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Research on the Transformation of Engineering Ethics Curriculum Teaching Mode Enabled by Artificial Intelligence

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Abstract. Against the backdrop of rapid development in artificial intelligence, the teaching philosophy, content system and instructional methods of the Engineering Ethics course are facing unprecedented challenges and opportunities. This study aims to explore new pathways for the deep integration of artificial intelligence into the Engineering Ethics curriculum. By designing three modules—knowledge graph, virtual simulation and intelligent evaluation—it constructs a teaching system that supports contextual learning, dynamic interaction and objective feedback. Preliminary practical research indicates that the findings of this paper can not only improve the immersion and engagement of the course, but also effectively strengthen students' ethical judgment and sense of responsibility in complex engineering scenarios. It thus provides a referential implementation framework for cultivating future engineers with both technical competence and ethical literacy under the background of emerging engineering education.

Keywords: Artificial Intelligence, Engineering Ethics, Contextual Learning, Ethical Literacy.

1 Introduction

In recent years, the rapid development of artificial intelligence has profoundly transformed human production modes, social structures, and the ethical environment of engineering practice[1][2]. The widespread application of artificial intelligence systems in engineering design, intelligent manufacturing, data-driven decision-making and other fields has posed new challenges to the responsibility boundaries and value judgments of engineering activities[3][4]. Existing Engineering Ethics courses mainly focus on safety responsibility, environmental protection, professional ethics and related topics. However, with the extensive embedding of artificial intelligence in engineering practice, emerging ethical issues such as algorithmic bias, data privacy, automated de-

C. V. Garcés et al. (eds.), *Proceedings of the 6th International Conference on Internet, Education and Information Technology (IEIT 2026)*, Atlantis Highlights in Social Sciences, Education and Humanities 53,
https://doi.org/10.2991/978-94-6239-733-0_9

cision-making and conflicts with human values have emerged continuously, which urgently need to be addressed and reconstructed in the Engineering Ethics curriculum system[5]. Meanwhile, advances in technologies including intelligent recommendation, learning analytics, virtual simulation and natural language interaction have endowed Engineering Ethics education with unprecedented potential for intelligence and personalization in content presentation, learning path design and teaching feedback[6]. As a course integrating knowledge instruction and value guidance, Engineering Ethics can, empowered by artificial intelligence, construct realistic, dynamic and interactive ethical scenarios in instructional design, thereby stimulating students' moral reflection and sense of responsibility[7][8]. Nevertheless, Engineering Ethics courses in most universities still suffer from problems such as rigid teaching content, outdated and monotonous teaching methods, and insufficient student participation[9]. In terms of curriculum content, insufficient attention is paid to emerging topics including artificial intelligence ethics, algorithmic responsibility and data security, and a systematic knowledge framework has not yet been formed. In terms of teaching methods, instruction and case analysis remain dominant, while intelligent technology-based contextual experience and interactive learning are lacking. These problems restrict the effectiveness and appeal of engineering ethics education[10]. On this basis, this study discusses from three dimensions: curriculum content reconstruction, teaching activity innovation and teaching support system construction, explores the transformation of the teaching mode of Engineering Ethics empowered by artificial intelligence, and investigates feasible paths for the curriculum to evolve toward intelligence, personalization and contextualization.

2 AI Technology-Enabled Content Design for Engineering Ethics Courses

As one of the most influential technologies of the era, artificial intelligence (AI) has not only redefined the boundaries of engineering practice but also driven profound changes in ethics.

The Engineering Ethics course in the new era must respond to the ethical challenges and opportunities brought by AI. Centered on the integration of AI and engineering ethics, it should reconstruct course content and highlight core topics including emerging attributes of AI ethics, algorithmic responsibility and data security, and conflicts in ethical values. As shown in Figure 1, AI-enabled curriculum design requires a renewed understanding of the AI engineering paradigm, clarification of ethical responsibilities, and balance between human and machine values.

Teaching content should focus on the fairness, transparency, and accountability of AI technologies. It should examine the impacts of algorithms on social equity, data abuse, and privacy protection, as well as the boundaries between efficiency and humanistic care, and between machine decision-making and human intervention.In teaching practice, AI technology can be used to construct virtual simulation scenarios such as autonomous driving, medical diagnosis, architectural design, industrial production, and intelligent scheduling, so as to strengthen students' ethical judgment and practical abilities.

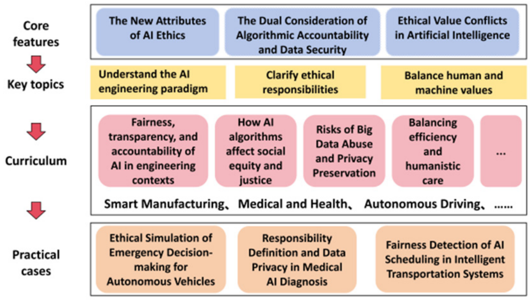

Fig. 1. Content Design of Engineering Ethics Curriculum Enabled by AI Technology

2.1 New Ethical Attributes of AI in the New Era

Most existing Engineering Ethics courses focus primarily on ethics in physical engineering and environmental engineering, which cannot address the new challenges posed by AI technology. Engineering ethics curricula in the new era should center on AI engineering ethics, guiding students to understand the new paradigm of AI engineering, reflect on AI's impacts on society and individuals, and explore ways to ensure fairness, transparency and accountability in the design and application of AI. Examples include preventing implicit algorithmic bias and safeguarding fairness in medical AI applications.

2.2 Dual Consideration of Algorithmic Responsibility and Data Security

In AI-enabled engineering ethics courses, algorithmic responsibility and data security serve as core topics. Through case analyses such as autonomous vehicle accidents and algorithmic bias on social media platforms, the course explores how to clarify the ethical responsibilities of developers, enterprises, and users in the design of intelligent systems. Especially in the field of data processing, with the application of big data and the reliance of artificial intelligence on massive data, ensuring data privacy and user security as well as preventing data abuse have become essential ethical issues that cannot be neglected in the curriculum of the new era.

2.3 Ethical Value Conflicts in Artificial Intelligence

The development of AI technologies has posed severe challenges to traditional ethical decision-making frameworks. The engineering ethics curriculum in the new era will conduct in-depth discussions on how AI addresses human-machine value conflicts. Combined with cases such as the application of AI in modern warfare and drone strikes, the course aims to cultivate students' ethical thinking and critical thinking. Against the backdrop of rapid advancement in AI technologies, there is an urgent demand for innovation in engineering ethics teaching activities. In the design of curriculum activities, artificial intelligence can provide strong support to facilitate the transformation toward personalization, contextualization and interaction.

3 AI Technology-Enabled Teaching Activities of Engineering Ethics Courses

With the rapid development of AI technology, innovation in engineering ethics teaching activities is imminent. AI can help curriculum activities achieve the transformation toward personalization, contextualization and interaction. As shown in Figure 2, the teaching process with AI as the core hub is presented: this system is student-centered. After the AI module captures students' needs, it pushes corresponding knowledge points from the knowledge system module, and then enables students to gain real experience through the virtual simulation experiment module. The experience results are fed back to the AI module to form a dynamic optimization cycle, ultimately constructing an intelligent teaching system with multi-module collaboration.

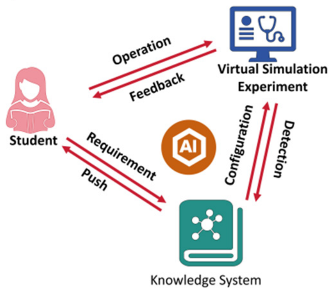

Fig. 2. Teaching Activity Flowchart

3.1 Knowledge System

Traditional Engineering Ethics courses are limited by rigid content and homogeneous modes, making it difficult to meet students' personalized needs, resulting in low engagement and superficial understanding.By reconstructing the course with AI technology, user portraits can be used to accurately analyze learning status and achieve precise content recommendation: cutting-edge topics such as AI ethical decision-making are provided for students with a solid foundation, while simplified explanations and basic cases are offered to those with weaker foundations, thus truly implementing differentiated teaching that caters to individual needs.

3.2 Virtual Simulation Experiment

Virtual simulation technology, as a key support for AI-enabled engineering ethics education, constructs highly realistic immersive scenarios and demonstrates remarkable value in modules such as "algorithmic responsibility" and "engineering decision-making". Relying on AI-driven systems, students can break through practical constraints and assume different roles in complex scenarios including autonomous driving and medical diagnosis. Through full-process practical operation, they intuitively evaluate the fairness, transparency, and security of algorithms. This closed-loop model of "theory–practice–reflection" not only deepens students' understanding of core issues such as responsibility and privacy, but also effectively compensates for the shortcoming of traditional teaching that overemphasizes theory while neglecting practice, promoting the internalization of ethical knowledge into core competencies.

3.3 Classroom Teaching Practice

By constructing high-fidelity virtual scenarios, AI technology turns abstract ethical principles into perceivable engineering practice. In autonomous driving ethics training, a digital twin platform simulates the "trolley problem" under extreme road conditions; students, as algorithm engineers and safety supervisors, weigh life value and responsibility boundaries in interactive crises and optimize decision logic with real accident data. In medical AI diagnosis training, privacy data and labeling bias are embedded, allowing students (as clinicians and developers) to face algorithmic misdiagnosis and data compliance challenges directly and formulate ethical manuals to strengthen responsibility awareness. Additionally, intelligent traffic scheduling and architectural design simulation projects guide students to explore algorithmic justice in the trade-off between efficiency and humanistic care. This immersive model breaks theoretical indoctrination limitations, enabling students to leap from technical rationality to ethical consciousness through the "trial and error–reflection–reconstruction" closed loop.

4 System Technical Architecture and Implementation

The system adopts a three-layer microservice architecture of "data–logic–application" to ensure the stable operation of multimodal knowledge processing, large model inference, and high-concurrency front-end interaction.The specific framework is shown in Figure 3.

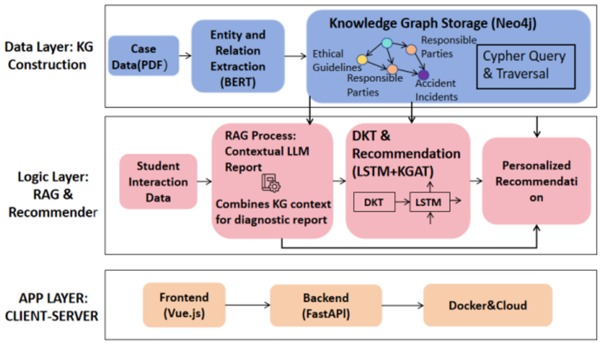

Fig. 3. Translation of the System Framework Diagram

4.1 Data Layer: Knowledge Graph Construction Based on Graph Database

In the process of data parsing and extraction, the system employs Python libraries such as pdfplumber to parse unstructured data from engineering ethics textbooks and case PDFs. A joint model for named entity recognition and relation extraction based on BERT is introduced to accurately extract core entities including "ethical guidelines", "responsible parties", "accident incentives" and their dependency relationships. The constructed domain knowledge graph is persistently deployed in the Neo4j graph database. The system uses Cypher Query Language to achieve millisecond-level multi-hop graph traversal, quickly retrieving the complex ethical logic chains behind specific engineering cases, and providing structured factual support for upper-layer inference.

4.2 Logic Layer: RAG Evaluation Mechanism and Quantitative Recomme ndation Algorithm

The logic layer of the system deeply integrates large language models and graph recommendation mechanisms to support core teaching interactions.

RAG-based Intelligent Evaluation: The system adopts a retrieval-augmented generation (RAG) architecture. After students submit their decisions in the simulation, the system converts natural language into graph query statements via Text2Cypher, extracts relevant "ethical guideline" nodes as context constraints, and inputs them into the LLM. In this way, it generates personalized diagnostic reports free of factual hallucinations and with strong interpretability.

Deep Knowledge Tracing (DKT) Modeling: For personalized recommendations, the system abandons traditional rule-based approaches and utilizes a Deep Knowledge Tracing model based on Long Short-Term Memory (LSTM) networks to dynamically evaluate students' cognitive levels. The student's interaction result r_t regarding knowledge point$q_t$at time step$t$is transformed into a one-hot encoded vector $\mathbf{x}_t$ and inputted into the network to update the student's "knowledge state matrix" in real time. The update logic for the hidden layer state $\mathbf{h}_t$ is defined as follows:

$$\mathbf{h}_t = \tanh(\mathbf{W}_{hx}\mathbf{x}_t + \mathbf{W}_{hh}\mathbf{h}_{t-1} + \mathbf{b}_h) \quad (1)$$

where $\mathbf{W}_{hx}$and $\mathbf{W}_{hh}$ denote the weight matrices, and $\mathbf{b}_h$ represents the bias term. Based on $\mathbf{h}_t$, the system outputs a prediction vector $\mathbf{y}_t$, which quantifies the student's mastery probability across various ethical knowledge points.

Knowledge Graph Adaptive Recommendation: Upon obtaining the predicted probabilities $\mathbf{y}_t$, the system performs collaborative computation by incorporating the topological structure of the graph (e.g., via the KGAT algorithm). For a candidate node k_i, the system calculates its comprehensive recommendation score $S_{rec}(k_i)$:

$$S_{rec}(k_i) = \alpha \cdot (1 - y_{t,i}) + \beta \cdot w_{KG}(k_{current}, k_i) \quad (2)$$

where $1 - y_{t,i}$ represents the student's current vulnerability (weakness) regarding the node, and w_{KG} indicates the relational weight from the current node to the candidate node within the graph. By selecting the node with the highest S_{rec} score, the system dynamically pushes the optimal subsequent simulation level or learning material, thereby forming a data-driven closed-loop learning path.

4.3 Application Layer: Frontend-backend separated architecture and cloud deployment

The system adopts a front-end and back-end separation architecture. The front end is built on Vue.js to form a responsive virtual simulation interactive interface; the back end uses the FastAPI framework, which efficiently handles high-concurrency requests from the front end through its asynchronous features, and schedules underlying graph database and large model inference tasks. Core back-end services and the graph database are packaged in Docker containers to ensure environmental consistency, and stable low-latency deployment is realized relying on a cloud collaboration mechanism.

5 Teaching Practice and Empirical Analysis

To verify the effectiveness of the AI-enabled engineering ethics teaching framework, this study conducted a controlled experiment in the fall semester of the 2025–2026 academic year, with quantitative evaluation and statistical analysis of teaching outcomes.

5.1 Experimental Design and Sample Size

A total of 120 undergraduate students from the School of Computer and Information Engineering at a university who enrolled in the Engineering Ethics course were selected as research samples. They were randomly divided into a control group (60 students) and an experimental group (60 students).The control group adopted the conventional teaching mode of "traditional lectures + in-class case discussions", while the experimental group fully utilized the AI-enabled teaching platform of "knowledge graph + virtual simulation + intelligent evaluation" constructed in this study. The experiment lasted for 8 weeks.

5.2 Statistical Analysis Methods and Results

This study used SPSS and Python data analysis packages (SciPy, Pandas) to conduct statistical tests on the collected samples. Preliminary statistical results show that, after controlling for no significant difference in pre-test scores ($p > 0.05$), the experimental group achieved a significantly higher average post-test score ($\mu = 86.4$, $\sigma = 5.2$) than the control group ($\mu = 78.1$, $\sigma = 6.4$), with a statistically significant difference ($t = 7.82$, $p < 0.01$).This indicates that the AI-enabled framework exerts a significant positive effect on improving students' ethical decision-making ability. In addition, through in-depth mining of interaction data from the experimental group, we plotted the cumulative distribution function of learning duration on the platform and the histogram of knowledge point interaction frequency. As shown in Figure 4 and Figure 5, more than

80% of students spent longer than the scheduled class hours on average interacting with the virtual simulation module, verifying the effectiveness of the platform in enhancing learning immersion and engagement.

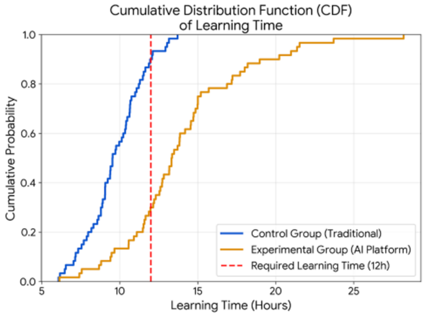

Fig. 4. Cumulative Distribution Function (CDF) of Learning Time between Experimental and Control Groups

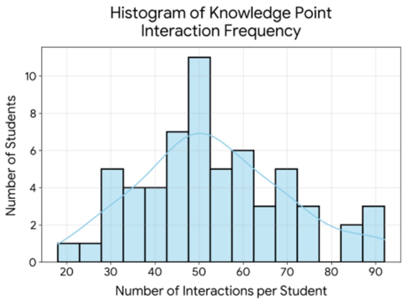

Fig. 5. Histogram of Knowledge Point Interaction Frequency in the Experimental Group

6 Conclusion

This paper focuses on the transformation of the AI-enabled teaching mode for Engineering Ethics. AI acts as both technical support and a key driver for the paradigm shift of ethics education, helping the course shift from knowledge indoctrination to equal emphasis on ability cultivation and value shaping, and promoting the transition from a static knowledge system to a dynamic learning system. The course integrates new topics such as AI ethics and algorithmic responsibility, uses intelligent recommendation and virtual simulation to improve students' ethical judgment and reflection, and adopts data-driven platforms to realize precise teaching and better learning effectiveness. Meanwhile, potential risks should be avoided, including value bias, one-sided ethical presuppositions in AI systems, and students' over-reliance on AI that weakens independent thinking. In the future, the integration of intelligent technology and curriculum should be strengthened, and an interpretable, auditable and intervenable teaching AI system should be built to support the cultivation of new-era engineering talents with both technical rationality and moral consciousness.

Acknowledgments

This work was supported by the Henan Province Graduate Education Reform and Quality Improvement Project (Grant No. YJS2025ZX33); the Henan University Graduate Education Teaching Reform and Quality Improvement Project (Grant No. SYL2025YJSKC16); and the Henan University Graduate Quality Demonstration Course (Premium Online Course) (Grant No. SYLKC2023008).

Disclosure of Interests

The authors have no competing interests to declare that are relevant to the content of this article.

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