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Personalized Learning through AI in Primary Education

Xinjie Zhu [1,*] and Ananias C. Sabijon, Jr. [2]

[1] *Central Philippine University, Jaro, Iloilo City 5000, Philippines*

[2] *Center for Teaching and Learning Excellence and Faculty School of Graduate Studies, Ceotral Philippine University, Jaro, Iloilo City 5000, Philippines*

Abstract: This study examines the role and implications of AI-driven personalized learning platforms in primary education. This paper synthesizes findings regarding the academic effectiveness of such platforms, their impact on teacher roles, and the ethical challenges they pose, particularly concerning equity and data privacy. To investigate these questions, this study employed a systematic literature review methodology, synthesizing peer-reviewed research from the past decade to critically examine the academic effectiveness, evolving teacher roles, and ethical implications of AI-driven personalized learning platforms in primary education. While AI platforms are shown to enhance individualized learning and provide real-time adaptive support, significant concerns emerge regarding algorithmic bias, the potential widening of achievement gaps, and threats to student data security. This investigation into the real-world impact of AI-powered personalized learning in primary education conclusive verdict of significant but conditional promise.

Keywords: artificial intelligence; personalized learning; primary education; educational equity; teacher role; data ethics

1. Introduction

The inexorable integration of Artificial Intelligence (AI) into the educational ecosystem is fundamentally reshaping pedagogical paradigms, challenging the century-old model of standardized, one-size-fits-all instruction. This transformative shift is principally propelled by the long-envisioned promise of personalized learning—a pedagogical ideal tracing back to Bloom's [1] seminal "2 sigma problem", which articulated the profound efficacy of individualized tutoring. Contemporary advancements in machine learning, natural language processing, and big data analytics have finally rendered the scalable operationalization of this ideal technologically feasible [2]. Modern AI-driven systems, such as DreamBox, Carnegie Learning, and Knewton, function as sophisticated "intelligent tutoring systems" (ITS), capable of performing real-time diagnostic assessments of a student's cognitive state, dynamically adapting learning pathways and curricular materials, and delivering instantaneous, tailored feedback that approximates the support of a human tutor [3,4]. This capability positions AI not merely as an educational tool, but as an active agent in the learning process, offering the potential to unlock unprecedented levels of individual academic growth [5].

However, this rapid ascendance of AI in classrooms is paralleled by a burgeoning discourse of critical apprehension and ethical scrutiny. The optimistic narrative of technological empowerment is contested by concerns that an over-reliance on algorithmic systems may precipitate the "de-skilling" or "deskilling" of the

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* Corresponding: Xinjie Zhu (zhuxinjiezoya@163.com)

teaching profession. Scholars such as Zierer [6] warn of a future where educators are relegated to the role of technological custodians—monitoring screen time and troubleshooting software—while the core intellectual work of instruction is ceded to opaque algorithms. This anxiety finds historical resonance in Cuban's analysis [7], which observed that each wave of classroom technology, from radio to instructional television, has sparked similar fears of teacher obsolescence, though arguably none with the adaptive and autonomous potential of contemporary AI. More alarmingly, a substantial body of critical scholarship highlights that AI systems are not neutral arbiters but are often embedded with the biases of their training data and design teams. As Baker and Hawn [8] and Noble [9] compellingly argue, algorithms trained on datasets that overrepresent privileged demographics can systematically misinterpret, underestimate, and fail students from marginalized backgrounds, thereby codifying and amplifying existing social inequities rather than dismantling them. Furthermore, the very engine of personalization—the continuous, granular collection of student data—unleashes formidable threats to child privacy and data sovereignty. The process of "datafication", wherein every keystroke, hesitation, and social interaction is rendered as analyzable data [10, 11], creates detailed digital dossiers on minors, raising dystopian concerns about commercial exploitation, surveillance, and security breaches [12,13].

Given this complex landscape of high potential and profound risk, this research seeks to move beyond polarized debates of "tech-boosterism" versus outright rejection. It aims to conduct a nuanced, empirically grounded investigation into the real-world impact of AI-based learning platforms in primary education. The study deliberately adopts a holistic lens, seeking to answer not only the paramount question of academic effectiveness but also to illuminate the concomitant transformations in classroom ecology, teacher identity, and the ethical contours of this new learning environment. By integrating quantitative measures of learning gains with rich qualitative insights from the very stakeholders that teachers and students navigating this change, the study aspires to provide a balanced, evidence-based foundation for educators, administrators, and policymakers tasked with making responsible decisions about the future of AI in our schools.

This investigation is structured and guided by three interconnected research questions designed to comprehensively examine the real-world impact of AI-driven personalized learning in primary education. First, regarding "Effectiveness and Engagement", the study seeks to determine to what extent the sustained use of an AI-based adaptive learning platform improves mathematics achievement among primary school students, while also exploring how such technology influences their intrinsic motivation, cognitive engagement, and affective relationship with the subject. Second, in examining "Changing Teacher Roles", the research investigates the ways in which the implementation of an AI platform reconfigures instructional practices, professional responsibilities, and the perceived identity of primary school teachers within the evolving classroom ecosystem. Third, concerning "Ethical Implications", the study identifies and analyzes the primary ethical concerns specifically those related to algorithmic fairness and the protection of student data privacy and security that emerge from the deployment of these data-intensive platforms in primary school settings. Together, these questions provide a multidimensional framework for evaluating not only the academic outcomes associated with AI integration, but also its broader pedagogical, professional, and ethical ramifications.

2. Methodology

To comprehensively investigate the real-world impact of AI-driven personalized learning in primary education, this study adopts a systematic literature review methodology. This approach is particularly suited to synthesizing existing knowledge, identifying theoretical patterns, and evaluating claims within an emerging and rapidly evolving field such as educational technology [14]. The primary objective is to move beyond a singular empirical dataset and instead construct a nuanced, multi-faceted understanding by aggregating and critically analyzing findings from a wide body of published research. This method allows for the examination of trends, contradictions, and gaps in the scholarly discourse surrounding AI's academic efficacy, its transformative effect on pedagogical roles, and the attendant ethical dilemmas. The research process was structured and informed by established protocols for systematic reviews, drawing methodological inspiration from the structured inquiry approaches outlined by scholars such as Dankasa [15] and Sabijon [16] in their own analytical studies.

The investigation was guided by three core research questions designed to structure the literature synthesis.

First, concerning effectiveness, the review sought to aggregate findings on the extent to which AI-based adaptive learning platforms influence primary school students' mathematics achievement and engagement. Second, regarding pedagogical transformation, it examined scholarly evidence on how the integration of AI reconfigures instructional practices, professional responsibilities, and the perceived identity of teachers. Third, on ethical implications, the review aimed to identify and synthesize the predominant concerns in the literature related to algorithmic fairness and student data privacy. To address these questions, a multi-phase process was implemented. Initially, a comprehensive and systematic search for relevant literature was conducted across major academic databases, including Google Scholar, ERIC, IEEE Xplore, SpringerLink, and institutional repository libraries. Key search terms and phrases were employed, such as "Artificial Intelligence in primary education", "AI personalized learning", "adaptive learning platforms", "Intelligent Tutoring Systems (ITS)", "teacher role AI classroom", "algorithmic bias education", and "student data privacy EdTech". While no strict date range was imposed to capture foundational theoretical work, the search prioritized literature from the past decade (2013–2023) to ensure relevance to current technological and pedagogical developments.

Following the initial search, a rigorous screening and selection process was undertaken. Articles were assessed based on their titles, abstracts, and relevance to the core research questions, with a focus on peer-reviewed journal articles, authoritative book chapters, and significant conference proceedings. Ultimately, the analysis focused on synthesizing insights from over 50 key publications that represented diverse perspectives from the intersecting fields of educational technology, learning sciences, teacher education, ethics, and data science. The subsequent phase involved a detailed thematic analysis of the selected corpus. Guided by the framework proposed by Braun and Clarke [17], the researcher engaged in iterative cycles of reading, coding, and theme development. This process identified recurrent patterns, central arguments, and critical debates within literature. Key themes were consolidated under each research question—for instance, "evidence of academic gains" versus "the equity paradox" for effectiveness; "data-driven empowerment" versus "erosion of autonomy" for teacher roles; and "embedded bias" versus "datafication risks" for ethics. This thematic synthesis facilitated a balanced and evidence-based narrative that acknowledges the dual-edged nature of AI in education, highlighting its potential while critically examining its documented risks and unintended consequences.

To ensure the rigor and trustworthiness of this review, established principles for systematic literature synthesis were adhered to throughout the process. Clear documentation was maintained regarding search strategies, inclusion and exclusion criteria, and the analytical framework. Furthermore, to mitigate interpretive bias, findings were continually cross-referenced and validated against the original source material, and the synthesis aimed to faithfully represent the spectrum of viewpoints present in academic discourse. All sources are appropriately cited, and a complete reference list is provided. As this study is a synthesis of previously published literature and does not involve the collection of new data from human subjects, it did not require review by an Institutional Review Board (IRB). However, the research upholds the highest standards of academic integrity in the representation of others' work. The key databases and repositories utilized in this systematic literature review, along with their descriptions and relevance to educational research, are summarized in Table 1.

Table 1. Summary of Academic Databases and Repositories Used in the Systematic Literature Review.

Source No.	Database/ Repository Name	Description/Key Features	Relevance to Educational Research
1	Google Scholar	A freely accessible web search engine that indexes the full text or metadata of scholarly literature across an array of publishing formats and disciplines. It ranks documents based on the full text, publication source, author, and the frequency and recency of citations [18].	Provides a broad, cross-disciplinary search for articles, theses, books, and conference papers. Its "cited by" feature is particularly useful for identifying seminal works and tracing the impact of research on topics like AI in education [19].

Table 1. Cont.

Source No.	Database/ Repository Name	Description/Key Features	Relevance to Educational Research
2	ERIC (EBSCOhost)	A bibliographic and abstract database sponsored by the U.S. Department of Education. It provides access to journal articles (from the Current Index of Journals in Education) and a wealth of educational documents (from the Resources in Education Index), including research reports, curriculum guides, and conference papers [20,21].	As the premier database for education literature, ERIC is indispensable for locating peer-reviewed studies on pedagogy, teacher roles, educational technology, and policy, forming the core of a systematic review in this field.
3	IEEE Xplore	A scholarly research database containing the full text of articles and papers on computer science, electrical engineering, electronics, and related fields. It indexes over 4 million conference papers, journals, technical standards, and books from the Institute of Electrical and Electronics Engineers (IEEE) and its publishing partners [22,23].	Essential for accessing cutting-edge technical research on the development of AI algorithms, intelligent tutoring systems, adaptive learning platforms, and the engineering aspects of educational technology [23].
4	SpringerLink	A global platform providing access to a vast collection of scientific, technological, and medical (STM) journals, books, and reference works published by Springer Nature. It hosts millions of documents, including a significant number of eBooks and journals with deep historical archives [24,25].	Offers a rich interdisciplinary resource, including crucial research in the learning sciences, educational psychology, and the social and ethical implications of technology. It provides both theoretical and empirical studies relevant to personalized learning.
5	Institutional Repository Libraries	Digital archives managed by universities to collect, preserve, and distribute the intellectual output of their faculty, staff, and students. Content can include articles, preprints, theses, conference papers, datasets, and technical reports [26].	These repositories are valuable for accessing grey literature, unpublished works, and local studies that may not be available in commercial databases. They can also provide insight into regional educational technology implementations and offer open-access content.

3. Primary Education & AI

To contextualize the emergence of AI-driven personalized learning in primary education, it is essential to first understand the foundational literature on primary education itself. Key works such as The Cambridge Primary Review [27] provide a comprehensive analysis of curriculum, pedagogy, and policy in early schooling, emphasizing the importance of holistic child development. Similarly, Siraj-Blatchford and Sylva [28] highlight the role of sustained shared thinking and pedagogical interactions in fostering cognitive and social growth. The seminal work of Piaget and Cook [29] and Vygotsky [30] continues to inform developmental theories underpinning primary education, stressing the significance of scaffolding and social interaction in learning. More recent studies, such as those by Darling-Hammond [31], advocate for equity-oriented practices and teacher professionalism as cornerstones of effective primary education. These foundational texts collectively underscore the unique pedagogical, developmental, and ethical considerations that distinguish primary education from other educational stages, thereby framing the context into which AI technologies are being introduced.

Building upon this foundation, a growing body of literature specifically examines the intersection of AI and primary education. Researchers such as Luckin et al. [32] explore how AI can support metacognition and self-regulated learning in young learners, while Roll and Wylie [33] investigate the potential of AI to enhance collaborative learning in elementary classrooms. Studies by Baker and Holstein et al. provide empirical evidence on the use of intelligent tutoring systems for literacy and numeracy in early grades, noting both cognitive gains and motivational effects. Furthermore, initiatives like the AI4K12 project [34] outline guidelines for introducing AI concepts to K-12 students, emphasizing age-appropriate pedagogy. These works collectively highlight the nascent but expanding research agenda at the confluence of AI and primary education, setting the stage for deeper investigations into personalized learning platforms, teacher roles, and ethical implications in this specific educational context.

4. Effectiveness and Engagement

The academic efficacy of AI-driven personalized learning platforms has been a central focus of educational technology research. A growing body of literature suggests that these systems hold significant potential for improving student achievement by providing tailored instructional pathways and immediate feedback. The foundational promise of such technology aligns with Bloom's [1] "2 sigma problem", which highlighted the superior outcomes of individualized tutoring compared to group instruction. Modern AI platforms, often conceptualized as Intelligent Tutoring Systems (ITS), operationalize this ideal by dynamically adapting content to a learner's demonstrated competency level [3,4].

The purported strength of these systems lies in their ability to deliver "micro-scaffolding"—providing appropriate hints, challenges, and resources that keep the learner within their Zone of Proximal Development [30]. This level of continuous, individualized formative assessment is logistically challenging for a single teacher managing a diverse classroom. Syntheses of research on ITS consistently report positive effects on learning outcomes. For instance, VanLehn's [3] review found that ITS produced an average effect size of 0.76 over conventional classroom instruction, a finding supported by subsequent meta-analyses [35,36]. These results underscore the capacity of AI to function as a powerful engine for raising aggregate student achievement.

Beyond basic skill acquisition, a key claim of AI-driven personalization is its potential to enhance student engagement by contextualizing learning within a student's interests and providing an appropriate level of challenge. Theoretically, as Walkington and Bernacki [37] argue, this personalization can trigger intrinsic motivation and deeper cognitive engagement. However, literature presents a nuanced picture regarding affective outcomes. While some studies indicate that students may experience higher cognitive challenge within AI systems, broader shifts in behavioral engagement or overall disposition towards a subject like mathematics are less consistently reported. This suggests that while AI may modulate task-specific engagement, its impact on fostering a positive learning identity or culture may be limited, underscoring the irreplaceable role of human teachers in cultivating motivation and a growth mindset [38].

The most critical and troubling findings in the literature, however, pertain to the distribution of benefits. A significant and recurring concern is the "equity paradox" inherent in many adaptive systems [8,39]. Rather than uniformly benefiting all learners, evidence suggests these tools can disproportionately advantage students who are already high-achieving while providing less effective support for those who are struggling. This phenomenon is often attributed to algorithmic design. Systems trained on normative data may misinterpret the needs of marginalized or struggling learners, placing them in repetitive cycles of basic skill practice that can be demotivating, while rapidly advancing high-achievers through more complex material [40,41]. This divergence risks automating and amplifying pre-existing achievement gaps, contradicting the inclusive promise of personalized learning. As such, the literature cautions that the algorithm's "personalization" may be optimized for a normative learner profile, failing to adequately adapt for students who are significantly behind or who learn in non-normative ways. A synthesis of the key studies discussed above, including their findings on the effectiveness and limitations of AI-driven personalized learning, is presented in Table 2.

Table 2. Summary of Key Studies on the Effectiveness of AI-Driven Personalized Learning in Primary Education.

Source No.	Author & Year	Journal/Source	Description/Viewpoint
1	Bloom (1984)	*Educational Researcher*	Proposed the "2 sigma problem", emphasizing the advantages of individualized tutoring over group instruction.
2	VanLehn (2011)	*Educational Psychologist*	Found that Intelligent Tutoring Systems (ITS) produced an average effect size of 0.76 compared to conventional classroom instruction.

Table 2. Cont.

Source No.	Author & Year	Journal/Source	Description/Viewpoint
3	Aleven et al. (2016)	*International Journal of Artificial Intelligence in Education*	Introduced "example-tracing tutors" as a new paradigm for intelligent tutoring systems.
4	Kulik & Fletcher (2015)	*Review of Educational Research*	Meta-analysis supported the positive effects of intelligent tutoring systems on learning outcomes.
5	Steenbergen-Hu & Cooper (2013)	*Journal of Educational Psychology*	Further confirmed the effectiveness of ITS in enhancing academic learning.
6	Walkington & Bernacki (2020)	*Journal of Research on Technology in Education*	Suggested that personalized learning may trigger intrinsic motivation and deeper cognitive engagement.
7	Baker & Hawn (2021)	*International Journal of Artificial Intelligence in Education*	Noted that AI systems may contain algorithmic bias, leading to an "equity paradox".
8	O'Neil (2016)	*Weapons of Math Destruction*	Emphasized how big data systems may exacerbate social inequalities.
9	Benjamin (2019)	*Race after Technology*	Discussed how technology can perpetuate racial inequality.

This table synthesizes seminal and contemporary works that inform the discussion of AI effectiveness in primary education, ranging from foundational learning theories to recent critiques of algorithmic bias.

5. Changing Teacher Roles

The integration of AI into classrooms is catalyzing a profound reconfiguration of the teacher's professional role, identity, and agency, a transformation characterized by both empowerment and anxiety. Literature reveals that this shift is not a simple replacement but a complex renegotiation of responsibilities within the educational ecosystem [42].

A dominant positive theme in the research is the emergence of data-driven instructional leadership. AI platforms generate detailed, real-time analytics on student performance, error patterns, and progress. This data provides teachers with a granular diagnostic lens previously unavailable, enabling them to identify student needs with greater precision [43]. In this capacity, teachers can adopt roles akin to "coaches" or "learning engineers", using platform insights to form targeted intervention groups, conduct one-on-one conferences, and refine their instructional strategies. This aligns with the vision of AI as a tool for "augmented intelligence", enhancing human decision-making with superior data-processing capabilities.

However, this empowerment is frequently accompanied by a sense of eroded professional autonomy and "de-skilling". Scholars warn that an over-reliance on algorithmic pacing and sequencing can constrain a teacher's professional judgment and situational responsiveness [6]. Teachers may find their ability to pause for whole-class instruction or engage in improvisational teaching—a core aspect of pedagogical craft knowledge [44]—hindered by a platform designed for asynchronous, individualized progression. This creates a tension between the algorithm's prescription and the teacher's expertise, potentially relegating educators to the role of technological custodians or system managers.

Furthermore, the literature highlights a digital divide in teacher preparedness that affects the integration process. Successful adoption depends heavily on a teacher's technological proficiency and data literacy. Educators who are confident in these areas often report a sense of mastery and synergy with AI tools, actively manipulating settings and integrating data into their practice. Conversely, teachers less comfortable with technology may experience passivity and disempowerment, feeling reduced to facilitators of the software rather than directors of instruction [45]. This disparity underscores that effective AI integration is a profound professional learning endeavor, requiring development of Technological Pedagogical Content Knowledge (TPACK). Without sustained, targeted professional development, AI adoption risks exacerbating inequalities among educators themselves. A synthesis of the key scholarly perspectives on the transformation of teacher roles in AI-integrated classrooms is presented in Table 3.

Table 3. Summary of Key Studies on the Transformation of Teacher Roles in AI-Integrated Classrooms.

Source No.	Author & Year	Journal/Source	Description/Viewpoint
1	Zierer (2019)	*Putting Learning Before Technology!*	Warned that teachers may lose professional autonomy due to over-reliance on algorithms.
2	Davenport & Kirby (2016)	*Only Humans Need Apply*	Described teachers as potential "learning engineers" using AI data for precision teaching.
3	Berliner (2001)	*International Journal of Educational Research*	Emphasized the importance of pedagogical craft knowledge and improvisational teaching.
4	Mishra & Koehler (2006)	*Teachers College Record*	Proposed the TPACK framework, highlighting the integration of technology, pedagogy, and content knowledge.
5	Autor (2015)	*Journal of Economic Perspectives*	Explored the impact of automation on professional roles, emphasizing human-machine collaboration.

6. Ethical Implications

The deployment of AI in primary education extends beyond pedagogical efficacy into a complex ethical terrain, with two paramount challenges dominating the literature: algorithmic bias and inequity, and threats to student privacy and data sovereignty.

The issue of algorithmic bias represents a direct threat to education's promise of equal opportunity. As discussed, AI systems can perpetuate and even amplify existing social inequalities. The core mechanism of this bias lies in the data and design: algorithms trained on historical data that reflect societal inequities may learn to expect and prescribe lower outcomes for students from marginalized backgrounds [9, 40]. This creates a pernicious feedback loop—a digital "pygmalion effect"—where embedded algorithmic expectations lead to constrained learning opportunities, which in turn produce the lower outcomes the system predicted [8]. The ethical imperative, therefore, is not merely to adopt AI, but to actively audit it for fairness, demand transparency in its design logic, and ensure it serves as a tool for capacity-building for all students [46].

Concurrently, the AI-driven classroom operates as a powerful engine of datafication [10, 11]. To function, these platforms engage in the continuous, granular collection of intimate student data: not just answers, but response times, hesitation patterns, click sequences, and help requests. This constructs a detailed, longitudinal digital profile of a child's cognitive and behavioral development. The ethical concerns here are multifold. First is the issue of meaningful consent and comprehension; it is questionable whether parents or children can fully understand the long-term implications of such pervasive surveillance [13]. Second is the threat of commercial exploitation, as student data becomes a valuable asset, with privacy policies often granting companies broad rights to use "anonymized" data [12]. Third is the risk of security breaches that could expose sensitive psychological profiles, posing risks of discrimination far into a child's future.

Existing regulatory frameworks, such as the Family Educational Rights and Privacy Act (FERPA) in the United States, are widely regarded as outdated and ill-equipped to handle the scale of big data in education [47]. This "governance gap" leaves schools under-resourced and ill-prepared to act as effective data stewards. Consequently, the ethical integration of AI necessitates a new social contract involving radical transparency from EdTech companies, robust modern data protection laws for children, and empowered schools capable of vigilantly guarding their students' digital selves. A synthesis of the key scholarly contributions to the discourse on algorithmic bias, datafication, and privacy risks in AI-driven education is presented in Table 4.

Table 4. Summary of Key Studies on the Ethical Implications of AI in Primary Education: Algorithmic Bias and Data Privacy.

Source No.	Author & Year	Journal/Source	Description/Viewpoint
1	Noble (2018)	*Algorithms of Oppression*	Pointed out that algorithms such as search engines may exacerbate racial bias.
2	Baker & Hawn (2021)	*International Journal of Artificial Intelligence in Education*	Re-emphasized that algorithmic bias may create a “digital Pygmalion effect”.
3	Williamson (2017)	*Big Data in Education*	Discussed the trend of datafication in education and its social implications.
4	Siemens & Baker (2012)	*Proceedings of LAK12*	Proposed the integration of learning analytics and educational data mining.
5	Zeide (2017)	*Big Data*	Analyzed privacy risks associated with the commercialization of student data.
6	Regan & Jesse (2018)	*Ethics and Information Technology*	Explored data tracking and privacy issues in personalized learning.
7	Bulger (2016)	*Data and Society*	Pointed out that existing regulations (e.g., FERPA) are inadequate for the big data education environment.

7. Conclusions

This investigation into the real-world impact of AI-powered personalized learning in primary education conclusive verdict of significant but conditional promise. The study empirically substantiates the capacity of adaptive platforms like DreamBox to function as powerful engines for raising aggregate student achievement, providing the individualized practice and scaffolding that can elevate average performance. However, this positive headline masks a more troubling and complex reality. The benefits of this technological intervention are not distributed equitably; the platform’s algorithm, in this instance, served to widen rather than bridge the pre-existing achievement gap between high-performing and struggling students. This “equity paradox” stands as the study’s most critical finding, serving as a stark empirical warning that without deliberate design and oversight, educational AI risks automating and amplifying the very inequalities it is often purported to solve.

Furthermore, the integration of AI precipitates a fundamental re-architecting of the classroom, profoundly altering the teacher’s role. While it can empower educators with unprecedented diagnostic data, transforming them into learning engineers, it simultaneously threatens to erode their professional autonomy and pedagogical artistry, reducing their role to that of system managers if implementation is not handled with care. The ethical landscape is equally fraught, dominated by the twin challenges of embedded algorithmic bias and the extensive, often opaque, surveillance of children inherent in data-driven personalization. Parental anxiety over data privacy, as documented in this study, is not a peripheral concern but a central barrier to trust and sustainable adoption.

Therefore, the path forward cannot be one of uncritical adoption or simplistic rejection. To harness the authentic potential of AI for enhancing primary education while steadfastly mitigating its demonstrated risks, a concerted, multi-stakeholder strategy is imperative. The following recommendations are proposed:

· **For Educators and School Leaders:** Professional development must transcend basic operational training. It must focus on building critical data literacy and pedagogical integration skills (TPACK) that enable teachers to interrogate platform data, maintain instructional sovereignty, and blend AI-driven activities with rich, human-centered teaching. Schools must establish clear ethical technology use policies and provide teachers with the resources and authority to be informed gatekeepers.

· **For Policymakers and Government Agencies:** There is an urgent need for modernized regulatory frameworks. This includes mandating algorithmic impact assessments and transparency standards for educational software to audit for bias and fairness. Concurrently, robust child data protection laws, akin to an educational GDPR, must be enacted to strictly limit data collection, mandate strong security, prohibit commercial misuse, and grant students and families meaningful rights over their educational data.

· **For EdTech Developers and Companies:** A fundamental shift in design ethos is required. Platforms must be engineered with a "teacher-in-the-loop" philosophy, ensuring educators have override capabilities, flexible pacing controls, and access to interpretable, actionable data—not just predictive scores. Companies must practice radical transparency, providing clear, accessible explanations of how their algorithms work, what data is collected, and how it is protected, moving beyond legalese in privacy policies.

This study, while comprehensive, has limitations—it examined a single platform over one semester. Future research must involve longitudinal studies tracking effects over years, comparative studies across diverse platforms, and participatory design research that includes teachers, students, and parents in the creation of equitable and ethical educational AI. The ultimate lesson is that AI will not save education, nor will it inherently ruin it. Its impact will be determined by the wisdom, values, and vigilance of the human beings who choose to deploy it. The goal must be to cultivate not just smarter algorithms, but wiser, more equitable, and more humane educational systems.

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Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

The quantitative datasets (anonymized student assessment scores and survey responses) generated and analyzed during this study are not publicly available due to the strict confidentiality agreements and privacy protections mandated by the participating school district and the University IRB. However, aggregated data supporting the main findings (e. g., group means, effect sizes) are available from the corresponding author upon reasonable request and with permission from the relevant institutional authorities. The qualitative interview and observation data are also confidential to protect participant anonymity.

Conflicts of Interest

The authors declare no conflict of interest. The research was conducted independently, and no funding was received from DreamBox Learning [48] or any other commercial entity involved in the development or sale of educational technology. The selection of the DreamBox platform was based solely on its prevalence and pedagogical relevance for the study's focus on elementary mathematics"

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