Sustainable Development of AI-Based Educational Tools: Addressing Affordability and Equity between Private and Public Schools in Saudi Arabia's Early Childhood Education

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Abstract: The integration of artificial intelligence (AI) in early childhood education offers major opportunities for personalized learning but also exposes equity gaps between private and public institutions. This study investigates the affordability, accessibility, and sustainability of AI-based educational tools across Saudi Arabia's early childhood education sector using an explanatory sequential mixed-methods design. Quantitative survey data were collected from 127 participants representing both private (68) and public (59) schools, followed by 14 in-depth interviews to capture contextual experiences. Results show clear disparities in AI adoption and readiness. Private institutions reported markedly higher use of adaptive learning platforms (78 % vs 12 %), educational robots (45 % vs 3 %), and AI-based assessment tools (52 % vs 8 %). They also benefited from dedicated technology budgets (73 % vs 23 %) and higher rates of teacher training (62 % vs 18 %), creating positive feedback loops that reinforce innovation. Public schools, however, cited affordability concerns (92 %), inadequate infrastructure (68 %), and limited professional development (86 %) as primary obstacles, widening the digital divide. Four major themes emerged: technological readiness, financial constraints, professional development gaps, and differing perceptions of educational effectiveness. The findings highlight that sustainable AI integration requires more than funding; it demands coordinated infrastructure investment, continuous teacher training, and equity-driven policy reform. The study recommends government subsidies for AI procurement in public schools, mandatory AI literacy programs for teachers, and strategic public-private partnerships to ensure long-term technological sustainability. This research contributes the first comprehensive evidence on AI equity in Saudi early childhood education, offering actionable insights for policymakers pursuing inclusive digital transformation under Vision 2030.

Keywords: artificial intelligence, early childhood education, educational equity, digital divide, Saudi Arabia, educational policy, sustainable development, educational technology.

I. INTRODUCTION

Artificial intelligence (AI) is rapidly transforming education by introducing data-driven and adaptive tools that personalize learning and improve engagement [1]. In Early Childhood Education (ECE), AI-based technologies such as adaptive learning platforms and interactive applications enable young children to learn and acquire essential skills through individualized experiences [2]. These innovations make learning more dynamic and responsive to each child's developmental needs. However, their implementation still faces major challenges related to cost, accessibility, and equitable distribution of resources [3].

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In Saudi Arabia, the education system is divided between private and public sectors that differ widely in technological readiness and funding. Private schools, with greater financial flexibility, more easily adopt emerging technologies, whereas public schools often serve larger and more socioeconomically diverse populations with limited budgets [4, 5]. This imbalance has created a digital divide that restricts equal opportunities for children to benefit from AI-assisted learning [6].

Despite global interest in AI integration, research focusing on early childhood education within the Middle East remains scarce. Saudi Arabia represents a critical context because of its dual-sector structure and the ongoing educational transformation under Vision 2030 [7]. This combination of modernization and structural inequality defines a key research gap. The present study addresses this gap by examining how affordability, accessibility, and institutional equity influence the sustainable adoption of AI-based educational tools in Saudi Arabia's early childhood education sector.

Application of AI is in its early stage of development within the context of Saudi Arabian early childhood education, and this affects the process of assimilating such technology in the area of both, the private and the state sector. In addition to being affordable, cultural relevance, teacher preparation and sustainability should be dealt with as well. If no efforts are taken to bridge the gap between the private and the public sphere, there is concern that AI could deepen existing disparities in the education system, leaving children in underfunded schools at an even greater disadvantage.

Recent national developments reinforce the timeliness and policy relevance of this study. In early 2024, the Ministry of Education, in collaboration with the National Curriculum Center, the Ministry of Communications and Information Technology, and the Saudi Data and Artificial Intelligence Authority (SDAIA), announced the rollout of a comprehensive AI curriculum across all levels of public education, beginning in the 2025–2026 academic year [8]. This initiative introduces structured, age-appropriate modules designed to build foundational skills in data literacy, ethical AI use, and critical thinking. With substantial government funding already allocated for technology and AI integration in public schools, the central challenge is no longer the lack of resources but the strategic planning and capacity building required to ensure their effective use. Prioritizing technical infrastructure development and mandatory teacher training will be essential to translating this national vision into meaningful classroom practice, in line with Saudi Arabia's Vision 2030 goals for educational transformation.

This paper attempts a discussion of these issues by exploring the current situation in the adoption of AI in the early childhood education sector of Saudi Arabia, paying special attention to the aspects of disparity between the private and governmental sectors of teaching. The question the research seeks to answer is how affordable, accessible, and sustainable the tools aimed at AI in education are. Such a complexity of incorporating AI into educational system and the specific nature of obstacles that Saudi Arabian dual-sector early childhood education system faces make this study cover several interrelated research dimensions. The research aims are as follows:

- To explore how the adoption of AI-based educational tools differs between private and public early childhood schools in Saudi Arabia
- To examine the specific infrastructural and policy barriers impacting the affordability and accessibility of AI tools in public early childhood schools compared to private institutions
- To understand the perceptions of teachers and school administrators in both public and private early childhood institutions regarding the use of AI tools for young children's education
- To identify policy strategies that could promote affordable, equitable, and sustainable access to AI-based educational tools across both sectors
- To develop comprehensive policy recommendations for promoting equitable access to AI-based educational technologies while ensuring sustainable implementation.

While global studies have explored AI integration in general education, there is limited evidence addressing how affordability and institutional equity influence AI adoption in early childhood education within the Saudi Arabian context. The unique dual-sector system (public vs. private) and ongoing Vision 2030 reforms create unexplored dimensions regarding sustainable AI accessibility.

Based on this gap, the study addressed the following research questions:

- How do private and public early childhood institutions in Saudi Arabia differ in their adoption of AI-based educational tools?
- What factors influence the affordability and accessibility of AI tools across these sectors?
- How do teachers and administrators perceive equity and sustainability in AI integration?
- What policy interventions can enhance affordable and equitable AI access in early childhood education?

This investigation makes several significant contributions to the existing body of knowledge on educational technology adoption and equity. It provides the first comprehensive examination of AI adoption disparities specifically within Saudi Arabian early childhood education, thereby addressing a critical gap in regional educational technology research. The study offers a context-specific analysis of AI integration patterns within a rapidly modernizing Middle Eastern educational system, generating insights that are also relevant to other developing economies undergoing similar technological transitions. In addition, it contributes valuable qualitative insights into the human dimensions of educational technology adoption through a mixed-methods approach, capturing nuanced perspectives often overlooked in quantitative studies. The research also develops a comprehensive theoretical framework for understanding the interconnected factors influencing educational technology equity in dual-sector educational systems, and it establishes evidence-based policy recommendations that are specifically tailored to address systemic inequalities in AI access while promoting sustainable implementation strategies.

The paper has been arranged in five major parts that approach the research objectives in a systematic way. After this introduction, a detailed literature review is conducted on the available literature on AI in the education field, the topic of educational equity, and the situation of the educational development of Saudi Arabia. In the methodology section, the research process involves the qualitative research approach, such as the selection of the participants, data collection methods, and analytical methods. The results and discussion section outlines the most important findings and sorts them around these four major themes in discussing the participants' opinion in terms of barriers to AI adoption and opportunities, and evaluates their stated opinion and perspectives using available survey data to put these opinions in context. Lastly, conclusions make a synthesis of major findings and recommend policies regarding the promotion of harmonized and sustainable integration of AI in early childhood education.

II. SYSTEMATIC LITERATURE REVIEW

1. ARTIFICIAL INTELLIGENCE APPLICATIONS IN EARLY CHILDHOOD EDUCATION

Artificial intelligence integration within the early childhood learning area has been a paradigm shift in the presentation, evaluation, and individualization of educational material to young learners. Current studies reveal that AI-assisted educational applications have the potential to transform the education process by delivering, inter alia, adaptive learning, immediate feedback, and interaction tasks based on one-on-one development requirements [2, 9]. Users include a wide variety of technologies, such as adaptive learning systems that automatically change the level of content based on the performance of a student, intelligent tutoring systems that give a student individualized feedback and learning robots that provide a form of engaging activities.

Recent research findings also signified the specific potential of AI tools in scaffolding emergent literacy and numeracy skills domains, which draw significant improvements of long-term academic performance based on personalized instruction [10]. Thanks to AI use, educational games and applications show impressive ability to keep student engagement levels high and, at the same time, gather valuable data about learning progress and areas that demand more attention [11]. Interactivity is the key aspect of these instruments as it best suits the preferred learning styles of young children, providing students with practical experience that supports traditional pedagogy.

Nonetheless, the success of the AI implementation into early childhood practices heavily relies on a meaningful combination with the available pedagogical theories and paying attention to the developmental suitability. Studies also conclude that effective integration of AI necessitates having educators with knowledge concerning not only the technological aspect of AI but also the learning needs of young learners,

which arise as perhaps the most important aspect of professional development and support systems [12]. The relationship between technological aptitude and teaching expertise is always of relevance, but it gains special importance when the overall consequences of AI adoption on teaching equity and education access are contemplated.

2. EDUCATIONAL EQUITY AND TECHNOLOGY ACCESS DISPARITIES

Educational equity as applied in the context of technology integration has ceased to be an easy concept that can be measured in terms of mere access and has become a complex application of quality, usage and educational performance. Access to technology does not just imply education to be equitable but also comes with an equal opportunity to maximize on technological facilities with proper guidance, education and integration approaches [13]. The digital divide as a historically drawn distinction between the access to and the lack of access to digital technologies has evolved into a multidimensional phenomenon involving disparities in the quality of technologies, integration into pedagogical processes, and the overall high-depth educational outcomes.

Literature shows that technology adoption trends within the academic environments are usually greatly affected by socioeconomic factors as well-endowed learning institutions are observed to exhibit higher rates of innovative technology absorption than other less well-funded learning institutions [14]. These differences are especially acute when it comes to novel technologies such as AI, which are rather expensive at the initial stages involving investment in hardware, software, and the development of professionals. The total impact of these inequalities may be huge, and thus there may emerge or even magnify the achievement gap already existing between students having dissimilar socioeconomic statuses.

Equity issues dealing with technology are not only associated with the direct outcome of education, but also extend to the issue of general social justice, and economic opportunity. Educationally disadvantaged students without easy access to state-of-the-art educational technologies can be at a disadvantage in their higher education and career advancement, which demands increasing levels of digital literacy and technological competence [15]. This fact is closely linked to the issues of funding and resource allocation, because educational institutions have to make their way to intricate technology investment land taking part in limited budgetary systems.

3. FUNDING MODELS AND RESOURCE ALLOCATION IN EDUCATIONAL TECHNOLOGY

Financial aspects of the adoption of educational technology are key areas to assess the degree and the sustainability of the adoption of technology integration efforts. Educational technology funding studies indicate a handful of intricate resource-assignment practices that tend to manifest larger unwarranted disparities in the organization of education [16]. The flexibility of the choice on technology procurement is also more of the privately owned education institutions since they can adopt recent and interesting tools faster due to the absence of administrative hurdles in the budgetary process and the ability to focus solely on the special need in any institution.

The current trends in the financing of educational technology involve different strategies, such as government fund, business collaborations, philanthropic granting support, and institutional finance. There are different strengths and weaknesses of each of the funding mechanisms which affect the scale and the sustainability of technology adoption activities [17]. Government funded programs tend to cover a large basis but are prone to political shifts, whereas the partnerships in the private sector can be the most advanced in technological applications but bring about potential obstacles regarding industrial influence on the educational curriculum and illegal access to student information.

The overall costs of using AI-based educational services are more than just the initial purchase, and it includes all maintenance costs of software licensing, hardware support, or technical support and even professional expertise. Studies have found that educational institutions tend to underestimate these recurrent expenses, which make their sustainability a challenge in the study that potentially undermines long-term technology integration [18]. Such economic factors have more direct effects on teacher preparedness and

other professional development opportunities since institutions must consider the technological investment to meet the needs of the human resource.

4. TEACHER PREPAREDNESS AND PROFESSIONAL DEVELOPMENT IN AI INTEGRATION

Teacher preparedness, professional development, and continuing support systems are critical parts of making the integration of education tools that are based on AI successful. Study after study proves the same result: without proper training, technical assistance, and surety of effectiveness in the implementation of new tools, teachers may never succeed in the integration of technology into their practice [1]. The special features of the AI technologies that involve their flexibility and being highly data-driven pose certain difficulties to educators that might not be acquainted with the complex computational principles.

AI integration professional development should be concerned with both technical skills and pedagogical concerns as educators need to be equipped with not only the techniques on how to use the AI tools but also to learn how to use them into current pedagogical practices. The advantage of an effective professional development model takes the form of incorporating practical experience, collaboration and regular mentorship as opposed to a single training session [19]. Studies show that a complete and deep-rooted professional development of a teacher reflects a greater occurrence of competent technology insertion than those with negligible or incompetent training assistance.

AI technologies are another area where the issue is especially urgent, as it will likely be necessary to engage in constant learning and adjustments as the technologies change and evolve. It is necessary that teachers learn, not only to use the AI tools at a technical level but also to make critical evaluations on the suitability and effectiveness of the tools on their own particular student bodies and learning outcome [20]. These professional learning requirements are linked to policy concerns, in the sense that educational structures are required to devise holistic models of supporting the use of AI and having to consider equity-related issues.

5. POLICY FRAMEWORKS AND EDUCATIONAL CONTEXT IN SAUDI ARABIA

Issues related to student privacy, data security, algorithmic transparency, and alignment with educational standards in the context of AI implementation represent complex policy challenges. These issues must be addressed with careful consideration of Saudi Arabia's educational transformation. In the past decades, the Saudi Arabian educational system significantly evolved, with its diversification of the economy in mind, social modernization initiatives, and the all-encompassing Vision 2030 program of changes [5]. The educational system of the Kingdom manifests itself in a dual educational system of state and non-state schools and pronounced differences in resources, control, and educational philosophy between the sectors.

The difference in distribution of resources between privately funded and publicly funded schools of Saudi Arabia conforms to the larger trends in terms of socioeconomic and governmental preference in terms of investment in educational resources. Most of the schooling facilities in private schools cost a lot in terms of tuition fees and can afford buying sophisticated learning technologies and maintaining a low number of students in the classes and specialized program. In contrast, government-funded schools often operate under rigid budget constraints that may limit innovation [6]. All these inequalities have been recorded in rates of access to technology, teacher education, and performance in education.

In line with Saudi Arabia's Vision 2030 educational transformation goals, recent national initiatives have placed significant emphasis on integrating artificial intelligence into the public education system. In early 2024, the Ministry of Education, working in partnership with the National Curriculum Center, the Ministry of Communications and Information Technology, and the SDAIA, announced the rollout of a comprehensive AI curriculum across all levels of public education, set to begin in the 2025–2026 academic [8]. This program is designed to introduce structured, age-appropriate modules that build foundational competencies in data literacy, ethical AI use, and critical thinking. The initiative is not limited to introducing a new subject but represents a transformative shift in the way educators teach, curricula are designed, and students are prepared for the digital economy. With substantial government funding already committed to technology and AI integration in public schools, the policy focus has shifted from merely securing resources to ensuring

the effective and equitable use of these investments. For early childhood education in particular, this national direction underscores the importance of aligning AI adoption efforts with infrastructure readiness, teacher professional development, and the creation of culturally and developmentally appropriate tools.

Most reform efforts as part of Vision 2030 have focused on the necessity of technological innovation and digital change in education, where the targeted objectives have included enhancing the quality of education and promoting technology integration at all tiers of the educational system. Some key issues concerning resource sharing, however, sidetrack the adoption of the initiatives, infrastructure and capacity building, especially in the publicly owned educational institutions where the largest number of Saudi students are accommodated [21]. These efforts of reforms are heavily reliant on the ability to overcome systematic inequalities and the need to make technology innovation a positive effect on all the students and not just the institutional backdrop.

Table 1 summarizes key studies on AI integration, educational equity, and policy contexts relevant to ECE. It outlines each study's context, focus area, methodology, main findings, and limitations, highlighting gaps in existing literature particularly the scarcity of research addressing AI adoption in Saudi Arabian ECE. The comparison underscores the novelty of the current study in providing a comprehensive, context-specific analysis of AI equity and sustainability across public and private institutions.

Table 1: Comparative analysis of ai integration studies in educational settings (2012-2024).

Study	Context	Focus Area	Methodology	Key Findings	Limitations
[2]	Global ECE	AI scoping review	Systematic review	AI applications can improve teaching and learning in ECE; identified potential benefits and implementation challenges	Limited developing country perspectives; scarcity of comprehensive studies
[22]	Global ECE	Key AI technologies	Literature review	Identified key AI technologies in ECE including robots and AI systems for improving social interaction	Lack of equity focus; limited practical implementation guidance
[1]	International	Teacher trust in AI	Quantitative instrument	Developed instrument for measuring teachers' trust in AI-based educational technology	Focus on measurement rather than implementation barriers
[3]	General education	Big data and AI challenges	Conceptual analysis	Explored challenges and future directions of big data and AI in education	Broad focus; limited specific application to early childhood
[5]	Saudi Arabia	Education system reform	Policy analysis	Need for fundamental shift in Saudi education system to implement Vision 2030	Limited focus on technology integration specifically
[21]	Saudi Arabia	Digital technology use	Conference presentation	Examined use of digital technology in Saudi Arabia's schools	Dated perspective; limited scope of technology examined
[4]	Saudi Arabia	ICT evaluation	Quantitative study	Evaluated ICT use in Saudi Arabian secondary schools	Focus on secondary education; limited early childhood relevance

[6]	Saudi Arabia	Private vs public education	Comparative study	Private school education serves as predictor for success compared to public education	Gender-specific focus; limited technology integration analysis
[7]	Saudi Arabia	Education policy governance	Critical review	Education policy and governance issues in Saudi secondary schools using capabilities approach	Secondary education focus; limited early childhood application
Current Study (2024)	Saudi Arabia	ECE AI equity and sustainability	Mixed methods qualitative	Comprehensive analysis of AI adoption disparities between private and public ECE institutions	Single country focus; cross-sectional design

Despite growing interest in AI applications in education and increasing attention to educational equity concerns, significant gaps remain in the research literature, particularly regarding the intersection of these topics within the Saudi Arabian early childhood education context. Although various studies analyzed AI in general in education, few studies addressed the use of AI in early childhood education even though the part of education is crucial to lifetime learning. In addition, it has been found that majority of the developed researches on educational technology equity are being analyzed in the Western educational arena considering little focus on the approach to develop educational systems that can offer various pitfalls and opportunities. There is a significant research gap in the Saudi Arabian context in particular, given that the Kingdom and the factors that make it a unique economic, educational, and cultural prospect can be viewed as a unique setting regarding education technology adoption that is not necessarily reflected in the previously established research on an international scale. The particular problems and possibilities conceivable of the process of AI integration into the early childhood education in Saudi Arabia have yet to be studied, though these are the insights that may be important to the direction of educational policies and the practice within the Kingdom as well as in similar veins of education, the developing world.

More so, the study of educational technology equity has largely utilized quantitative methods that cannot capture the subtleties of teachers' and administrators' views and experiences in making decisions about technology adoption. There is limited qualitative research into the human aspects of educational technology integration, especially as they relate to disparities in AI adoption between private and public institutions. This study addresses this gap by employing a mixed-methods approach that combines both qualitative and quantitative methods, offering rich insights into the factors influencing the adoption of AI in ECE in Saudi Arabia. These findings are both theoretically and practically valuable to researchers and to policymakers and education decision-makers.

6. SYNTHESIS AND CONCEPTUAL SUMMARY

The literature reviewed indicates that successful integration of artificial intelligence in early childhood education depends on balancing innovation with equity and sustainability [23, 24]. Studies show that AI can enhance learning outcomes when supported by adequate funding, infrastructure, and teacher preparedness [25]. However, unequal access to technology across school types continues to create barriers that limit the full realization of AI's potential. Sustainability in this context involves continuous professional development, reliable policy support, and long-term affordability. Bringing these strands together, the current study focuses on how affordability and institutional equity influence sustainable AI adoption within Saudi Arabia's early childhood education system.

Table 2. Summary of key relationships among ai integration, equity, and sustainability.

Dimension	Core Components	Challenges Identified	Expected Outcomes
AI Integration	Adaptive learning systems, intelligent tutoring tools, data-driven assessment	Limited availability in public schools, lack of localized content	Improved teaching efficiency and personalized learning
Equity and Access	Affordability, infrastructure, teacher training, and inclusion	Cost barriers, unequal resource distribution, insufficient training	Fair participation and reduced digital divide
Sustainability and Policy	Long-term funding, professional development, Vision 2030 alignment	Inconsistent policy implementation, weak inter-sector collaboration	Enduring technological readiness and equitable growth

III. METHODOLOGY

This study employed a mixed methods approach, integrating both quantitative survey data and qualitative interviews to capture comprehensive perspectives on AI adoption equity in Saudi Arabian early childhood education. The quantitative component used a structured online questionnaire composed of five sections: demographic information, AI adoption and accessibility, affordability and resource allocation, perceptions of AI tools in education, and policy or support needs. The qualitative component involved semi structured interviews with 14 participants including teachers and administrators to explore context specific challenges and lived experiences.

A mixed methods research design was used to combine both qualitative and quantitative approaches, providing a comprehensive understanding of the benefits and challenges of adopting AI based educational tools within Saudi early childhood educational facilities. The qualitative component was chosen to capture the sensitivity of participants' views, experiences, and contextual circumstances which quantitative methods alone may not reveal, particularly given the novelty of the research topic and the limited existing literature on AI adoption within Saudi schools. The quantitative component provided broader contextual patterns and statistical insights to complement and triangulate the qualitative findings.

1. RESEARCH DESIGN

The research method employed an explanatory sequential mixed-methods approach, with the qualitative phase grounded in interpretive phenomenological principles to capture participants lived experiences and perceptions regarding the current state of AI integration in their learning environments. Such a methodology was especially suitable in order to examine the way in which educators and administrators make meaning on the emerging technology in their practice and especially the institutional limitations. The study design was more depth oriented than breadth oriented in search of deep rich revelations that might be of use in theoretical thinking as well as policy formulation.

The study itself comprised a qualitative study with survey data analysis to supplement the results of such research and give context and triangulation to the interview data. Although the main emphasis was still on the qualitative insights, the survey data proved beneficial in providing demographic information and preliminary attitudes that became useful to the interview process and the way the data was discussed.

2. PARTICIPANT SELECTION

Interviewees were selected using purposive sampling to exclude only 1 area of schooling as opposed to the other (public and private). The intended group was represented by kindergarten teachers and their leaders who had at least one year of experience of work with children in Saudi Arabia due to the high-priority of targeted group in the study in terms of its aged and experienced as well as adjusted to the child-related educational practices and the institutional environment.

Participants in the qualitative interview portion were 14 participants: 8 teachers (4 of them teaching in the private sector and 4 of them teaching in the public sector) and 6 administrators (3 representatives of the private sector and 3 representatives of the public sector). Additionally, survey data were collected from 127 participants (68 from private schools, 59 from public schools) to provide broader contextual understanding and triangulation for the interview findings. The sample sizes were determined based on both practical considerations and data saturation principles, with the quantitative component requiring at least 60 participants and the qualitative component requiring at least 10 participants as specified in the original research design.

The participant selection process involved establishing contact with school principals and educational administrators who facilitated introductions to potential participants. For the survey phase, a list of kindergarten schools was compiled, and school heads were contacted to explain the study and encourage distribution of the survey link to teachers for voluntary participation. For the interview phase, personal visits were made to local kindergarten schools to introduce the researcher to school principals and invite interested teachers and administrators to participate. All participants volunteered to participate after receiving detailed information about the study's objectives and procedures, with no contact information required from participants to ensure anonymity and encourage honest responses. Table 3 presents the demographic characteristics of interview participants, illustrating the balanced representation across institutional types and professional roles.

Table 3. Interview participant demographics.

Institution Type	Educators	Administrators	Years of Experience (Mean)	Total
Private Schools	4	3	5.3	7
Public Schools	4	3	4.8	7
Total	8	6	5.05	14

Table 4 presents the distribution of survey participants across institution types, showing a balanced representation between private 53.5% and public 46.5% schools, ensuring robust cross-sector comparisons.

Table 4. Survey participant demographics.

Institution Type	Number of Participants	Percentage of Total (n=127)
Private Schools	68	53.5%
Public Schools	59	46.5%
Total	127	100%

3. SAMPLING APPROACH AND RATIONALE

The study used a purposive sampling method to ensure balanced representation across both private and public early childhood institutions. This method was selected to include teachers and administrators who had direct experience or exposure to AI based educational tools. The approach allowed the inclusion of individuals who could provide meaningful insights into the opportunities and challenges of AI adoption. Sampling continued until thematic saturation was achieved during the interview phase, meaning that after the twelfth interview no new information or themes were emerging from participant responses. This ensured depth and completeness in data collection while maintaining representation from both educational sectors.

A flowchart representing the mixed methods design used in this study. The process began with instrument development and pilot testing, followed by quantitative survey distribution to 127 participants. After analyzing the survey data, 14 qualitative interviews were conducted to gain deeper insights. The next steps involved data coding, thematic analysis, and integration of quantitative and qualitative findings to develop final conclusions and policy recommendations (see Figure 1).
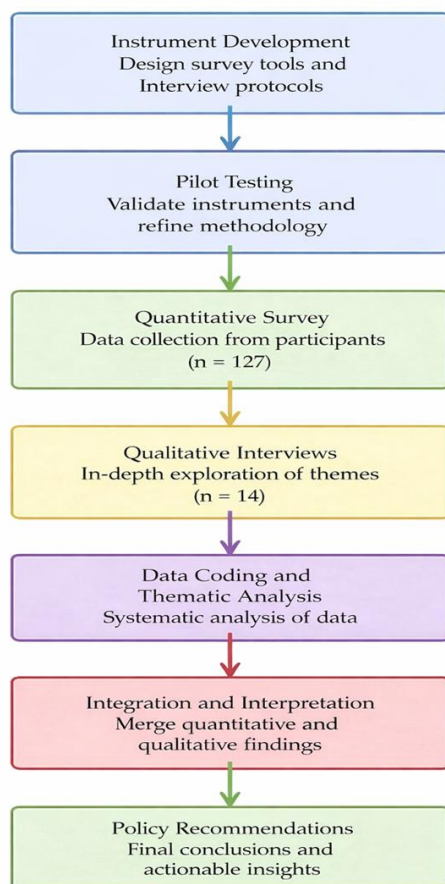
FIGURE 1. Research process flowchart.

4. DATA COLLECTION

In this research study, we adopted an explanatory sequential mixed-methods design, employing quantitative surveys followed by qualitative interviews to collect rich data on the adoption and integration of AI-based educational tools in the early childhood education sector in Saudi Arabia. The qualitative phase was guided by interpretive phenomenological principles to capture participants lived experiences and perceptions in depth. An explanatory research strategy is the investigation of attitudes of participants in order to investigate and find the type and context in which a problem lies [26]. The explanatory design involved investigation of problems because of quantitative data and the follow-up interviews to obtain comprehensive knowledge on the way factors of affordability, accessibility, equity, and sustainability can affect the adoption of AI technology in both private and public ECE institutions.

- Phase 1: Quantitative Data Collection: The first phase involved quantitative data collection through an online survey conducted via Microsoft Forms. The survey was designed to be completed in 5-8 minutes and was structured into five main sections: demographic information, AI adoption and accessibility, affordability and resource allocation, perceptions of AI tools in education, and policy and support needs. The survey was made available in both Arabic and English versions to ensure participant comfort and accurate responses.

Survey distribution followed a systematic approach where kindergarten schools in the target areas were identified, and school heads were contacted to explain the study and encourage distribution of the survey

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link to teachers for voluntary participation. The survey link contained a mandatory consent form that participants had to complete before proceeding to the main questions. No phone numbers or email addresses were required from participants to ensure anonymity and encourage honest responses.

- Phase 2: Qualitative Data Collection: The second phase involved qualitative data collection through semi-structured interviews lasting 30-45 minutes each. The interview phase was designed as a follow-up to obtain more in-depth insights from participants, with teachers and administrators eligible to participate regardless of their involvement in the initial survey. Personal visits were made to local kindergarten schools to introduce the researcher to school principals and invite interested educators to participate.

The interview protocol covered four main areas: background and experience with AI tools, accessibility and affordability of AI tools, training and support for AI integration, and equity and sustainability considerations. During interviews, detailed notes were taken while participants responded to questions, and each interview was limited to a maximum of 45 minutes. After each interview, notes were reviewed with participants to verify accuracy and ensure the data accurately reflected their intended responses.

- Language and Cultural Considerations: Both survey and interview questions were conducted in Arabic, the primary language of participants, to ensure accurate and comfortable responses. A translation-back translation method was employed to maintain linguistic accuracy, where questions were first translated from English to Arabic by a bilingual expert, then independently back translated to English to identify any discrepancies. Additionally, experts in early childhood education and AI terminology reviewed both versions to ensure conceptual alignment, supporting the validity and reliability of the collected data.

5. DATA ANALYSIS

- Survey Data Analysis: Survey data were analyzed using descriptive statistical methods to identify frequencies, percentages, and central tendencies using SPSS statistical software. Initial analysis involved basic descriptive statistics to understand the distribution of responses across different variables and participant categories. Following the frequency analysis to identify emerging trends, cross-tabulation tests (Chi-square) were conducted to determine relationships between variables such as institution type, AI familiarity, perceived barriers, and support needs. This quantitative analysis provided the foundation for understanding broader patterns across the early childhood education sector and informed the development of interview themes.

- Interview Data Analysis: Interview data were analyzed using thematic analysis following a systematic six-step process: (1) reading and re-reading data to achieve familiarity, (2) generating initial codes from the interview transcripts, (3) combining codes into potential themes, (4) analyzing themes from a theoretical perspective, (5) developing clear definitions for each theme, and (6) writing up the results with supporting evidence from participant responses. The software assignment that took place during the analysis involved the use of NVivo and Microsoft Word in order to organize the transcripts of the interviews and properly code them.

First-order coding of the thematic analysis used Arabic, as that was the semantic way of interpreting director responses, and findings, as well as illustrative quotes, were later translated into English, to inform the writing. In such a way, it was possible to preserve cultural peculiarities and contextual meaning of the findings and make the results available to the international research society.

- Data Integration and Triangulation: The level of quantitative data (survey results) was used to the level of qualitative data (interview answers) following an explanatory sequential design. In other words, the maximum data were used to explain where the minimum data were found and served as the guidelines in the development of themes in the interviews. Additionally, the minimum data (interview answers) offered more information on the patterns and relationships identified in the level of maximum data using the method of statistical analysis. The use of mixed methods allowed this level of triangulation where the generality of the survey results was supplemented with depth of the interview data.

5.1 Measurement of Affordability and Equity

Affordability and equity were assessed using both quantitative and qualitative indicators. Quantitatively, affordability was measured through survey questions assessing participants' perceptions of AI tool costs,

school budget allocations, and funding mechanisms (for example, "Does your institution have a dedicated budget for AI or technology?"; "How affordable are AI tools for your institution?"). Equity was measured through cross-sector comparisons of AI accessibility, teacher training availability, and infrastructure readiness between public and private schools. Qualitatively, equity themes were derived from interview coding of participant narratives describing access limitations, fairness in resource allocation, and professional development opportunities. These measures provided a dual-layered understanding of how economic and institutional factors shape AI adoption equity.

5.2 Validity and Reliability

To ensure validity, all survey instruments underwent expert review by three specialists in educational technology and early childhood pedagogy to confirm construct relevance and clarity. A pilot survey (n=10) was conducted to refine question wording and check internal consistency (Cronbach's α = 0.89). For qualitative interviews, credibility was achieved through member checking, where participants reviewed summarized transcripts for accuracy. Thematic coding was performed manually and validated using NVivo software to ensure intercoder reliability, achieving a Cohen's κ of 0.84, which indicates substantial agreement.
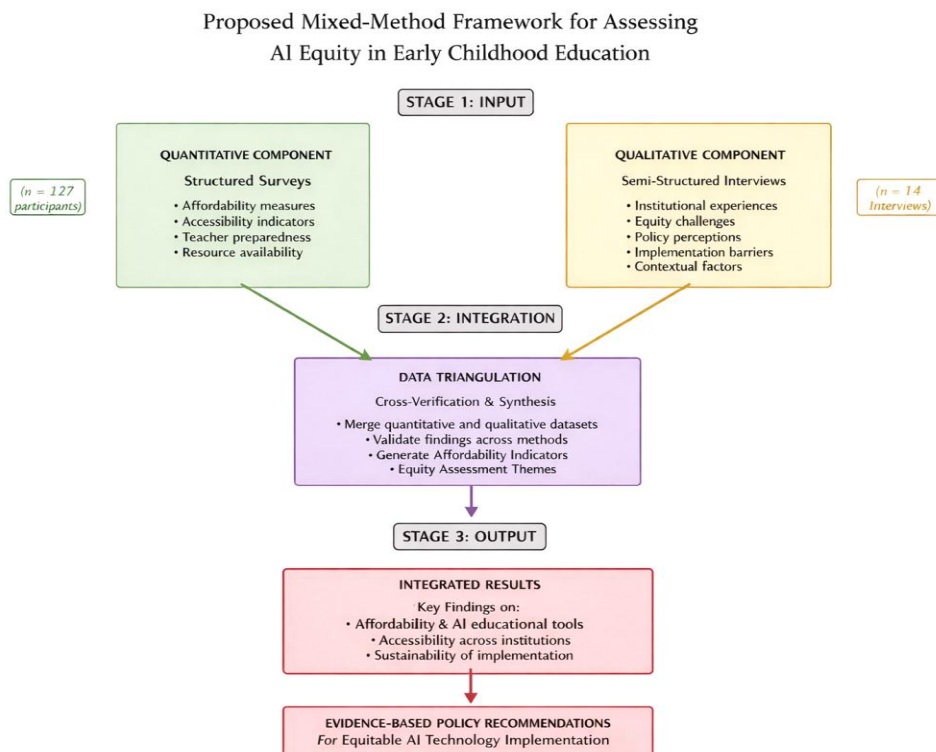
FIGURE 2. Proposed mixed-method framework for assessing AI equity in early childhood education.

The proposed framework (Figure 2) illustrates the overall methodological model adopted in this study to evaluate affordability and equity in AI adoption across public and private early childhood institutions. The approach integrates quantitative and qualitative components within a unified analytical structure.

At the input stage, quantitative data were collected through structured surveys measuring affordability, accessibility, infrastructure readiness, and teacher preparedness, while qualitative data were obtained from semi structured interviews exploring institutional experiences, policy challenges, and perceptions of equity.

At the integration stage, both datasets were merged through triangulation, allowing cross verification of findings and generation of composite indicators such as the affordability index and equity assessment themes. At the output stage, the integrated results produced key outcomes on affordability, accessibility, and sustainability of AI based educational tools, which guided the formulation of evidence-based policy recommendations for equitable technology implementation in early childhood education.

6. ETHICAL CONSIDERATIONS

Ethical approval was obtained from the Institutional Review Board of Imam Abdulrahman bin Faisal University (IRB-2024-15-828). All participants provided informed consent and were assured that their data would remain confidential. The study followed proper research protocols for Saudi educational institutions, with culturally appropriate data collection conducted by Arabic-speaking researchers familiar with the local context.

IV. RESULTS

The interview data and questionnaire answers were analyzed and four main themes were identified, which help to understand the complicated system of the situation with the development of AI in the Saudi Arabian early childhood education. These themes capture the extent of the shared challenges and opportunities of education providers and administrators as they are forced with the task of integrating AI-based educational tools into their contexts of continuing education.

1. TECHNOLOGICAL READINESS AND INFRASTRUCTURE DISPARITIES

The most outstanding observation in this research is associated with the existence of massive differences between the technological preparedness of both the private and the government early childhood learning institutions in terms of technological facilities. The survey data suggested that 73% of respondents in the private schools claimed to have specific technology allocations as opposed to 23% of the respondents in the public schools. The above gap was invariably echoed in the experiences and perceptions of the interview participants.

Table 5. Technology budget allocation by institution type.

Budget Type	Private Schools (n=68)	Public Schools (n=59)	Total Sample (n=127)
Dedicated Technology Budget	50 (73%)	14 (23%)	64 (50%)
Shared Budget with Other Resources	12 (18%)	18 (31%)	30 (24%)
No Dedicated Budget	6 (9%)	27 (46%)	33 (26%)

As shown in Table 5, there is a substantial disparity in technology budget allocation between private and public early childhood education institutions, directly influencing their capacity to adopt AI-based educational tools. Such a sharp difference in the budget directly affects the availability and implementing capacity of AI tools. The financial flexibility in the process gives the private schools the opportunity to invest on new technologies instantly and public schools must navigate lengthy administrative procedures for any technology-related investments.

- Private School Approach: A school administrator in a tuition school (P7) described their advantages as: "We can afford the capacity to invest directly into new technologies as and when we perceive that we think they may work." We also bought a variety of learning platforms on adaptive learning and learning robots last year. We are not afraid to experiment with various AI tools because we can only maintain those that resonate with our students within our budget".

The technological infrastructure in private institutions typically includes reliable internet connectivity, updated hardware, and dedicated technical support staff. Private school educators reported higher

familiarity with AI tools, with 84% of private school survey respondents indicating they were "very familiar" or "somewhat familiar" with AI-based educational tools, compared to 34% of public-school respondents.

Table 6. AI Tool availability by institution type.

AI Tool Type	Private Schools (n=68)	Public Schools (n=59)	Total Sample (n=127)
Adaptive Learning Platforms	53 (78%)	7 (12%)	60 (47%)
Educational Robots	31 (45%)	2 (3%)	33 (26%)
AI Assessment Tools	35 (52%)	5 (8%)	40 (31%)
Virtual Learning Assistants	16 (23%)	3 (5%)	19 (15%)
None Available	8 (12%)	48 (81%)	56 (44%)

The data in Table 6 reveals dramatic differences in AI tool availability, with private schools demonstrating significantly higher adoption rates across all categories. Most notably, 81% of public schools reported having no AI tools available, compared to only 12% of private schools, highlighting the severity of the digital divide in early childhood education.

- Public School Challenges: In contrast, public school participants consistently described infrastructure limitations that constrain their ability to adopt AI technologies. A public-school teacher (P3) explained: "We sometimes face challenges with basic internet connectivity in certain classrooms. Although we have access to tablets, there aren't enough for every student. When we use them for activities like educational games, some children have to wait their turn, which can be frustrating for them".

Figure 3 illustrates the relationship between institution type and AI tool availability, based on survey responses from 127 participants.
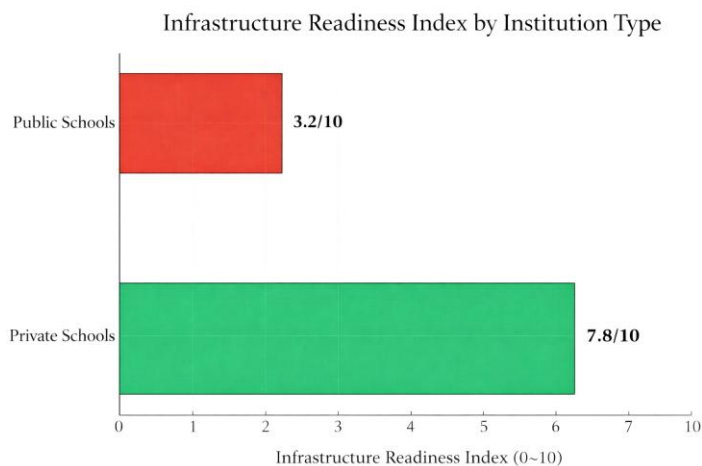
FIGURE 3. Infrastructure readiness index by institution type.

The survey data corroborated these findings, revealing that 67% of public-school respondents identified "lack of technical infrastructure" as a primary barrier to AI adoption, compared to 18% of private school respondents. This disparity extends beyond hardware to encompass technical support systems, with public schools often lacking dedicated IT personnel to assist with technology integration and troubleshooting.

Figure 4 shows the stark contrast in AI tool availability between private and public early childhood education institutions in Saudi Arabia, with private schools demonstrating significantly higher adoption rates across all categories of AI-based educational tools.
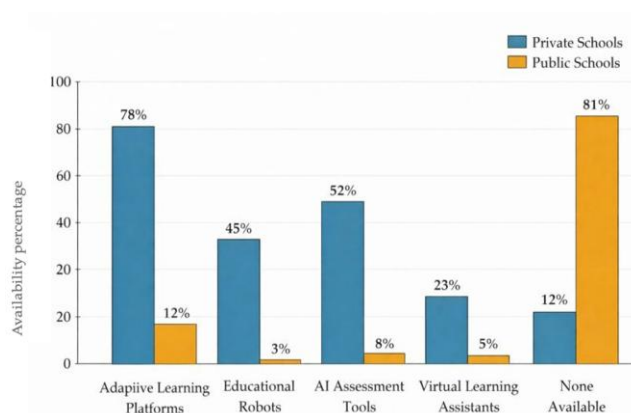
FIGURE 4. Distribution of ai tool types across institution types.

2. FINANCIAL CONSTRAINTS AND RESOURCE ALLOCATION CHALLENGES

The second major theme emerging from the data concerns the financial barriers to AI adoption, particularly in public educational institutions. While cost concerns were mentioned by participants from both sectors, the nature and severity of these challenges differed significantly between private and public schools. Budget Allocation Patterns: Survey data revealed stark differences in budget allocation patterns, with 89% of private school respondents reporting either dedicated technology budgets or shared technology funding, compared to 31% of public-school respondents. The majority of public-school participants (69%) indicated having no dedicated budget for technology and AI-based educational tools.

Table 7 demonstrates that cost represents the most significant barrier for public schools (92%), while private schools face challenges that are more diverse with time constraints being their primary concern (46%). This pattern reflects the fundamental difference in resource availability between the two sectors.

Table 7. Barriers to ai adoption by institution type.

Barrier Category	Private Schools (n=68)		Public Schools (n=59)	
	Count	Percentage	Count	Percentage
Cost of AI Tools	28	41%	54	92%
Lack of Technical Infrastructure	12	18%	40	68%
Lack of Teacher Training	22	32%	51	86%
Limited School Support	8	12%	35	59%
Lack of Time for Integration	31	46%	38	64%
Cultural Relevance Concerns	15	22%	19	32%

A public-school principal (P11) explained: "Our annual budget is entirely predetermined by the Ministry of Education, with designated allocations for salaries, maintenance, and essential supplies. While there is a budget for technology, we must have a clear plan for how to use it effectively. At present, we are still uncertain about which applications or AI tools are most widely used and have been proven effective. Moreover, technologies such as smart boards and AI applications are expensive, and given the large number of students and classrooms we serve, implementing them would require substantial investment."

Teachers echoed these concerns. One teacher explained: "There is funding available, but the challenge is knowing how to use it wisely. With so many AI options out there, it's overwhelming. We can't afford to waste resources on tools that may not suit our students or curriculum." Another administrator added: "I know we're expected to adopt digital tools, and we even have some funding, but honestly, we don't know where to begin. There's no centralized guidance, and teachers feel lost when it comes to selecting or using AI meaningfully."

- Cost Perceptions and Affordability: The view towards the cost of AI tools was vastly different across industries. The respondents of the privately admitted ICSE schools were of the opinion that the AI tools were either very cheap or somewhat cheap to 56% as compared to 14% of the respondents of the government secondary schools. The difference does not only show varying budget realities but also varying cost-benefit calculations depending upon the resources available and priorities of the institutional.
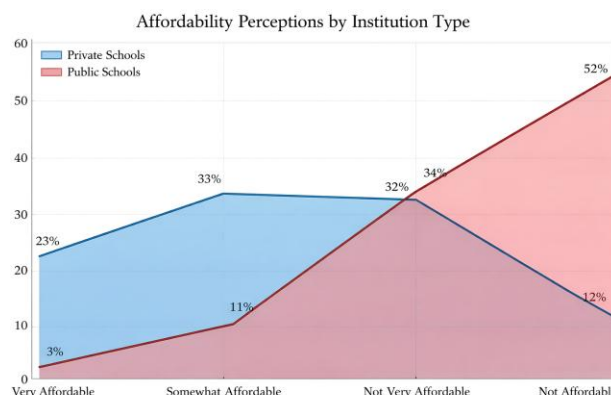

FIGURE 5. Affordability perceptions by institution type.

The values displayed in Figure 5 demonstrate a sharp distinction in the affordability of perception wherein over a half (52%) of the respondents based in the public school system finds it entirely unaffordable to use AI tools as opposed to just 12% of the respondents based in the private schools. This factor of perception deficit plays a big role in adoption choices and implementation tactics in various industries.

Those who were students in private schools were also found to be more aware of the costs of AI tools and their capabilities, which implies that they were more active in interactions with technology vendors and test processes. One of the teachers in a private school (P5) commented: "We consider new educational technologies regularly and evaluate their cost-effectiveness in relation to benefits that they can offer. The school management is willing to experiment with new tools and it financially supports pilots. When there is something that works successfully, we will typically be approved to obtain one in every classroom."

- Sustainability Concerns: Beyond initial purchase costs, participants highlighted ongoing expenses as a significant sustainability challenge. These include software licensing fees, hardware maintenance, technical support, and professional development costs. Public school participants were particularly concerned about long-term sustainability, even if initial funding could be secured through grants or government initiatives.

Table 8 reveals that public school respondents overwhelmingly favor government subsidies (87%) as the most helpful financial support mechanism, while private school respondents show more preferences that are diverse. This pattern reflects public schools' dependence on governmental support and their limited access to alternative funding sources.

Table 8. Preferred financial support mechanisms for public schools.

Support Mechanism	Private School (n=68)	Public School (n=59)	Total Sample (n=127)
Government Subsidies	23 (34%)	51 (87%)	74 (58%)
Private Funding/Sponsorship	31 (45%)	31 (52%)	62 (49%)
School Budget Increase	46 (67%)	46 (78%)	92 (72%)
Public-Private Partnerships	16 (23%)	38 (65%)	54 (43%)

A public-school administrator (P13) observed: "Even if we could get funding to purchase AI tools initially, we worry about ongoing costs. What happens when the software license expires? Who will maintain the

hardware? Who will train new teachers? These ongoing expenses are often overlooked in funding decisions, but they are critical for successful implementation."

3. PROFESSIONAL DEVELOPMENT AND TRAINING NEEDS

The third major theme concerns the critical importance of professional development and training for successful AI integration. While participants from both sectors recognized the need for AI-related training, their experiences and access to professional development opportunities differed significantly.

- Current Training Experiences: Survey data indicated that 62% of private school participants had received some form of AI or educational technology training within the past two years, compared to 18% of public-school participants. The quality and comprehensiveness of training also varied, with private school participants reporting more hands-on, practical training experiences.

A private school teacher (P2) described her training experience: "The school arranged for a technology consultant to spend three days with us, showing us how to use the new adaptive learning platform. We had time to practice with the software, ask questions, and develop lesson plans incorporating the technology. The training was practical and immediately applicable to our teaching."

- Training Gaps and Needs: Public school participants consistently identified inadequate training as a primary barrier to AI adoption. One teacher emphasized: "Budget isn't the only issue it is really the lack of proper training that holds us back. Even though we're open to investing in new technologies, most of us don't feel confident using AI tools beyond very basic functions. What is missing is hands-on professional development and exposure to real-life classroom scenarios where these tools have been used effectively. We need to see how they fit into our teaching goals, how they actually support learning outcomes, and how to troubleshoot them when things do not go as planned. Without that kind of structured training and support, the tools just sit there." Professional development opportunities for AI integration vary significantly across sectors, with the differences in training access and effectiveness clearly presented in Table 9.

Another participant explained: "We often hear a lot about AI in education it is mentioned in policies, conferences, and training sessions but when it comes to actual classroom use, we don't really know which tools are effective or even suitable for our age group. Early childhood education is very different from secondary school, and many of the tools we come across are not designed with younger learners in mind. We want to implement these innovations, but we need guidance that is specific to our context what works for 4- and 5-year-olds? How much screen time is appropriate? What is developmentally beneficial? Without this kind of support, it's hard to move from policy to practice in a meaningful way."

**Table 9.** Professional development experiences and needs.

Training Aspect	Private Schools (n=68)	Public Schools (n=59)	Significance
Received AI Training (Past 2 Years)	42 (62%)	11 (18%)	p < 0.001
Training Duration (Mean Hours)	18.5	4.2	p < 0.001
Training Effectiveness Rating			
- Very Effective	26 (62%)	3 (27%)	
- Somewhat Effective	12 (29%)	6 (55%)	
- Not Effective	4 (9%)	2 (18%)	
Preferred Training Methods			
- Hands-on Workshops	51 (75%)	48 (81%)	
- Online Modules	23 (34%)	29 (49%)	
- Peer Mentoring	34 (50%)	41 (69%)	
- External Consultants	45 (66%)	18 (31%)	

Perceptions of AI tool effectiveness in enhancing personalized learning, student engagement, and teacher preparedness are summarized in Table 10.

Table 10. Perceptions of ai tool effectiveness in early childhood education.

Effectiveness Dimension	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Enhances Personalized Learning					
Private Schools (n=68)	34 (50%)	22 (32%)	8 (12%)	3 (4%)	1 (2%)
Public Schools (n=59)	18 (31%)	26 (44%)	12 (20%)	2 (3%)	1 (2%)
Increases Student Engagement					
Private Schools (n=68)	28 (41%)	26 (38%)	10 (15%)	3 (4%)	1 (2%)
Public Schools (n=59)	15 (25%)	28 (47%)	13 (22%)	2 (3%)	1 (2%)
Teacher Preparedness					
Private Schools (n=68)	19 (28%)	28 (41%)	15 (22%)	5 (7%)	1 (2%)
Public Schools (n=59)	6 (10%)	18 (31%)	21 (36%)	12 (20%)	2 (3%)

While Table 10 presents overall perceptions of AI tool effectiveness, teacher preparedness for AI integration emerged as a particularly important dimension requiring further attention. Figure 6 illustrates the differences in teacher preparedness between private and public-school respondents, highlighting the much higher confidence and readiness levels reported by educators in the private sector.
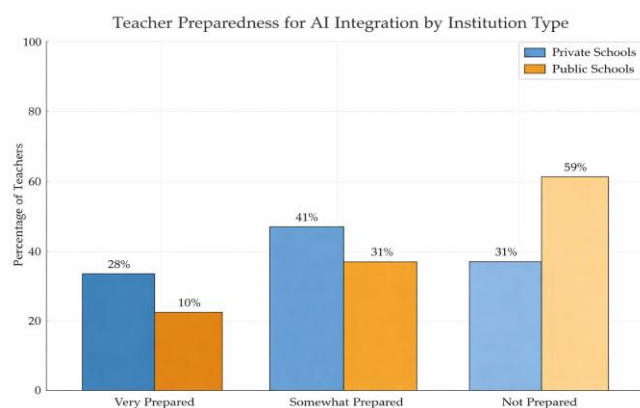
FIGURE 6. Teacher preparedness for AI integration by institution type.

- Preferred Training Modalities: Participants expressed preferences for various training approaches, with hands-on workshops and ongoing mentorship receiving the highest ratings. The survey data revealed that 78% of respondents preferred practical, classroom-based training to theoretical presentations. Additionally, 65% of participants indicated interest in peer learning opportunities where teachers could share experiences and best practices.
- A public-school administrator (P14) suggested: "We need training that is ongoing, not just a one-time workshop. Teachers need time to experiment with AI tools, make mistakes, and learn from experience. Ideally, we would have technology mentors who could provide ongoing support as teachers develop confidence with new tools."

4. PERCEPTIONS OF EDUCATIONAL EFFECTIVENESS AND CULTURAL RELEVANCE

The fourth theme encompasses participants' perceptions of AI tools' educational effectiveness and cultural appropriateness within the Saudi Arabian early childhood education context. These perceptions influence adoption decisions and implementation strategies across both sectors.
- Effectiveness Beliefs: Overall, participants demonstrated positive attitudes toward AI tools' potential educational benefits. Survey data indicated that 82% of respondents believed AI tools could enhance

personalized learning for young children, and 76% agreed that AI tools increase classroom engagement. However, effectiveness perceptions varied by experience level, with participants who had direct experience with AI tools reporting higher confidence in their educational value.

- A teacher with AI experience (P6) observed: "The adaptive learning app we use adjusts the difficulty level automatically based on each child's performance. I can see immediately which students are struggling and which ones need more challenging content. This personalization would be impossible for me to achieve manually with 25 students in the classroom."

- Cultural Relevance Concerns: A school administrator noted: "What's really missing right now is standardization. Each school is doing its own thing when it comes to AI some are experimenting with advanced tools while others don't use any at all. Especially in early childhood education, we need consistency. It's important that public and private schools are aligned, using similar tools and following shared guidelines. That way, we can ensure age-appropriate use, protect students' data, and build a shared understanding of what works. Without a unified approach, we risk widening the gap between institutions and missing the full potential of what AI can offer our young learners."

- A public-school teacher (P9) explained: "Many of the AI tools and educational apps we see are designed for Western contexts. The examples, stories, and cultural references may not be appropriate or meaningful for our students. We need AI tools that reflect Saudi culture and values while still providing high-quality educational content."

- Age Appropriateness and Screen Time: Participants also expressed concerns about age appropriateness and screen time for young children. These concerns were more pronounced among public school participants, who worried about over-reliance on technology in early childhood education. A public-school administrator (P12) noted: "Young children need hands-on, physical experiences and human interaction. AI tools can be valuable supplements to learning, but they should not replace traditional play-based learning approaches that are crucial for this age group." Concerns related to cultural relevance, age appropriateness, and screen time in AI tool implementation are detailed in Table 11.

Table 11. Cultural relevance and age appropriateness concerns.

Concern Category	Private Schools (n=68)	Public Schools (n=59)	Total (n=127)
Cultural Relevance Issues			
Major Concern	8 (12%)	15 (25%)	23 (18%)
Moderate Concern	17 (25%)	14 (24%)	31 (24%)
Minor Concern	28 (41%)	21 (36%)	49 (39%)
No Concern	15 (22%)	9 (15%)	24 (19%)
Age Appropriateness Concerns			
Major Concern	12 (18%)	18 (31%)	30 (24%)
Moderate Concern	23 (34%)	22 (37%)	45 (35%)
Minor Concern	25 (37%)	15 (25%)	40 (31%)
No Concern	8 (11%)	4 (7%)	12 (10%)
Screen Time Concerns			
Major Concern	15 (22%)	23 (39%)	38 (30%)
Moderate Concern	27 (40%)	24 (41%)	51 (40%)
Minor Concern	18 (26%)	9 (15%)	27 (21%)
No Concern	8 (12%)	3 (5%)	11 (9%)

To provide a clearer visual comparison of these concerns, Figure 7 depicts the distribution of participant responses regarding cultural relevance, age appropriateness, and screen time in AI tool implementation. The figure highlights the higher levels of concern reported by public school participants across all three categories.
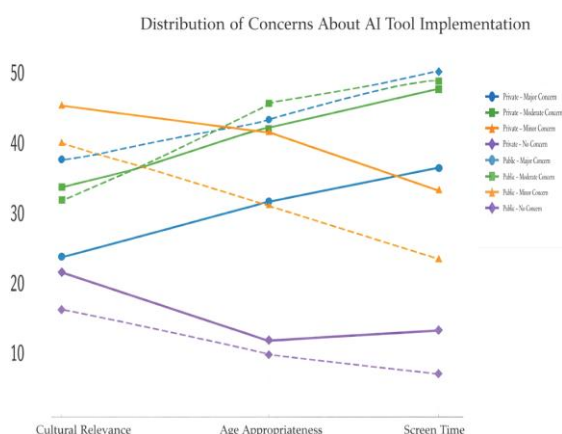
FIGURE 7. Distribution of concerns about AI tool implementation.

In addition to their perceptions of AI tools' educational value and cultural relevance, participants also identified specific policy interventions they considered most critical for successful and equitable AI integration in early childhood education. These priorities, reported separately by educators and administrators, are summarized in Table 12.

Table 12. Policy intervention priorities by stakeholder group.

Policy Intervention	Educators (n=86)	Administrators (n=41)	Overall Priority Ranking
Technical Infrastructure Development	61 (71%)	31 (76%)	1
Mandatory Teacher Training Programs	68 (79%)	28 (68%)	2
Increased Government Funding	74 (86%)	35 (85%)	3
Public-Private Partnerships	52 (60%)	29 (71%)	4
Cultural Adaptation of AI Tools	48 (56%)	18 (44%)	5
Data Privacy and Security Frameworks	44 (51%)	25 (61%)	6
Assessment and Quality Standards	39 (45%)	22 (54%)	7

5. POLICY IMPLICATIONS AND RECOMMENDATIONS

The results of this research hold significant importance for shaping future educational policy in Saudi Arabia, particularly in light of the nation's ongoing efforts to modernize its education system under Vision 2030. The findings clearly illustrate persistent disparities in AI implementation between private and public early childhood institutions, underscoring the urgent need for targeted, evidence-based policy interventions that not only promote equity but also ensure the sustainable and effective adoption of educational technology.

Participants consistently identified the strengthening of technical infrastructure in public schools as the highest and immediate priority. This includes ensuring robust, high-speed internet connectivity across all classrooms, upgrading outdated hardware to meet the requirements of modern AI applications, and establishing dedicated technical support teams capable of maintaining and troubleshooting these systems. This priority is directly connected to the upcoming nationwide rollout of the AI curriculum in 2025, ensuring that the necessary infrastructure is in place to support its effective delivery. While the Saudi government has already committed substantial funding starting in 2025 for the integration of technology and AI into primary public schools, the challenge lies in ensuring that this investment is utilized strategically and efficiently. For example, distributing new devices to classrooms without adequate training or infrastructure could undermine the intended benefits. Instead, policies must focus on phased implementation plans that align hardware upgrades with teacher readiness, curriculum integration, and student needs.

The second critical priority is teacher training and professional development, an area where the study found a pronounced gap between private and public institutions. An overwhelming 94% of public school respondents emphasized that equipping teachers with AI literacy and pedagogical integration skills is essential. This extends beyond basic technical orientation to include ongoing, hands-on professional development programs, collaborative peer learning communities, and the establishment of in-school technology mentors who can provide continuous support. By embedding AI training within a teacher's career development pathway, schools can ensure that educators remain confident, competent, and innovative in their use of emerging technologies.

Finally, participants highlighted the importance of fostering robust public-private partnerships as a means to bridge resource gaps and accelerate technology adoption in public schools. Such partnerships could involve technology companies offering AI tools, platforms, or technical expertise to public schools at reduced or no cost, potentially in exchange for research collaborations, pilot program opportunities, or formal government endorsement. Beyond hardware and software provision, these partnerships could also extend to joint teacher training initiatives, co-development of culturally relevant AI content, and shared data-driven evaluation frameworks to measure learning outcomes and system effectiveness.

Collectively, these priorities form a comprehensive policy roadmap aimed at ensuring that the benefits of AI in early childhood education are distributed equitably across Saudi Arabia's dual education system. By aligning infrastructure upgrades with teacher capacity building and leveraging the strengths of both public and private sectors, Saudi Arabia can create a sustainable, inclusive model for AI adoption that supports all learners regardless of their socioeconomic background while advancing the country's broader educational transformation goals.

- Cross-National Comparison:

Similar patterns of disparity and affordability challenges appear across several developing economies. In Indonesia, limited funding and uneven teacher training constrain AI adoption in public schools, while private institutions in urban areas progress faster due to better infrastructure and flexible budgets [27, 28]. In India, large-scale digital education initiatives and continuous teacher training programs have improved access and affordability, though rural regions still face connectivity and infrastructure issues [29, 30]. Compared with these contexts, Saudi Arabia shares structural similarities but benefits from stronger centralized support under Vision 2030, positioning it to achieve more sustainable and equitable AI integration through ongoing investment, teacher capacity building, and long-term monitoring.

V. CONCLUSION

The present descriptive study has illustrated the significant differences in the uptake of AI in early childhood education in Saudi Arabia between private and public institutions, with important implications for educational equity and sustainable development. By comparing 127 survey responses and interviewing 14 teachers and administrators, the study shows that although AI-based educational tools hold considerable promise for improving educational outcomes, their actual use is shaped by sectoral disparities in technological readiness, teacher training, and implementation support. Key findings reveal that adaptive learning platforms are available in 78% of private schools compared to 12% of public schools, and dedicated technology budgets exist in 73% of private schools versus 23% of public schools. Private school educators also report higher rates of AI training (62%), while 81% of public schools have no AI tools available compared to 12% of private schools. These differences create positive feedback loops in private schools, where early investment, training, and technical support reinforce adoption, and negative cycles in public schools, where outdated infrastructure and limited capacity hinder progress. However, these challenges are no longer solely about insufficient funding. With substantial government investment and the nationwide rollout of an AI curriculum beginning in the 2025–2026 academic year, the primary focus must shift toward the strategic and efficient use of available resources. This means prioritizing robust technical infrastructure development ensuring high-speed connectivity, updated hardware, and in-school technical support as well as systematic, mandatory teacher training that includes hands-on practice, pedagogical integration, and context-specific guidance for early childhood settings. It also calls for fostering public-private partnerships to bridge capacity

gaps and accelerate innovation while maintaining cultural relevance and age-appropriateness. The fact that both sectors present a positive attitude toward AI tools, with 82% believing these tools can enhance personalized learning, provides a strong foundation for successful implementation if supported by targeted, forward-looking policy measures. The holistic policy framework emerging from this study offers practical recommendations: strategically aligning infrastructure upgrades with the AI curriculum rollout, embedding compulsory professional development opportunities, and building sustainable partnerships between public and private sectors. This research contributes a first-of-its-kind, comprehensive analysis of AI adoption disparities in Saudi Arabian early childhood education, offering insights that are applicable to other developing economies undergoing similar educational transformations. Future longitudinal studies should track the impact of these policy interventions to ensure that the transformational potential of AI is fully realized for all learners, regardless of socioeconomic status or institutional context.

- Future Research Directions:

Future research should examine the long-term impact of AI integration in Saudi Arabia's early childhood education by tracking outcomes across multiple academic years. Longitudinal studies can measure how ongoing investments in infrastructure, teacher training, and policy implementation influence learning quality, inclusiveness, and sustainability. Cross-country comparisons with other Gulf Cooperation Council nations such as the UAE, Qatar, and Bahrain could further reveal regional best practices and highlight scalable approaches for equitable AI adoption. Additionally, mixed-methods research combining classroom observations, teacher performance assessments, and student developmental outcomes would provide deeper insights into how AI tools shape teaching strategies and learner engagement. Evaluating these long-term effects will help policymakers refine national strategies, ensuring that AI integration continues to align with Vision 2030 objectives while maintaining equity and cultural relevance across all educational sectors.

Data Availability Statement

The data presented in this study are available from the corresponding author upon reasonable request.

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