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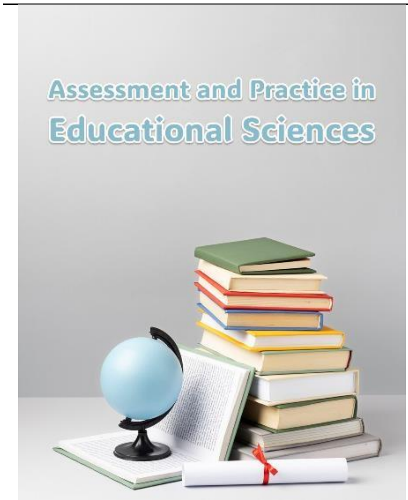

Validation of the Model of Ethical Requirements of Artificial Intelligence in Education

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ABSTRACT

The present study was conducted with the aim of validating a model of the ethical requirements of artificial intelligence (AI) in education. In terms of purpose, the research was applied; in terms of data type, it employed an exploratory mixed-methods design; and in terms of implementation, it was carried out using a paradigmatic grounded theory approach in the qualitative phase and a cross-sectional survey method in the quantitative phase. The qualitative participants consisted of experts and specialists in the fields of artificial intelligence and information technology in education, including university faculty members and thematic administrators within the education system. The sample was selected purposively using the snowball sampling method, and interviews were conducted with 23 participants until theoretical saturation was achieved. The quantitative population included all district and secondary school administrators in the city of Tehran, totaling 1,880 individuals. Based on Cochran's formula, a sample size of 319 was determined and selected through stratified random sampling. Qualitative data were collected through fieldwork using semi-structured interviews, while quantitative data were gathered through fieldwork using a researcher-developed questionnaire. To establish the trustworthiness of the qualitative findings, triangulation methods—including dependability, credibility, confirmability, and transferability—were employed, indicating that the data possessed adequate validity. The validity of the quantitative instrument was assessed through face validity followed by content validity, with the content validity ratio (CVR) for each component exceeding 0.42. The reliability of the instrument was calculated using Cronbach's alpha, with coefficients for all components exceeding 0.70. Qualitative data were analyzed using theoretical coding, and quantitative data were analyzed using confirmatory factor analysis. The results indicated that the model of ethical requirements of artificial intelligence in education comprised 22 axial codes and 100 open codes within six dimensions of the paradigmatic model, all of which were confirmed by experts in the qualitative phase. According to the findings, the core phenomenon of ethical requirements of AI in education included three axial codes and 13 open codes; the causal conditions comprised three axial codes and 15 open codes; the contextual conditions included three axial codes and 16 open codes; the intervening conditions consisted of three axial codes and 14 open codes; the strategies encompassed five axial codes and 23 open codes; and the consequences included five axial codes and 19 open codes. Finally, the developed model was evaluated in the quantitative phase through confirmatory factor analysis, and the model fit indices indicated confirmation of the model. By accurately identifying conditions, strategies, and consequences, the proposed model provides a realistic yet normative representation of AI ethics in education. **Keywords:** Model validation, ethical requirements, artificial intelligence, education.

Introduction

The rapid expansion of artificial intelligence (AI) technologies has profoundly transformed contemporary educational systems, reshaping pedagogical practices, governance structures, assessment mechanisms, and institutional decision-making processes. From adaptive learning platforms and automated feedback systems to predictive analytics and generative content tools, AI has increasingly become embedded within formal education at all levels. This transformation has been widely framed as an opportunity to enhance personalization, efficiency, and scalability in teaching and learning environments (1, 2). However, alongside these promises, the growing reliance on AI has generated complex ethical challenges that extend beyond technical performance and into fundamental questions of fairness, accountability, transparency, and human dignity within educational contexts (3, 4).

A central concern in the discourse on AI in education relates to the normative assumptions embedded within algorithmic systems and the ways these systems shape educational values, relationships, and power structures. Educational AI systems are not neutral tools; rather, they are sociotechnical assemblages shaped by data politics, institutional priorities, and governance regimes that influence how learners are categorized, evaluated, and guided (5). The increasing standardization and datafication of education through AI-driven metrics has raised concerns about objectivity being redefined as algorithmic compliance, potentially marginalizing contextual judgment and professional autonomy (6). These dynamics underscore the need to critically examine the ethical foundations guiding AI deployment in education rather than focusing solely on technological innovation.

International organizations have emphasized the urgency of addressing ethical dimensions of AI in education through normative frameworks and policy guidance. UNESCO's Recommendation on the Ethics of Artificial Intelligence provides a global reference point by highlighting principles such as human rights protection, inclusiveness, transparency, and sustainability, with explicit relevance to educational systems (7). Similarly, the OECD has framed AI in education as a governance challenge requiring ethical safeguards to ensure trust, equity, and long-term societal benefit (8). While such frameworks articulate high-level principles, translating these principles into operational and context-sensitive models within national education systems remains a significant challenge (4, 9).

At the institutional level, educators and administrators are increasingly confronted with ethical dilemmas arising from AI-mediated decision-making. Issues such as algorithmic bias in student assessment, surveillance through learning analytics, data privacy violations, and opaque automated recommendations have been documented across diverse educational settings (10, 11). Teachers' perspectives reveal tensions between the pedagogical benefits of AI tools and concerns over loss of professional judgment, accountability gaps, and reduced relational dimensions of teaching (10). These challenges are further intensified by the limited ethical literacy of students and educators regarding AI systems, highlighting the need for structured ethical guidance within educational institutions (12).

Recent empirical studies have shown that students perceive AI in education as both an opportunity and a risk, particularly with respect to fairness, autonomy, and trust. Undergraduate learners acknowledge AI's potential to enhance learning efficiency but express concerns about data misuse, biased outcomes, and reduced human interaction (13). Similar findings have been reported in higher education contexts, where ethical uncertainty often accompanies increased adoption of AI-driven instructional and administrative tools (14). These perceptions underscore the importance of embedding ethical requirements not only at the policy level but also within the everyday operational practices of educational systems.

Algorithmic fairness has emerged as a particularly critical ethical concern in education, given AI's reliance on large-scale data sets that may reproduce or amplify existing social inequalities. Research has demonstrated that algorithmic decision-making can disadvantage certain student groups if biases in training data or model design are not systematically addressed (15). In educational contexts, such biases may affect student placement, grading, access to resources, and long-term academic trajectories, raising profound ethical questions about justice and inclusion (16). Consequently, ethical AI in education must be understood as a multidimensional construct encompassing technical, pedagogical, social, and institutional considerations.

The ethical implications of AI extend beyond immediate classroom practices to broader civic and societal dimensions of education. Generative AI technologies, in particular, have introduced new ethical challenges related to academic integrity, authorship, and civic responsibility (17). The increasing use of AI-generated content in learning environments has prompted debates over plagiarism, intellectual property, and the development of students' moral reasoning and critical thinking capacities (18). These developments suggest that ethical AI in education cannot be reduced to compliance mechanisms but must engage with deeper educational aims related to character formation, autonomy, and democratic participation (19).

Several scholars have emphasized that ethical AI in education requires moving beyond principle-based approaches toward contextually grounded and institutionally embedded models. While ethical principles such as transparency and accountability are necessary, they are insufficient on their own to guarantee ethical outcomes in complex educational systems (4). Empirical analyses reveal gaps between ethical guidelines and actual practices, particularly in environments where AI adoption is driven by efficiency pressures and market logics (9). This disconnect highlights the need for integrative models that align ethical requirements with causal conditions, contextual factors, institutional strategies, and educational outcomes.

From a governance perspective, AI has become a powerful instrument shaping educational policy and reform agendas. Data-driven governance models increasingly rely on AI analytics to inform decision-making, often privileging quantifiable indicators over qualitative educational values (5). This shift raises ethical concerns about accountability, transparency, and democratic oversight, particularly when algorithmic systems influence high-stakes decisions affecting students and teachers (11). Addressing these challenges requires ethical frameworks that explicitly consider power relations, institutional responsibility, and the role of human judgment in AI-mediated governance.

Recent interdisciplinary research has called for holistic approaches to AI ethics in education that integrate technical safeguards with pedagogical, social, and environmental considerations. Ethical sustainability, including the environmental impact of AI infrastructures and long-term societal consequences, has gained attention as an emerging dimension of educational ethics (20). Furthermore, scholars have emphasized the importance of aligning AI ethics with Education 5.0 paradigms, which prioritize human-centered innovation, social responsibility, and ethical literacy (21). These perspectives reinforce the need for comprehensive models capable of capturing the complexity of ethical AI in education.

Despite the growing body of literature on AI ethics, there remains a lack of empirically validated models specifically designed to operationalize ethical requirements within educational systems. Existing studies often focus on isolated ethical dimensions or rely on conceptual discussions without systematic validation (22, 23). Moreover, much of the current research emphasizes higher education, leaving secondary education and broader institutional structures underexplored (1). This gap underscores the necessity of developing and validating integrative models that reflect the realities of educational practice while adhering to internationally recognized ethical standards.

Grounded theory approaches offer a valuable methodological framework for addressing this gap by enabling the systematic identification of ethical dimensions grounded in empirical data and expert perspectives. By integrating qualitative insights with quantitative validation, such approaches can generate robust models that reflect both normative ideals and practical constraints (16). In the context of AI in education, this methodological integration is particularly important given the rapidly evolving technological landscape and the diversity of stakeholder interests involved.

In light of these considerations, there is a pressing need for a validated, context-sensitive model that articulates the ethical requirements of artificial intelligence in education by systematically linking causal factors, contextual conditions, intervening variables, strategic responses, and educational outcomes. Such a model can provide a coherent framework for policymakers, educational leaders, and practitioners to assess, design, and govern AI systems in ways that are ethically grounded, socially responsible, and educationally meaningful.

Accordingly, the aim of this study is to develop and validate a comprehensive model of the ethical requirements of artificial intelligence in education using a systematic grounded theory approach combined with confirmatory factor analysis.

Methods and Materials

This study is applied in terms of purpose, exploratory mixed-methods (qualitative and quantitative) in terms of data, and, in terms of research implementation, employs a systematic grounded theory approach (qualitative phase) and a cross-sectional survey design (quantitative phase). The statistical population in the qualitative phase included all experts and university faculty members with scholarly contributions in the fields of ethics in education and artificial intelligence, as well as senior administrators in the education system who were knowledgeable and informed in this area and who met the following criteria: a master's degree or higher, more than 15 years of professional experience in the education system, and at least five years of managerial experience. Qualitative sampling was conducted using the snowball technique and continued until theoretical saturation was achieved. The interview process concluded after conducting interviews with 23 participants. The statistical population of the quantitative phase consisted of all district and secondary school administrators in the city of Tehran, totaling 1,880 individuals. To determine the sample size, Cochran's formula was applied, yielding a sample of 319 participants, who were then selected using stratified random sampling.

In the qualitative phase, both library-based and field methods were used for data collection. Initially, a library-based approach was employed to examine the theoretical foundations and research background. Subsequently, field methods were used to collect data. A semi-structured interview guide was developed, and data were obtained from experts based on the interview protocol. In the quantitative phase, data were collected through field methods using a researcher-developed questionnaire. This questionnaire consisted of 100 items across 22 components and was designed based on a seven-point Likert scale.

To validate the research findings, the triangulation method proposed by Lincoln and Guba was applied, considering four criteria: dependability, credibility, confirmability, and transferability (Lincoln & Guba, 1985). In practice, the researcher employed triangulation across multiple sources, methods, researchers, and theories to collect richer data and examine the phenomenon from different perspectives, thereby enhancing the validity (dependability and credibility) and generalizability (transferability) of the findings. Dependability was ensured by selecting participants with maximum variation in experiences and continuing sampling until data saturation was reached. The internal validity of the content analysis was assessed through face validity. Credibility was enhanced through careful examination of the data by an external auditor. Confirmability was established by sharing the research process with several research colleagues to verify the accuracy of the procedures. Transferability was addressed by capturing diverse viewpoints and experiences of different participants regarding the phenomenon. To facilitate transferability, the researcher provided a clear description of the research context, participant selection procedures and characteristics, data collection methods, and the analysis process, enabling readers to judge the applicability of the findings to other contexts. Additionally, presenting rich and detailed findings accompanied by appropriate quotations further enhanced transferability.

In the quantitative phase, content validity was assessed using the content validity ratio (CVR), and reliability was measured using Cronbach's alpha. The results are presented in Table 1.

Table 1. Content Validity and Reliability Values of the Questionnaire Components

Components	CVR	α	Components	CVR	α
Protection of students' privacy	0.742	0.931	Continuous monitoring and evaluation	0.849	0.914
Responsibility and accountability	0.783	0.880	Development of ethical codes	0.751	0.921
Enhancement of public awareness	0.726	0.865	Goal-setting in design and development	0.814	0.926
Definition of ethical duties	0.789	0.910	Communication and dialogue with stakeholders	0.792	0.917
Creation of ethical obligation and motivation	0.835	0.891	Integration with existing educational systems	0.811	0.906
Defining ethical boundaries in development	0.860	0.922	Ethical decision-making	0.853	0.933
Human emotions	0.756	0.873	Fair and diverse data distribution	0.799	0.892

Ethical knowledge and cognition	0.773	0.887	Preservation of users' human dignity	0.786	0.930
Systemic risks and misuse	0.728	0.874	Future environmental sustainability	0.780	0.900
Inclusiveness and accessibility	0.805	0.925	Enhancement of autonomy and critical thinking	0.884	0.939
Diversity, participation, and human-centeredness	0.807	0.903	Educating a competent student	0.890	0.830
Transparency and explainability	0.835	0.902	Creating transformation in the education system	0.910	0.810

The CVR coefficients for all questionnaire components were calculated, and all values exceeded 0.70. Considering the acceptable threshold reported by Lawshe (1975) of 0.42, the results indicate that the questionnaire possesses adequate content validity. In addition, the reliability of the questionnaire was assessed using Cronbach's alpha, with all component coefficients exceeding 0.70, indicating acceptable reliability.

For the analysis of qualitative data, theoretical coding (open, axial, and selective coding) was conducted using the systematic grounded theory approach. Data were generated and analyzed through three stages of coding, and the coding process was carried out using MAXQDA version 24.4. Quantitative data were analyzed using confirmatory factor analysis, and all statistical computations were performed using SPSS version 24 and LISREL software.

Findings and Results

Based on the research questions posed in the present study, the researcher, drawing on systematic grounded theory, first conducted the coding process in three stages and then examined the model fit. The results are presented below.

By transcribing the interview texts, highlighting key concepts, and standardizing keywords, the researcher generated an initial list of primary codes. After harmonizing and refining similar codes, open codes were derived. At this stage, 281 initial codes were identified, which, through merging similar codes and standardizing the primary codes, were reduced to 100 open codes.

Subsequently, the extracted open codes were categorized using MAXQDA software and organized under broader concepts, such that codes within each category were conceptually and semantically related. Accordingly, the 100 open codes were organized under 22 axial codes, as presented in Table 2.

Table 2. Open and Axial Codes Related to the Ethical Requirements of Artificial Intelligence in Education

Axial Codes	Open Codes
Inclusiveness and Equity	Non-discrimination in algorithmic decision-making among students with diverse characteristics; fair treatment of all students through algorithm design; accessibility of AI systems for all students and teachers; consideration of students' cultural diversity by AI and respect for it
Diversity, Participation, and Human-Centeredness	Comprehensive coverage of students and teachers across different regions and diverse characteristics; participation of all stakeholders in the development and use of AI; attention to human principles in AI systems; continuous usability and flexibility of AI systems
Transparency and Explainability	Building students' trust to use AI educational capacities; identification of error sources and their consequences across algorithms and AI data sources; improving system accuracy to enhance transparency of algorithmic performance in student learning; increasing trust and predictability of AI systems among teachers and students; combating cheating and plagiarism
Protection of Students' Privacy	Protection of students' search information related to academic assignments; safeguarding students' data and interests; use of advanced encryption to protect students' privacy; obtaining explicit consent from students for data disclosure; secure storage of students' educational data; prevention of misuse of students' activities on AI platforms
Responsibility and Accountability	Preserving teachers' roles as final decision-makers; accountability of AI producers and actors for proper system performance; adherence to ethical principles toward students and education in AI application and production; use of experts to supervise and control AI systems; identification and elimination of unintended AI biases against students; establishment of accountability mechanisms for harms caused to students by producers
Enhancement of Public Awareness	Familiarizing students with basic AI concepts; enabling students to defend their rights in AI use; acquiring foundational knowledge and vigilance against digital misuse
Definition of Ethical Duties	Defining specific roles for AI ethics committees in schools and the education system; compensating for algorithmic decision-making harms through observable and impartial methods by developers; appointing responsible individuals or entities to compensate students and teachers; defining duties of educational policymakers regarding AI use in schools; specifying ethical requirements for teachers and students as general users; specifying ethical requirements for coders and AI system developers; international cooperation between education authorities and AI system producers to promote ethical compliance

Creation of Ethical Obligation and Motivation	Ensuring non-infringement of international human rights in the design, development, and deployment of technologies; embedding inspection measures and processes for teachers and students to verify how and when AI technologies are applied; resilience and security of education-related AI systems against data manipulation; motivating all educational stakeholders to comply with AI ethical requirements
Defining Ethical Boundaries in Development	Developing systems, applications, and algorithms using diverse student demographic data; reflecting the needs and values of different student groups in system development; maintaining accurate records and documentation of AI system design and decision-making processes in education; developing AI in education to preserve students' human dignity; developing AI in education to protect the environment of students and future generations
Human Emotions	Attention to and encouragement of students' human values; respect for students' judgments influenced by AI; understanding and responding to human emotions by AI to create meaningful interaction with students and sound ethical judgment; increasing dependence of students and teachers on AI; reduction of human interactions and emotions among students with greater reliance on machines
Ethical Knowledge and Cognition	Negative impact of AI on students' ethical knowledge and cognition; changes in users' understanding of ethics in education; dominance of AI over human intelligence among students; erosion of students' cr eativity and innovation by diminishing cognitive capacity; influence on students' beliefs through AI's mental control
Systemic Risks and Misuse	Violation of material and intellectual property of educational content producers; incorrect counseling to AI us ers in education; forgery and deception in educational content production through various methods; provision of unrealistic and fabricated educational content to audiences
Continuous Monitoring and Evaluation	Human oversight to review and validate critical educational decisions made by AI; enabling auditability of AI systems in education; ensuring proper and correct functioning of systems used by students; caution and prevention in AI use with awareness of potential risks through continuous oversight by ed ucation authorities; defining governance frameworks for AI development and use in education
Development of Ethical Codes	Identifying and formulating ethical codes in education; identifying and enforcing education -related codes such as respect for privacy, integrity, and avoidance of deception; collecting ethical issues from users and converting them into binding AI codes; institutionalizing and reinforcing salient ethical values in learning and education; developing executive guidelines for AI production, development, and application in education
Goal-Setting in Design and Development	Developing clear policies on permissible AI use; considering offenses and penalties for AI designers and developers in education to protect users; responsible collection and storage of user data and information by AI producers; assigning secure credentials to users to protect students' and teachers' information; protecting material and intellectual property of educational content producers; formulating new laws and regulations to govern AI development and use in education
Communication and Dialogue with Stakeholders	Encouraging dialogue among diverse stakeholders about the future of AI systems; increasing awareness and commitment of intelligent information system developers in education; enhancing public awareness among users and AI developers regarding ethics in education; increasing investment in research and education on ethics and AI
Integration with Existing Educational Systems	Coordination and integration of AI systems with learning management systems; interoperability and alignment with educational standards; scalability and maintenance of performance of existing systems
Ethical Decision-Making	Designing systems capable of explaining decisions; supporting students' progress and problem-solving through AI systems; preventing misuse and harm to users in the education system; assisting students' ethical decision - making in assignment writing; preventing plagiarism and misuse of others' educational content by teachers
Fair and Diverse Data Distribution	Special attention to the digital divide and social inequalities among students in schools; development of universally accessible platforms; production of educational content suitable for the entire student population; avoidance of biased information and data by AI platform developers; generation of consistent outcomes for all students and users with diverse conditions and characteristics
Preservation of Users' Human Dignity	Serving users through AI systems in education; enhancing the welfare and human dignity of students and teachers through AI; participation of all stakeholders—especially students and teachers—in AI development and use
Future Environmental Sustainability	Long-term benefits of AI use for students; predicting future behavior and creating useful insights for students through AI; use of environmentally low-risk hardware in AI design and development
Enhancement of Autonomy and Critical Thinking	Preventing excessive dependence of students and teachers on AI; preserving and strengthening students' critical thinking skills; using AI as a complementary tool rather than a substitute for teachers

In the third stage, the extracted open and axial codes were presented to experts, who were asked to express their views regarding these codes. After receiving feedback and applying revisions—particularly involving the transfer and integration of certain codes—the open and axial codes were ultimately confirmed. In addition, the relationships among the codes were established by the experts, and the open and axial codes were positioned within the components of the Strauss and Corbin systematic (paradigmatic) model.

The results of the three stages of open, axial, and selective coding using the systematic grounded theory approach are presented in Table 3.

Table 3. Codes Derived from the Systematic Coding Process

Model Components	Axial Codes	Open Codes	Model Components	Axial Codes	Open Codes
Causal Conditions	Protection of students' privacy	1–6	Strategies	Continuous monitoring and evaluation	59–63
	Responsibility and accountability	7–12		Development of ethical codes	64–68
	Enhancement of public awareness	13–15		Goal-setting in design and development	69–74
Contextual Conditions	Definition of ethical duties	16–22		Communication and dialogue with stakeholders	75–78
	Creation of ethical obligation and motivation	23–26		Integration with existing educational systems	79–81
	Defining ethical boundaries in development	27–31	Consequences	Ethical decision-making	82–86
Intervening Conditions	Human emotions	32–36		Fair and diverse data distribution	87–91
	Ethical knowledge and cognition	37–41		Preservation of users' human dignity	92–94
	Systemic risks and misuse	42–45		Future environmental sustainability	95–97
Core Phenomenon	Inclusiveness and equity	46–49		Enhancement of autonomy and critical thinking	98–100
	Diversity, participation, and human-centeredness	50–53			
	Transparency and explainability	54–58			

In order to validate the model of ethical requirements of artificial intelligence in education, the Kolmogorov–Smirnov test was first conducted.

Table 4. Results of the Kolmogorov–Smirnov Test

Significance Level	Degrees of Freedom	K–S
0.720	318	5.39

The results presented in Table 4 indicate that the significance level obtained for the variable of ethical requirements of artificial intelligence in education (0.720) is greater than 0.05, and the K–S value is 5.39. Therefore, the distribution of data related to the ethical requirements of artificial intelligence in education is normal. Accordingly, the conditions for using parametric tests for data analysis are met. Subsequently, in order to generalize the results to the population from which the sample was drawn and to determine the significance of the relationships between observed and latent variables, confirmatory factor analysis was employed, the results of which are presented in the following section.

Table 5. Summary of Goodness-of-Fit Indices for Measurement and Structural Models

Model Component	χ^2	df	χ^2/df	RMSEA	P-value	GFI	AGFI	CFI	IFI
Core phenomenon	387.98	132	2.94	0.029	< .001	0.92	0.90	0.95	0.95
Causal conditions	822.63	287	2.87	0.063	< .001	0.93	0.92	0.96	0.95
Contextual conditions	995.63	351	2.84	0.067	< .001	0.91	0.90	0.94	0.93
Intervening conditions	429.15	154	2.79	0.023	< .001	0.91	0.90	0.95	0.94
Strategies	1304.82	455	2.88	0.053	< .001	0.93	0.92	0.96	0.96
Consequences	785.46	267	2.94	0.071	< .001	0.92	0.90	0.95	0.95
Overall structural model	3840.78	1343	2.86	0.064	< .001	0.92	0.90	0.96	0.95

The confirmatory factor analysis results indicated that the measurement and structural components of the ethical requirements of artificial intelligence in education were statistically acceptable and conceptually coherent. Across all dimensions of the model, the factor loadings of the observed variables exceeded the minimum acceptable threshold of 0.40, demonstrating strong relationships between observed indicators and their corresponding latent constructs. In addition, the associated t-values for the retained indicators were outside the ±1.96 range at the 0.05 significance level, confirming the statistical significance of the measurement paths. These findings collectively indicate that the observed variables were capable of adequately explaining the latent variables and played a meaningful role in construct measurement.

With respect to the core phenomenon of the model, the confirmatory factor analysis showed that the three axial dimensions—*inclusiveness and equity*, *diversity, participation, and human-centeredness*, and *transparency and explainability*—had strong and statistically significant relationships with the latent construct. The factor loadings ranged from 0.86 to 0.90, and the corresponding t-values ranged from 15.94 to 18.77, indicating that these dimensions reliably captured the conceptual essence of the core phenomenon. The goodness-of-fit indices further demonstrated that the measurement model for the core phenomenon was well fitted to the data, supporting the validity of this central construct within the overall model.

The confirmatory factor analysis of the causal conditions similarly demonstrated robust results. The axial dimensions of *protection of students' privacy*, *responsibility and accountability*, and *enhancement of public awareness* exhibited high factor loadings (0.91–0.96) and statistically significant t-values (14.10–18.12). These findings indicate that the causal conditions were well defined and that the observed indicators effectively explained the latent construct. The fit indices confirmed that the causal conditions component achieved an acceptable to good level of model fit.

In relation to the contextual conditions, the results showed that *definition of ethical duties*, *creation of ethical obligation and motivation*, and *defining ethical boundaries in development* were all strongly associated with the latent contextual construct. Factor loadings ranged between 0.91 and 0.95, with corresponding t-values exceeding the critical threshold. These results confirm that the contextual conditions provide a stable and meaningful explanatory framework for understanding the background factors influencing the ethical requirements of artificial intelligence in education.

The analysis of intervening conditions also yielded satisfactory results. The dimensions of *human emotions*, *ethical knowledge and cognition*, and *systemic risks and misuse* demonstrated strong factor loadings (0.88–0.95) and statistically significant t-values (16.25–18.71). This indicates that intervening conditions play a substantial role in shaping how ethical requirements are mediated and enacted within educational contexts influenced by artificial intelligence.

For the strategic dimension of the model, the confirmatory factor analysis showed that *continuous monitoring and evaluation*, *development of ethical codes*, *goal-setting in design and development*, *communication and dialogue with stakeholders*, and *integration with existing educational systems* were all significant contributors to the latent strategies construct. Factor loadings ranged from 0.90 to 0.95, and all corresponding t-values were statistically significant. These results suggest that the strategic actions proposed by the model are empirically supported and collectively form a coherent set of mechanisms for operationalizing ethical requirements in practice.

The confirmatory factor analysis of the consequences dimension further supported the validity of the model. The axial dimensions of *ethical decision-making*, *fair and diverse data distribution*, *preservation of users' human dignity*, *future environmental sustainability*, and *enhancement of autonomy and critical thinking* all demonstrated strong factor loadings (0.90–0.96) and statistically significant t-values. These findings indicate that the proposed consequences are meaningful outcomes of implementing ethical requirements of artificial intelligence in education and are empirically distinguishable yet conceptually aligned.

Beyond the measurement models, the structural equation modeling results clarified the relationships among the latent constructs. The structural model specified directional paths from the exogenous latent variable—ethical requirements of artificial intelligence in education—to the endogenous latent variables, including causal conditions, contextual conditions, intervening conditions, strategies, and consequences. The standardized path coefficients (gamma parameters) and their associated t-values indicated that these relationships were statistically significant, demonstrating that the theoretical structure of the model was empirically supported. The overall structural model exhibited a satisfactory level of fit with the data, indicating that the hypothesized relationships among constructs were consistent with the observed covariance structure.

Taken together, the results confirm that the ethical requirements of artificial intelligence in education model possesses acceptable construct validity, internal consistency, and structural coherence. The model developed in the qualitative phase—comprising 100 open codes and 22 axial codes organized under six components of the Strauss and Corbin systematic paradigmatic framework—was empirically validated in the quantitative phase through confirmatory factor analysis and structural equation modeling. The findings support the robustness of the model and its suitability as a comprehensive framework for analyzing, designing, and evaluating ethical approaches to artificial intelligence in educational systems.

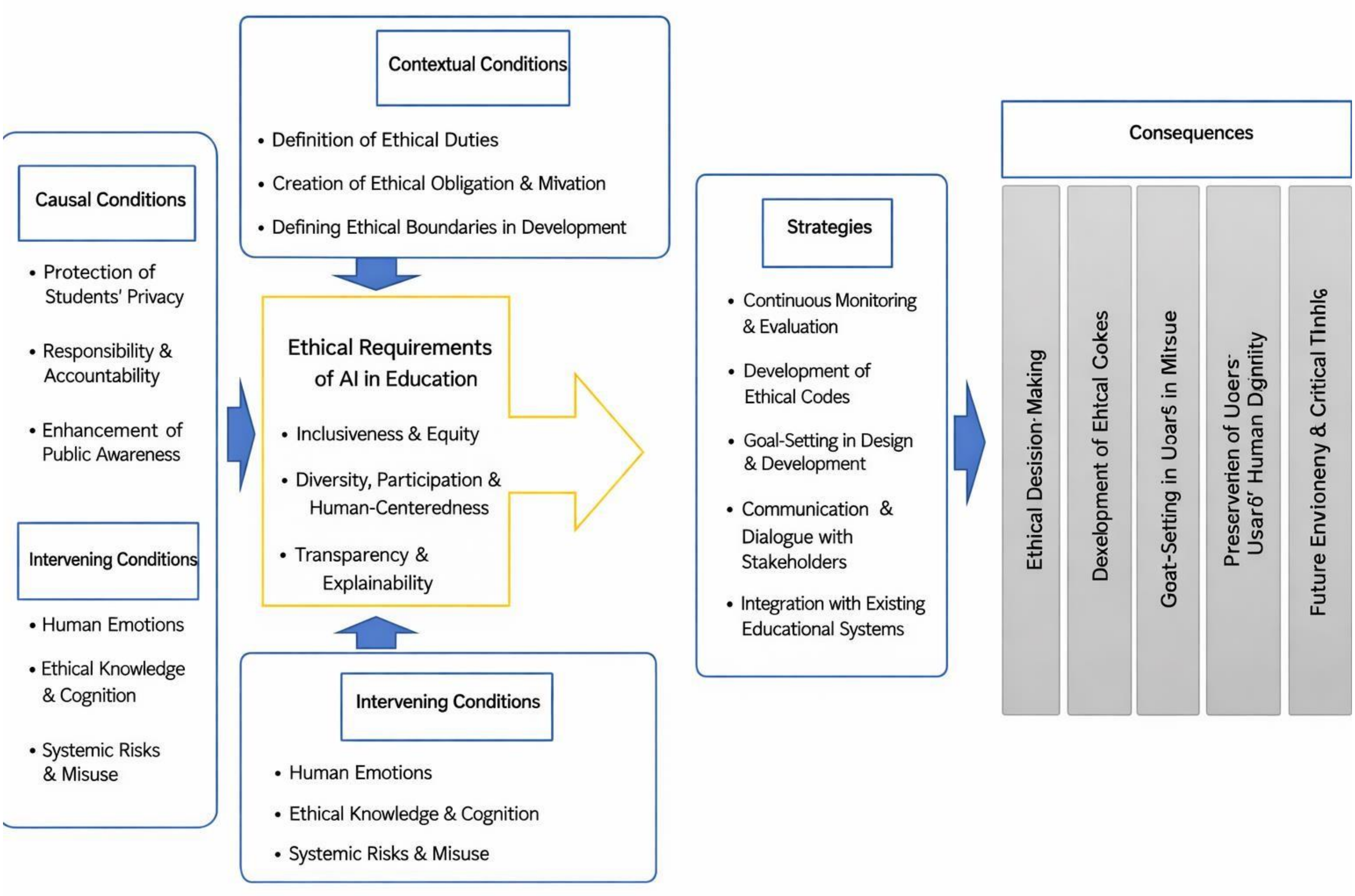

Figure 1. Final Model of the Study

Discussion and Conclusion

The present study aimed to develop and empirically validate a comprehensive model of the ethical requirements of artificial intelligence (AI) in education by integrating a systematic grounded theory approach with confirmatory factor analysis and structural equation modeling. The findings provide strong empirical support for a six-component paradigmatic model encompassing the core phenomenon, causal conditions, contextual conditions, intervening conditions, strategies, and consequences. Overall, the results demonstrate that ethical AI in education is a multidimensional construct that cannot be reduced to isolated principles or technical safeguards, but instead emerges from the interaction of institutional, social, pedagogical, and technological factors.

At the center of the validated model lies the core phenomenon, defined through inclusiveness and equity, diversity, participation and human-centeredness, and transparency and explainability. The strong factor loadings and statistically significant paths associated with these dimensions indicate that ethical AI in education is fundamentally grounded in values related to fairness, respect for human agency, and intelligibility of algorithmic processes. This finding aligns closely with prior theoretical and empirical work emphasizing that ethical AI must prioritize human-centered design and equitable treatment of learners rather than efficiency-driven optimization alone (2, 3). The prominence of transparency and explainability further reinforces arguments that opaque algorithmic systems undermine trust and accountability in educational settings (4, 9).

The confirmed role of causal conditions—namely protection of students' privacy, responsibility and accountability, and enhancement of public awareness—highlights the foundational drivers that give rise to ethical requirements in educational AI systems. The strong empirical relationships observed in this dimension reflect widespread concerns regarding data governance, surveillance, and unclear responsibility chains in AI-mediated education (5, 11). Consistent with studies on algorithmic fairness and data ethics, the findings suggest that safeguarding learners' privacy and clarifying accountability are prerequisites for ethical AI adoption, rather than secondary considerations (15). Moreover, the importance of public and stakeholder awareness resonates with research indicating that ethical risks are exacerbated when users lack sufficient understanding of how AI systems function and affect educational outcomes (10, 13).

The contextual conditions component—comprising definition of ethical duties, creation of ethical obligation and motivation, and defining ethical boundaries in development—was also empirically validated with strong fit indices. These results underscore that ethical AI in education is shaped by normative and institutional contexts that determine how responsibilities are distributed and enforced. This finding supports critiques of principle-based ethics that argue ethical guidelines alone are insufficient unless embedded within institutional cultures, governance mechanisms, and incentive structures (4). The emphasis on ethical boundaries in AI development aligns with international policy frameworks that call for anticipatory governance and value-sensitive design in educational technologies (7, 8).

Intervening conditions, including human emotions, ethical knowledge and cognition, and systemic risks and misuse, were found to significantly mediate the ethical functioning of AI in education. The inclusion of human emotions as a validated dimension is particularly noteworthy, as it reflects growing recognition that AI systems influence not only cognitive outcomes but also affective and relational aspects of learning. This result is consistent with research suggesting that excessive reliance on AI may weaken human interaction, empathy, and moral engagement in educational environments (3, 21). Similarly, the role of ethical knowledge and cognition reinforces calls for integrating AI ethics education into curricula to support learners' moral reasoning and critical engagement with technology (12, 19). The identification of systemic risks and misuse further echoes concerns about generative AI, misinformation, and academic misconduct in education (17, 24).

The strategies component of the model demonstrated particularly strong empirical support, indicating that ethical AI in education requires proactive and coordinated institutional actions. Continuous monitoring and evaluation, development of ethical codes, goal-setting in design and development, communication with stakeholders, and integration with existing educational systems were all confirmed as essential strategic responses. These findings align with governance-oriented research emphasizing that ethical AI is sustained through ongoing oversight rather than one-time compliance checks (6, 11). The importance of stakeholder dialogue mirrors calls for participatory approaches to AI governance that include educators, students, developers, and policymakers in ethical deliberation (14, 23).

The validated consequences of the model—ethical decision-making, fair and diverse data distribution, preservation of users' human dignity, future environmental sustainability, and enhancement of autonomy and critical thinking—highlight the broader educational and societal impacts of ethical AI implementation. These outcomes reflect a shift from narrow performance metrics toward holistic educational values. The strong association between ethical AI and autonomy and critical thinking supports concerns that uncritical adoption of AI may deskill learners unless deliberately designed as a supportive, rather than substitutive, tool (2, 18). Additionally, the inclusion of environmental sustainability as an ethical consequence aligns with emerging literature that situates AI ethics within long-term social and ecological responsibility (20, 25).

At the structural level, the overall model demonstrated good fit indices, confirming the theoretical coherence of the Strauss and Corbin paradigmatic framework in explaining ethical AI in education. The significant paths from the overarching construct of ethical requirements to causal, contextual, intervening, strategic, and outcome dimensions suggest that ethical AI is best understood as a dynamic system rather than a static checklist. This systemic perspective is consistent with meta-analytical and bibliometric studies that emphasize the fragmented yet interconnected nature of AI ethics research in education (1, 16). By empirically validating these relationships, the present study advances the literature by providing a structured and operationalizable model that bridges normative ethics and empirical educational practice.

Overall, the discussion of findings suggests that ethical AI in education requires alignment between values, governance structures, human capacities, and technological design. The study supports arguments that ethical challenges in educational AI are not merely technical problems but deeply embedded in institutional decision-making, power relations, and educational philosophies (5, 22). By integrating diverse ethical dimensions into a validated model, the findings contribute to a more nuanced and actionable understanding of how AI can be ethically governed within educational systems.

Despite the strengths of this study, several limitations should be acknowledged. First, the empirical data were collected within a specific national and institutional context, which may limit the generalizability of the findings to other educational systems with different governance structures, cultural norms, or levels of technological maturity. Second, although the mixed-methods design enhanced the robustness of the model, the quantitative phase relied on self-reported data, which may be subject to response bias or social desirability effects. Third, the rapidly evolving nature of AI technologies means that some ethical concerns may emerge or change over time, potentially requiring periodic revision of the model. Finally, while the model captures a broad range of ethical dimensions, it does not explicitly differentiate between various AI applications (e.g., generative AI, learning analytics, or adaptive assessment), which may have distinct ethical profiles.

Future research could extend this study by testing the validated model across different educational levels, such as primary education, vocational training, or higher education, to examine its contextual robustness. Comparative cross-national studies would be particularly valuable in exploring how cultural, legal, and policy environments influence ethical requirements of AI in education. Longitudinal research designs could also be employed to investigate how ethical perceptions and practices evolve as AI technologies become more deeply embedded in educational systems. Additionally, future studies might refine the model by examining specific AI applications separately or by integrating students' and teachers' behavioral outcomes as mediating variables. Finally, experimental and intervention-based research could assess the effectiveness of specific ethical strategies identified in the model.

From a practical perspective, educational policymakers and institutional leaders can use the validated model as a diagnostic and planning tool to assess the ethical readiness of AI initiatives. Institutions should prioritize the development of clear ethical codes, continuous monitoring mechanisms, and transparent accountability structures before large-scale AI deployment. Teacher professional development programs should incorporate AI ethics literacy to strengthen educators' capacity for ethical decision-making. Educational technology developers should be encouraged to collaborate closely with educators and learners to ensure human-centered and inclusive design. Finally, integrating ethical considerations into everyday educational practices—rather than treating them as external constraints—can help foster sustainable, trustworthy, and pedagogically meaningful uses of artificial intelligence in education.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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