termed "feedback overload"). The studies reviewed generally reported positive outcomes, suggesting that with careful design (e.g., only alerting when necessary, phrasing hints supportively), AI can strike the right balance. For ADHD learners, finding this balance is key: the feedback should be neither so sparse that errors slip by nor so intrusive that it interrupts their thinking flow. When implemented effectively, real-time feedback functions as a continuous system of guidance and reinforcement, helping students with ADHD stay on task and manage academic challenges.

Emotional and Social-Emotional Support through AI

In addition to academic difficulties, students with ADHD often face challenges in the emotional and social realms. They may experience higher levels of frustration, anxiety, or low self-esteem related to school, especially if they have a history of academic struggles or negative feedback. Many also have difficulty with emotional regulation, for example, managing anger or disappointment, and may struggle with social cues and peer relationships. It is crucial that interventions for ADHD address these emotional and social dimensions, not just academic skills. AI technologies, when thoughtfully implemented, can also contribute to improving emotional outcomes and providing social-emotional support for students with ADHD. They do so by creating more inclusive and responsive learning environments, and by directly targeting skills like emotional regulation and self-monitoring. This section explores these benefits, which are sometimes less obvious than academic gains but are equally important for the overall well-being and success of students.

Providing a Safe Learning Space

One recurring theme in qualitative reports is that students with ADHD often feel less judged by an AI tutor or tool than by human teachers or peers. The neutrality and patience of an AI system can reduce the anxiety a student might feel about making mistakes. This atmosphere encourages risk-taking in learning; students are more likely to attempt answers, ask questions, or try again after errors when they don't fear negative reactions. By creating a safe space, AI tools can help build confidence over time. Several sources noted increased self-confidence among ADHD students using AI interventions. For example, after working with an AI math tutor for a semester, students reported feeling more confident in math class and participating more, whereas previously they might have been withdrawn[4]. The non-judgmental nature of AI is particularly beneficial for those with ADHD who have experienced academic failure or criticism in the past; it provides a kind of emotional reset, allowing them to engage with learning material without the affliction of previous negative experiences.

Adaptive Emotional Support and Regulation

Cutting-edge AI in education is increasingly exploring affective computing; the ability for systems to detect and respond to users' emotions. For students with ADHD, timely emotional support can be just as important as cognitive support. An illustrative example comes from[14] who introduced SensEmo, a smartwatch-driven learning tool designed to detect students' emotions and attention levels in real time via heart rate and skin conductance. When a student displayed signs of frustration or waning focus, the system alerted the teacher to adapt instruction, such as slowing down or offering encouragement. In a classroom trial, SensEmo achieved 88.9% emotion-recognition accuracy and resulted in a 40% increase in quiz performance compared to traditional instruction without such feedback. This highlights how AI-based emotional sensing can offer timely scaffolding to boost both engagement and academic outcomes for students with attentional challenges.

Encouraging Social Interaction and Communication

Interestingly, some AI tools can also encourage social development for students with ADHD. A common issue for these students is difficulty in social cues or teamwork settings; they might impulsively dominate conversations, or conversely, feel isolated due to their differences. AI-driven collaborative platforms or educational games can create structured social scenarios where ADHD and non-ADHD peers interact on a more level playing field. For instance, an AI-mediated group learning game might assign roles to each team member (ensuring an ADHD student gets a chance to contribute meaningfully without being overshadowed) and gently enforce turn-taking by only accepting input from one student at a time. Through such structured interaction, students with ADHD get practice in collaborative skills in a fun, supported manner.

A case study[15] examined how an AI-powered education technology platform, designed to adapt in real-time based on student performance data, supported collaborative learning environments. In classrooms using this system, students were grouped based on complementary skill levels and learning needs. The AI facilitated the group's work by distributing tasks evenly, monitoring engagement levels, and offering prompts or scaffolding when the group veered off-task. Teachers reported that students with attention difficulties, including those with ADHD, benefited from this structure, they were more likely to stay engaged and contribute meaningfully during group activities. The AI's support reduced the usual chaos of peer collaboration by ensuring fairness and keeping the group focused, which helped ADHD students access the social and cognitive benefits of collaborative learning without being overwhelmed by its challenges. These findings suggest that AI tools can enhance not just individual learning pathways but also group dynamics, offering inclusive solutions that account for diverse learner needs.

Building Self-Esteem through Mastery

Self-esteem in students with ADHD often suffers due to repeated setbacks or negative feedback in school. By improving academic performance (as detailed earlier) and providing emotional support, AI interventions indirectly boost self-esteem. However, some tools also explicitly aim to build a growth mindset and positive self-perception. They might track personal progress over time and show students how much they have improved, reinforcing the idea that effort leads to growth. For example, a learning app might have a dashboard where a student can see that they have mastered 5 new skills in the past month or that their reading speed has increased. This concrete evidence of improvement can be very empowering for ADHD students who may not otherwise notice their own growth amidst daily struggles. In the Lima adaptive learning case, teachers reported that students with ADHD started taking pride in their achievements logged by the AI app, such as consecutive days of meeting a goal, and this pride translated to more confidence in tackling new challenges.

Emotional and Ethical Safety

It's also worth touching on the ethical side of emotional support, ensuring that AI does not inadvertently cause emotional harm. AI systems need to be designed to avoid any language or responses that could be interpreted as harsh, sarcastic, or overly critical, as children (especially those with emotional sensitivities like many with ADHD) could be negatively impacted. The good news is that many educational AI developers are aware of this

and employ child-friendly, encouraging tones. Nonetheless, this review emphasizes the importance of involving psychologists and special educators in the design of AI interaction styles. One ethical framework[6] argues for "trustworthy AI" in sensitive contexts, which includes the requirement of ensuring human agency and oversight and respecting the fundamental rights and dignity of users. In practice, this means AI should never be punishing or shaming a student. Instead, it should empower students; for instance, giving them choices (which can restore a sense of control) or asking them how they feel ("Are you frustrated? Would you like a hint or a break?"), thereby teaching self-reflection. Used correctly, AI can promote a more positive teacher-student relationship as well: if AI handles routine corrective feedback, the teacher can focus more on encouraging and bonding with the student, rather than constantly nagging about errors or behavior. This shift in teacher role from disciplinarian to mentor, facilitated by AI, can greatly benefit the emotional climate for ADHD students.

In conclusion, AI tools, beyond enhancing academic skills, have shown capacity to nurture the emotional well-being and social development of students with ADHD. They do so by creating a supportive learning atmosphere, modeling and prompting good emotional regulation strategies, reducing anxiety through immediate support, and enabling positive social and self-reflective experiences. While the research specifically on emotional outcomes is still emerging, early indicators are that students with ADHD feel more understood and supported when working with well-designed AI systems. This suggests AI could become a valuable component in holistic ADHD interventions; not replacing counselors or human connection, of course, but supplementing traditional supports by being an ever-present "guide" that assists with both learning and coping skills. As one student insightfully summarized to researchers (from a case[13]): "The app doesn't just help me learn, it kind of keeps me calm and on track. I get less angry at myself now when I can't do something – I just ask for a hint." That shift in attitude, from self-criticism to problem-solving, is precisely the kind of emotional growth that shows the potential AI has when leveraged responsibly in education.

Ethical and Implementation Considerations for Responsible AI Use

While the opportunities for leveraging AI to support students with ADHD are significant, it is imperative to address the ethical and practical challenges that accompany the integration of AI into educational settings. "Responsible AI" in this context means deploying technology in a way that is fair, transparent, secure, and aligned with the best interests of students. There are several key areas of concern that researchers, educators, and policymakers must navigate: algorithmic bias and fairness, privacy and data security, transparency and accountability, generalizability and validity of AI models, teacher training and implementation support, equity of access, and managing expectations around AI capabilities. Each of these is discussed below, along with insights from the literature on how to mitigate potential risks.

Algorithmic Bias and Fairness

AI systems learn from data, and if that data contains biases, the system can inadvertently perpetuate or amplify those biases. In an educational context, an AI might, for example, rate ADHD students as "high risk" or "low performing" more frequently if historical data reflects biases or if certain behaviors (like fidgeting or rapid guessing) are over-weighted as negative when they might correlate with ADHD. This raises a concern: that AI could inadvertently discriminate against or stigmatize students with ADHD (or any other group). Bulut et al. (2024)[5] highlight that the implementation of AI in education raises concerns about fairness and equity, noting that algorithmic bias in decision-making can lead to unfair treatment or inaccurate assumptions. For example, if an AI early-warning system for academic failure is not properly calibrated, it might flag a disproportionate number of neurodivergent students, leading to unnecessary interventions or lowered expectations for them. Ensuring fairness requires several steps: using diverse, representative training data (including data from students with ADHD, different cultural backgrounds, genders, etc.), applying bias-detection audits to AI models, and incorporating fairness constraints into model design. In the context of ADHD, it may be necessary to customize AI behavior, for instance, allowing more leeway for inattention markers before concluding a student is disengaged, or distinguishing between different causes of similar behaviors. Involving stakeholders (students, parents, special educators) in the design and testing of AI tools can help identify biased outputs. One practical approach mentioned by some scholars is a "bias bounty", inviting independent experts to probe the system for bias issues, similar to how security experts are invited to find vulnerabilities in software. Ultimately, the goal is to have AI that recognizes the strengths of ADHD learners (such as creativity or hyperfocus on topics of interest) and not just their challenges, thereby treating them fairly and not pigeonholing them due to a diagnosis or atypical behavior profile.

Transparency and Accountability

AI decisions can sometimes be a "black box"; not even developers fully understand how a complex model (like a deep neural network) arrives at a specific recommendation. In education, lack of transparency is particularly problematic because teachers, parents, and students have a right to know why an AI is making a suggestion or decision, especially if it impacts student

learning paths or evaluations[6]. For instance, if an AI system recommends moving a student to a remedial track, there must be a clear rationale (e.g., specific skill gaps identified) that can be communicated.

The concept of "explainable AI" (XAI) is gaining traction, designing AI systems that can provide human-understandable justifications for their outputs[5]. Teachers need this level of transparency to trust and effectively use AI insights in real-time instructional decisions. As noted by[5], "Teachers and educators must be able to understand the rationale behind AI recommendations to use them effectively and responsibly". Though the findings of the preprint have not yet been peer-reviewed.

If an AI flags that a student with ADHD is at risk of not mastering a topic, the system should ideally explain, for example, "The student has attempted this type of problem 5 times and was only successful once, indicating a pattern of difficulty in concept X." Such an explanation allows the teacher to verify the accuracy of the inference and intervene appropriately.

Accountability goes hand in hand with transparency. Ultimately, responsibility for student outcomes lies with educators and schools, not the AI tools themselves. Therefore, there need to be mechanisms to hold AI systems accountable for their performance. This includes regular evaluations of their accuracy and fairness, as well as clear protocols for overriding or correcting AI decisions when human educators deem it necessary[5,6]. Ensuring that AI systems are assistive rather than autonomous, such as allowing them to suggest personalized lesson plans, but requiring teacher review and approval, helps maintain human-centered accountability.

Some educational institutions have formed ethics committees or guidelines for AI usage, often referencing frameworks like FATML (Fairness, Accountability, and Transparency in ML) to ensure they adhere to these principles[16]. Adopting such frameworks means continuously scrutinizing AI systems for adherence to ethical norms and having recourse if something goes wrong (for instance, an appeal process if a student or parent feels an AI-based decision was harmful).

Privacy and Data Security

AI systems in education often require collecting and analyzing student data, from academic performance data to potentially sensitive information like behavior logs or even biometric data (as in the case of attention tracking via cameras). This raises significant privacy concerns, particularly for minors and particularly in contexts like special education where data might be more sensitive (e.g., disability status, psychological profiles). Laws such as FERPA (in the U.S.) protect student educational records, and any AI implementation must comply with such regulations. Parents and students should have control and insight into what data is being collected and how it's used. For example, if a reading app is monitoring how long a student spends on each page, parents should be informed and ideally have the option to opt out or see that data themselves. A specific concern for students with ADHD (or any disability) is stigmatization or misuse of data. The review identified that data governance policies are needed: Who owns the data produced by AI educational tools? Typically, it should be the student or their family. Best practices include data anonymization whenever possible, encryption of personal information, and clear retention policies (e.g., data gets deleted after a certain period or when a student leaves the school). The Student Privacy Compass[17] report notes the complexity of data sharing with third-party vendors in the age of AI and advocates for transparency and strict data agreements to ensure student information isn't exploited. In implementation, schools should seek AI providers that demonstrate strong privacy protections, perhaps evidenced by independent audits or certifications. Furthermore, involving parents early with getting informed consent and explaining the benefits and risks can build trust. One strategy some districts use is to have privacy and ethics boards that review any new ed-tech tool (especially AI-based ones) for compliance with privacy standards before it's approved for use.

Generalizability and Validity of AI Models

Many AI tools are trained on data from specific populations or contexts. A system that works well in one school or demographic might not automatically work well in another. For example, an AI model that predicts when a student is off-task might have been trained on observations of a small group of students and might wrongly interpret cultural behaviors or certain ADHD coping strategies as off-task. If an AI isn't validated for students with ADHD, it might misinterpret their high activity or multitasking (some ADHD students learn better when, say, doodling or standing) as disengagement. Thus, the generalizability of AI models is a concern. Educators should be cautious not to over-rely on AI judgments without considering individual context. Research in AI and ADHD is still growing, so many current tools are not "ADHD-specific" but general; they need adaptation and testing with neurodiverse groups. To ensure validity, AI systems should undergo pilot testing in the target environment (e.g., run the system in a class with ADHD students and compare its outputs with teacher assessments to see if it aligns well). If discrepancies are found, developers might need to retrain or adjust models (this could include adding more ADHD-specific data or features into the model). The literature also suggests the importance of continuous monitoring of AI accuracy, these systems should not be "set and forget." If an AI is recommending interventions for students, schools should track outcomes to ensure the recommendations are actually beneficial. If an AI identifies 10 students as needing reading support for example, and 8 of them indeed improve

after support but 2 did not actually need it (false positives), that feedback should loop back into refining the model. On the flip side, we must be wary of false negatives, an AI might miss some students who need help. A concrete example: a predictive system might focus on grades and miss a student who has decent grades but is quietly struggling emotionally. Human oversight is therefore critical to catch cases the AI misses. In all, validating AI tools in diverse, real-world settings and maintaining human judgment in the loop can help address issues of generalizability and accuracy, ensuring that the AI's guidance is both reliable and relevant to each student's situation.

Teacher Training and Integration

No matter how advanced an AI tool is, its success in the classroom largely depends on teachers being properly trained and comfortable with it. A recurrent issue noted is that without adequate professional development, teachers may underutilize or misuse AI tools. For instance, a teacher might not know how to interpret the dashboard of an AI learning analytics system and either ignore potentially valuable alerts or be overwhelmed by data. Worse, if teachers mistrust or misunderstand the AI, they might actively work around it, nullifying any benefit. The introduction of AI in classrooms requires change management: teachers need to learn new skills (both technical and pedagogical) to orchestrate AI and human instruction together. The literature suggests some best practices: involve teachers in the development/pilot process (they will feel more ownership and provide crucial feedback), provide ongoing training sessions (not just one-off workshops) including how to read AI reports, how to intervene based on AI signals, and how to explain AI-driven insights to students and parents. One study[18] found that when teachers received regular coaching on integrating adaptive learning software into their lesson plans, student outcomes improved more than in classes where teachers had the software but minimal training. Teachers who were well-trained could, for example, review AI feedback on what concepts students struggled with during homework and then adjust their next-day teaching to cover those gaps, effectively closing the loop between AI data and instruction. In contrast, untrained teachers sometimes either ignored the data or misinterpreted it (like thinking a student was slacking off when actually the AI logs showed the software had a glitch that logged them out). Hence, building teacher capacity is non-negotiable for responsible AI use. This includes not only initial training but also ongoing support (e.g., a helpdesk or community of practice for teachers to share experiences). Additionally, clarifying the teacher's role vis-à-vis the AI is important to reduce any fear that "AI will replace teachers." Emphasizing that the AI is a tool under the teacher's control and highlighting success stories of teachers using AI to make their lives easier can increase the likelihood of using it.

Equity of Access (Cultural and Socioeconomic Considerations)

The digital divide is a serious concern. If AI tools become a key part of effective education, students who lack access to technology or stable internet, or schools that cannot afford cutting-edge AI systems, could be left behind. Many AI-driven interventions require devices (computers, tablets) and connectivity. Students from low-income families or under-resourced schools might not have these at sufficient scale. For students with ADHD specifically, inequities can be exacerbated if, say, only families who can afford a premium subscription to an AI tutoring app get the extra help. There is also the matter of cultural responsiveness: AI content may not reflect the diversity of student backgrounds, potentially disengaging those who don't see themselves in the material. For example, an AI reading tutor might present passages that assume certain cultural knowledge which some students lack, making it harder for them to participate. To ensure equity, initiatives must be taken to make AI tools widely available and affordable, perhaps through government funding, open-source educational AI projects, or sliding scale licensing for schools. Moreover, AI developers should incorporate universal design principles, making sure tools are usable for students with different needs and languages. Some tools, for instance, now offer multilingual support or adjustable interfaces (text-to-speech for those who struggle with reading, etc.), which can benefit subgroups of ADHD students (like those with comorbid dyslexia). Another aspect is adapting AI to different age groups and ADHD subtypes: an elementary student with primarily hyperactive-impulsive ADHD might need a different interface (more game-like, more physical movement integrated) compared to a high school student with primarily inattentive ADHD (who might benefit from more structure and nudges). There is a lack of AI systems tailored by ADHD subtypes in the current literature, which seems to be an area for future development, but the principle of personalization implies we should head that way. Ensuring equity also means actively monitoring outcomes: do all groups of students benefit equally from AI? If one subgroup of students with ADHD is benefiting significantly more from an AI tool than another, it warrants investigation into whether the tool is inadvertently optimized for certain behavioral patterns while overlooking others. Continuous equity audits can help identify and address such disparities.

Managing Expectations and Human Oversight

Finally, a softer yet important point is setting realistic expectations about what AI can and cannot do. Over-reliance or unrealistic expectations could lead to frustration or abandonment of the technology. For instance, if a school implements an

AI system expecting it to automatically "fix" ADHD students' behavior, they will be disappointed because the human element of encouragement, relationship-building, and expert judgment remains essential. Overhyping could also lead to underestimating the risks discussed above. Therefore, part of responsible integration is educating all stakeholders (teachers, parents, students) about the AI's capabilities and limitations. A responsible deployment might include a kickoff meeting where the school communicates that the new system is intended to support personalized learning and provide timely feedback, but emphasizes that it is only a tool under human supervision. Educators can explain that the system may occasionally make errors or lack full context about a student, and in such cases, decisions will be guided by teacher judgment and family input. Encouraging a mindset that AI offers suggestions, not verdicts, allows for collaboration between human insight and machine insight. One framework suggested in the literature is the "human-in-the-loop" model, which advocates for a human (teacher or specialist) to review or mediate AI outputs, especially for consequential decisions[5,19]. For example, an AI might identify a student as needing counseling due to certain emotional signals; rather than acting directly on that, a school counselor would receive the recommendation and then personally check in with the student to validate the concern and determine appropriate action. This approach helps catch errors and allows for personalized support beyond what AI systems can provide.

In summary, ensuring that AI is responsibly leveraged for students with ADHD involves a multifaceted set of considerations. Fairness, transparency, privacy, validity, educator training, and equitable access must all be addressed through deliberate design and policy choices[5,19]. The overarching principle is that AI in education should adhere to the same ethical standards we expect of educators: do no harm, promote equity, respect student rights, and support every child's potential[20,21]. Current research and early implementations offer a roadmap of both pitfalls to avoid and strategies that work. For example, involving ADHD advocates and neurodiversity experts in the design of AI tools helps ensure that such tools are attuned to learners' real-world needs[4]. Encouragingly, major organizations and governments have begun developing formal guidelines, such as UNESCO's Guidance for AI in Education and the European Union's Guidelines for Trustworthy AI, which emphasize principles like human agency, privacy, inclusiveness, and accountability[20,21]. As these frameworks gain traction, it is anticipated that future AI deployments will undergo more rigorous vetting and oversight.

Discussion

The literature reveals that artificial intelligence, when applied thoughtfully, has the potential to significantly enhance educational experiences for students with ADHD. By offering personalized learning pathways, immediate feedback loops, and organizational support, AI technologies directly address many challenges that have long impeded the academic progress of ADHD learners. Academic outcomes can improve because AI tutors and adaptive platforms help maintain engagement, fill knowledge gaps, and create consistent work habits in students who otherwise struggle with inattention and executive dysfunction. Emotional and social outcomes may also benefit because AI-driven tools can reduce student frustration through timely support, build confidence by providing a nonjudgmental learning environment, and assist in teaching self-regulation strategies.

A key contribution of this paper is a conceptual framework (Figure 2) that synthesizes how specific ADHD-related challenges can be mapped to AI-driven interventions and, in turn, how those interventions lead to improved outcomes. The framework identifies four major challenge domains for ADHD students: (1) Sustaining Attention and Engagement, (2) Executive Functioning and Organization, (3) Emotional Regulation and Motivation, and (4) Social Interaction and Communication. For each domain, one or more AI strategies identified in the reviewed literature are linked to expected outcome improvements. For example, in domain (1), Sustaining Attention, the AI strategy of adaptive content delivery combined with real-time attention monitoring is associated with increased on-task time and assignment completion. In domain (3), Emotional Regulation, the AI strategy of affect-sensitive tutoring (recognizing and responding to emotions) is linked to reduced emotional outbursts and greater student self-confidence. This framework demonstrates that AI is not a monolithic solution but rather a toolkit of capabilities that must be matched to the specific needs of learners with ADHD.

Although the evidence supporting these connections is promising, it remains in an early stage of development. Many of the reviewed studies were small-scale or pilots, demonstrating potential but lacking large sample validation. More longitudinal research is needed to assess whether initial gains, such as a one-semester 15% improvement in test scores, persist over time and translate into broader outcomes such as graduation rates or college readiness. Future research should also aim to isolate the effects of AI interventions from confounding factors by employing robust experimental designs, including randomized controlled trials where feasible.

Another area warranting further research is the integration of AI with established, non-technological interventions. For decades, educators have employed strategies such as token economies, visual schedules, and cognitive-behavioral techniques to support students with ADHD. AI systems often mirror the principles underlying these strategies. For instance, the immediate feedback offered by AI reflects the reinforcement logic behind token systems and daily report cards[22]. Similarly, personalized lesson pacing through AI aligns with accommodations provided through IEPs and 504 plans, such as differentiated assignments or extended breaks[2]. The primary advantage of AI lies in consistent, adaptive delivery of these supports without

Table 2 AI Strategies Aligned with ADHD Challenge Domains and Expected Outcomes

ADHD Challenge Domain	AI Strategies	Expected Outcomes
Sustaining Attention and Engagement	Adaptive Content Delivery; Real-Time Attention Monitoring; Gamified Learning Mechanics	Increased On-Task Behavior; Longer Focus Periods; Higher Assignment Completion
Executive Functioning and Organization	AI-Based Planners; Task Management Assistants; Intelligent Reminders	Improved Time Management; Better Task Sequencing; Increased Follow-Through
Emotional Regulation and Motivation	Affect-Sensitive Tutoring; Emotion-Adaptive Prompts; Encouragement Triggers	Reduced Emotional Outbursts; Higher Self-Efficacy; Improved Persistence
Social Interaction and Communication	Emotion Recognition Training; Collaborative Learning Platforms	Enhanced Peer Relationships; Better Emotion Recognition; Improved Classroom Participation

adding to teacher workload. However, AI lacks the nuanced empathy and metacognitive coaching offered by human educators. A hybrid approach, combining AI-based tools for daily structure with human-led coaching or counseling, may offer the most promise. This hypothesis warrants empirical testing to determine whether ADHD students achieve better outcomes under blended support models.

Ethical considerations are essential when deploying AI in educational settings. Limitations such as generalizability, false positives in predictive analytics, and inadequate teacher training must be acknowledged. For example, AI may erroneously flag a student as disengaged when the student is engaged in nontraditional learning behaviors (e.g., brainstorming or self-directed exploration), potentially leading to unnecessary interventions. Ensuring that AI-generated alerts are reviewed by educators can help mitigate such risks. Teacher training is another critical component; AI implementations are most effective when educators feel empowered rather than displaced. Research indicates that in classrooms where AI was adopted successfully, teachers reported having more time for individualized student support because AI took over repetitive tasks such as grading [23].

Cultural and contextual factors must also be considered. ADHD presents differently across individuals and populations, and the effectiveness of AI tools may vary based on socioeconomic status, cultural norms, and resource availability. Culturally responsive AI tools, those that reflect students' linguistic and lived experiences, may be necessary to ensure engagement and effectiveness across diverse populations. Developers should incorporate diverse voices during design and testing to ensure broad applicability.

This literature review employed a qualitative approach rather than a formal systematic review or meta-analysis. While it followed structured processes inspired by PRISMA guidelines, it is possible that recent or emerging studies were not included. Additionally, some references cited (e.g., gray literature or non–peer-reviewed sources) were included to reflect the evolving nature of the field but should be interpreted with appropriate caution. The review focused on K–12 education, and future work should explore the role of AI in supporting postsecondary students and adults with ADHD.

Overall, the evidence suggests cautious optimism. While AI is not a cure-all, it holds the potential to significantly enhance learning for ADHD students, particularly when it delivers personalized, consistent, and immediate support that aligns with best practices in special education. Technology's promise lies in enabling more scalable, equitable, and data-informed interventions without diminishing the critical role of human educators.

Collaboration across disciplines, among technologists, educators, clinicians, and families, is essential for continued progress. Participatory design processes that bring together all stakeholders may lead to tools that are not only innovative but also user-friendly and pedagogically sound.

This review finds that artificial intelligence, when thoughtfully designed and ethically implemented, can meaningfully support both academic and emotional outcomes for students with ADHD. AI-driven personalized learning systems have demonstrated improvements in attention, task completion, and knowledge retention by adapting to individual needs and providing real-time feedback. AI tools that integrate affective computing and emotional intelligence, such as detecting frustration and offering positive reinforcement, also contribute to greater student confidence and emotional regulation.

To realize these benefits, stakeholders must proactively address challenges related to fairness, transparency, privacy, educator training, and equitable access. For instance, algorithmic decision-making must be auditable, and AI tools should be accompanied by mechanisms that allow teachers to review, modify, or override outputs when needed. Ethical guidelines such as UNESCO's AI and Education: Guidance for Policymakers and the European Commission's Ethics Guidelines for Trustworthy

AI offer helpful frameworks for ensuring that educational AI respects human agency, inclusiveness, and accountability[20,21]. Ultimately, AI should serve as a scaffold, supporting ADHD students in ways that amplify rather than replace the role of teachers. When used responsibly, AI has the potential to transform learning environments into more inclusive, responsive, and empowering spaces for neurodiverse learners.

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