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AI-Driven "Spintronics Industry + Law" Curriculum Reconstruction

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Abstract: With the cross-fertilization of artificial intelligence (AI) technology and spintronics, the traditional AI teaching system has revealed its limitations in terms of industrial adaptability and interdisciplinary integration. In order to cope with this challenge, this study takes Introduction to Artificial Intelligence as the basis, and proposes a conceptual framework of "technical-legal" double helix teaching model, aiming at reconstructing the existing curriculum through three-dimensional teaching design innovation: (1) In the technical level, adding the cutting-edge topic of "Spintronics and Neuromorphic Computing," through simulation and literature study, students are guided to explore the principle of brain-like computation based on STT-MRAM; (2) at the legal level, the teaching paradigm of "integrating the awareness of legal compliance into technological research and development" is constructed, and it is planned to develop a library of legal science and technology seminars containing cases such as analysis of intelligent contracts; (3) at the practical level, the establishment of an "industry-academia-research" program is explored and improve the comprehensive practical ability of students by simulating the cooperation projects between schools and enterprises. The expected goal of this teaching reform program is to enhance students' technological innovation thinking and legal risk prevention awareness, and to provide a teaching reform idea with reference value for exploring the cultivation path of " AI + Law " composite talents.

Keywords: Artificial intelligence education; Spintronics; Neuromorphic computing; Intellectual property; Industry-education integration

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1. From skills training to competency development: Fundamental challenges for AI education

1.1. The limitations of the current AI education model

The current AI curriculum in higher education institutions shows obvious structural defects: the teaching goal is limited to the teaching of skills, neglecting the cultivation of critical thinking and comprehensive assessment ability. The existing curriculum mainly focuses on the implementation of algorithms, programming frameworks and other operational skills, and the cultivation mode tends to produce "technical implementers" who master specific tools, rather than "technical evaluators" who have a global vision and judgement [1]. This educational philosophy deviates significantly from the needs of high-level AI talent.

The deviation is reflected in three dimensions. First, the course content structure is unbalanced, with excessive emphasis on the application training of mature technologies and a lack of a critical analysis framework for cutting-edge technologies. Although students are proficient in applying mainstream deep learning frameworks, they generally lack systematic evaluation methods and judgment bases in the face of emerging technology paradigms such as neuromorphic computing and quantum machine learning [2]. Second, instructional design ignores the uncertainty and complexity of technological development. Traditional teaching modes tend to present deterministic knowledge and standardized solutions, while industrial practice is full of multi-dimensional decision-making challenges such as technology route selection, performance-cost trade-offs and compliance constraints. Third, there is a serious lack of interdisciplinary integration, which makes it difficult for students to understand the social embeddedness of technological innovation. Intellectual property protection, data compliance requirements, algorithmic ethics, and other factors have a fundamental impact on the development of AI technology, but the existing curriculum system has marginalized them [3].

Taking innovations in AI hardware as an example, new computing paradigms such as Physical Neural Networks (PNNs) and spintronics are exploring possible paths to break away from traditional von Neumann architectures [4]. This technology has the potential to solve the arithmetic bottleneck and energy consumption problems, but it still faces many uncertainties from laboratory prototypes to industrialized applications. Existing AI education treats such cutting-edge technologies at two extremes: avoiding them altogether or reducing them to conceptual introductions, both of which fail to provide students with a systematic methodology for assessing the maturity of the technology and tools for critical analyses. This lack of teaching deprives students of important training opportunities to understand the evolution of technology and assess the feasibility of innovation.

1.2. Structural factors for the lack of capacity development in technology assessment

The causes of the above educational difficulties are multi-level and systematic. Analyzed from the level of the curriculum system, the current mechanism of teaching materials writing and curriculum updating is difficult to adapt to the rapid iteration of AI technology. However, the deeper problem is not the construction of competence, but the lagging behind of educational concepts, which still takes the transfer of knowledge as the primary goal [2]. This concept makes the newly introduced technical content more of a static knowledge point than a dynamic mind training material.

There are obvious paradigmatic limitations at the level of teaching methodology. Currently, practical teaching is dominated by "validation" experiments, in which students' main task is to reproduce known results, with less exposure to open-ended and exploratory problems. For example, in neural network courses, the experimental design usually focuses on the optimization of model accuracy, while the computational complexity, energy consumption, deployment constraints, privacy risk, and other practical engineering considerations are rarely involved. This paradigm reinforces the "technology implementation" mindset and inhibits the development of "technology evaluation" skills.

The knowledge structure of the faculty also constitutes an important constraint. Complex teachers with interdisciplinary backgrounds, familiarity with industrial practices, and understanding of legal norms are extremely scarce [5]. Most teachers' professional backgrounds are focused on specific technical areas, making it difficult to guide students to develop a multi-dimensional assessment perspective. This problem is further exacerbated by the disconnect between industry and education, with teachers having limited access to positive and realistic industry examples.

Fundamentally, the current AI talent [6], the positioning of training objectives needs to be urgently re-examined. The response at the level of educational practice when national strategic documents, such as the New Generation Artificial Intelligence Development Plan, point out the systemic and complex characteristics of AI development is still significantly lagging behind [7]. In the context of the deep integration of AI technology and various industries, the industry needs not only engineers with programming skills but also high-level talents who can make comprehensive decisions under multiple constraints, such as technical feasibility, commercial value, legal compliance, and ethical norms. This change in demand requires the education sector to fundamentally reconstruct the target system and implementation path of AI talent training.

2. Technology assessment and legal compliance: Towards an interdisciplinary competence framework

In order to realize the transition from "technology implementer" to "technology evaluator," this study constructs a theoretical framework that integrates technology evaluation and legal thinking. The core of this framework is to cultivate students' ability to consider legal constraints in the process of technological innovation, which is a key ability that is urgently needed by the AI industry but is missing in the education system.

2.1. Legal dimensions of technology assessment capacity

Technology assessments must be conducted within a legal framework. In the case of spintronics and PNNs, for example, technology assessments must consider three legal dimensions: intellectual property viability, data compliance, and technical standards compliance.

Intellectual property feasibility assessment requires students to understand the relationship between the technological innovation space and the patent map. When evaluating the STT-MRAM technology route, students not only need to analyze its technological advantages, but also need to examine the distribution of core patents, and the layout of basic patents of giants such as IBM and Samsung in this field directly affects the technological space for the latecomers to choose. Students need to master the "free implementation analysis" method to determine whether the technical program infringes on risk. This ability to cultivate the technical understanding and legal analysis of the depth of the integration, not only to understand the physical principles of the magnetic tunnel junction, but also to interpret the scope of protection of the patent claims.

Data compliance assessment is especially critical in AI applications. Edge computing devices based on PNNs that are used for face recognition or medical diagnostics must comply with regulations such as the Personal Information Protection Act and the Data Security Act. Students need to understand how the concept of "privacy by design" affects hardware architecture choices; for example, a design of PNNs that supports federated learning may be more advantageous in terms of compliance. This kind of collaborative technical-legal thinking is at the heart of the training objectives.

Technology standards compliance involves both mandatory and industry standards. When evaluating new AI hardware, students need to identify relevant safety standards, EMC standards, environmental standards, etc., and understand the impact of standards compliance on technology commercialization. Especially in the context of international trade, where technical standards are often used as a tool for trade barriers, this understanding is critical to technology assessment.

2.2. Cognitive modelling of legal risk identification

Based on risk management theory, this study proposes a "technology decision point-legal risk mapping" model. The model breaks down the technology development process into key decision points and identifies the potential legal risks of each decision point. At the stage of technology route selection, the main legal risks include: patent infringement risk, whether the selected technology solution falls into the scope of others' patent protection; technology blockade risk, whether the core technology is restricted by export control; standard essential patent risk, whether it is necessary to obtain fair and reasonable patent protection; and whether it is necessary to obtain fair and reasonable patent protection. Whether a fair, reasonable, and non-discriminatory license is required. Students use case studies to learn about legal considerations at the early stages of technology selection.

At the data use stage, risk identification focuses on: data source legitimacy, whether there is a legal authorization for training data; data cross-border flow restrictions compliance requirements for using data from outside the country; algorithmic transparency requirements; and the domain-specific interchangeability requirements. By analyzing real-life data breaches and regulatory penalties, students understand how seemingly purely technical decisions can trigger legal liability.

At the production stage, it is necessary to consider: product liability risks, the allocation of legal responsibility for AI decision-making errors; consumer protection, the legal consequences of algorithmic discrimination; and industry access requirements, the industry access requirements-industry-specific AI application restrictions. This lifecycle legal risk awareness is a must for technology evaluators.

2.3. Evidence-based and integrated assessment methods

Technology assessment needs to be based on evidence—the legal dimension—students should master the legal due diligence methodology and patent evidence analysis skills, to be able to interpret patent documents, in particular, to be able to analyze the evolution of technology and the stability of patents, and the analysis needs to be a deep technical understanding, not purely legal work.

Evidence of compliance is collected at a number of levels: legal and regulatory texts, regulatory guidance, enforcement cases, industry best practices, and so on. Students need to develop the concept of a "hierarchy of compliance evidence," mandatory laws and regulations have the highest level of validity, but industry self-regulation and best practices provide more specific guidance. These different layers of requirements need to be considered together when assessing the compliance of AI applications.

The quantitative approach to risk assessment draws on legal risk management practices. Through the "risk matrix" tool, the likelihood and impact of legal risks are mapped in two dimensions to help technical decision makers prioritize risk responses. For example, if patent infringement is a low likelihood but significant impact, a "risk transfer" strategy, such as purchasing patent insurance, is needed; if data compliance risk is a high likelihood but controllable, a "risk reduction" strategy, such as data desensitization, is needed.

3. Specific strategies and implementation of pedagogical reforms

3.1. Theoretical modelling: A pedagogical framework aimed at integrating technological exploration and legal awareness

In order to construct an educational model of the synergy between technology and law, we propose a pedagogical framework whose central goal is to lead students to understand, rather than to ask them to solve, the unsolved problems of the industry: that any technological innovation is embedded in complex legal and ethical norms. The pedagogical assessment it advocates focuses on the depth of students' knowledge of the potential of technology and their ability to critically analyze legal principles in simulated situations.

For example, we use spintronics as a forward-looking entry point for teaching. Students will be made aware of the opportunities and challenges ahead for this technology as a potential vehicle for future neuromorphic computing, such as the extreme conditions of device fabrication and the complexity of circuit design. Teaching activities will be centered on this reality.

Combining technology and law, students use professional simulation software to simulate the performance of a spintronic device that has been published in academic literature, then analyze the real patent documents related to the technology, interpret the scope of the patent's claims, and discuss the case of "what kind of subsequent design may constitute infringement." This "simulation-analysis" mode of practice allows students to experience the close relationship between technology development and intellectual property protection in teaching activities, replacing the original unrealistic "design-avoidance" concept.

Similarly, in exploring broader AI applications, the framework avoids asking students to "design" a system that perfectly prevents algorithmic bias—a huge challenge that the AI field itself faces today. Teaching activities will be designed as critical case studies. Students will examine real-world cases of failed AI applications, such as data privacy breaches and algorithmic discrimination, and will analyze their technological root causes and legal consequences, as well as explore the effectiveness and limitations of existing regulatory frameworks.

3.2. Technological dimension: Case design for teaching physical neural networks

Physical neural networks (PNNs), as a cutting-edge direction in the implementation of artificial intelligence hardware, provide an ideal case for teaching the technical dimension of this course. Different from traditional software simulation, PNNs make use of the intrinsic properties of physical systems to directly perform neural computation, among which spintronic devices provide a unique advantage for simulating the brain neural system theoretically due to their non-volatile and low-power consumption characteristics.

The teaching module adopts a progressive structure of "literature reading–critical analysis–application exploration." At the materials level, the course guides students to analyze the academic literature to understand the key role of new magnetic materials, especially how researchers can modulate the magnetic properties of materials through doping and other means to achieve higher performance in applications such as STT-MRAM. Students need to recognize that most of these studies are at the laboratory stage and understand the distance between basic research and engineering applications. At the device integration level, using the example of a proof-of-concept spintronics MOSFET, students will analyze the technical challenges of integrating spintronic logic with silicon-based logic, and then understand the technological leap from a single device to a complex system.

The development of critical thinking is a core objective of the module. When students encounter performance claims such as "PNNs consume 40 per cent less energy," they need to learn to interrogate the experimental conditions, the scale of the test, and the integrity of the system. Through the introduction of NASA's Technology Maturity Level (TRL) assessment tool, students will learn to determine the stage of technology development and distinguish between a demonstration of principle and a practical system. The "Technology Feasibility Analysis" project designed in the course requires students to evaluate the business plan of edge AI chips based on PNNs, taking into account the technology maturity, development cost, and market risk.

In the application exploration session, the course takes an intelligent transport system as an example and builds a multi-dimensional thinking framework to enable students to understand the complexity of technology application. The technical dimension focuses on the match between the low power consumption and parallel processing capability of PNNs and the demand for real-time traffic data processing; the economic dimension requires students to estimate the deployment cost and compare it with existing solutions; and the social dimension explores the balance between privacy protection and public safety.

The interface between this module and the legal dimension is achieved through the topic of intellectual property. After students fully understand the technical characteristics of PNNs, the course guides them to think about how to design intellectual property protection strategies in cutting-edge technology areas. Should we choose patent disclosure or a trade secret? How to balance academic communication and commercial interests? These discussions organically integrate technology learning with legal awareness cultivation, laying a foundation for cultivating AI talents with a comprehensive vision.

3.3. Legal dimension: Compliance awareness development for AI applications

Incorporating legal content into AI education aims to develop the ability of students to recognize potential legal risks early in the design of the technology and to know when to seek professional support. This ability is particularly critical at a time of rapid commercialization of AI, when technology decisions often have far-reaching legal consequences.

The module is taught in a three-tiered system. At the basic cognitive level, students can understand the legal implications behind each technological choice through the exercise "Legal Mapping of Technological Decisions." For example, in the data preprocessing section of machine learning, the question of data legality is introduced simultaneously: Is the source of training data legal? Does it involve privacy? The key is to "translate" the legal definition of "personal information" into technical language, such as mapping the legal definition of "personal information" into the classification of database fields, and translating the legal standard of "anonymization" into specific technical solutions.

The application analysis layer develops students' ability to innovate under legal constraints. Taking the campus facial recognition attendance system as an example, students need to analyze the legal basis for collecting facial data, the compliance requirements for the storage period, and the definition of responsibility for misidentification, etc. By analyzing real cases, such as enterprises being punished for collecting location information in violation of the law, students will understand the tension between technical feasibility and legal compliance. The integrated practice layer fosters interdisciplinary collaboration through the "AI Product Compliance Assessment Project." Students develop a compliance program for an intelligent resume screening system, covering complex topics such as algorithmic fairness, privacy protection, and transparency in decision-making. In a "Compliance Consultation" format, students act as legal advisors to present the technical solutions and answer questions, which is closer to real-life workplace scenarios than a "Moot Court."

Specific instructional activities include: "Case of the Week" seminars to analyze AI legal news with a focus on understanding how technology choices can lead to legal consequences; "Compliance Checklist" workshops to help students develop a technology-legal mindset; and "Legal Risk Identification" exercises to build risk warning skills. These activities are embedded in the technology curriculum, such as exploring intellectual property protection strategies and technology export controls in the study of PNNs, so that compliance thinking becomes a habit of mind for students.

3.4. Practical platform building: Building bridges between technological awareness and ethical reflection

In order to support the implementation of the aforementioned teaching content, this program designs two core practical platforms: a hardware technology cognitive platform and an algorithmic fairness experimental environment.

3.4.1. Hardware technology awareness platform

In view of the high threshold for the fabrication of spintronic devices, we have adopted a "demonstration-simulation-analysis" teaching strategy. The platform consists of three components: firstly, samples of spintronic devices and working principle models provided by collaborating research institutes are displayed. Students can visualize the physical structure of these devices and focus on understanding the working principle rather than the manufacturing process. Next is a computational simulation workstation equipped with simulation software such as COMSOL and Micromagnetic. Students use these tools to simulate the basic behaviors of spin devices, such as magnetoresistance changes, spin transport, and other phenomena, allowing them to understand the physical fundamentals of PNNs at an affordable cost. Finally, there is a performance analysis lab bench that uses off-the-shelf spintronics evaluation boards, similar to an Arduino but based on spin devices, to allow students to test basic neural computation functions and compare their performance differences with conventional hardware. This avoids the need for expensive manufacturing equipment while retaining the pedagogical value of hands-on experimentation.

3.4.2. Algorithmic fairness experimental environment

To develop students' ability to identify and mitigate algorithmic biases, we constructed an experimental environment based on an open-source tool centered on a repository of pedagogical datasets that contain preconstructed biases of different types deliberately introduced. For example, in a recruitment dataset, historical data may reflect gender bias; in credit data, geographic location may be correlated with ethnicity. The student's task is to identify, quantify, and propose mitigation strategies, not to eliminate bias. Students will be able to use the experimental environment to provide standardized assessment tools, such as Fairness Indicators, AIF360, and other open source libraries, to assess the model's fairness metrics and understand the trade-offs between different definitions of fairness. Importantly, we stress that there is no perfect solution, and that the key is to make trade-offs and choose the best.

For data security education, we use containerized isolation environments that allow students to experience common security threats in a secure sandbox. For example, we demonstrate how SQL injection can lead to data leakage and how differential privacy can protect privacy while maintaining data utility. These demonstrations take place in a controlled environment, ensuring pedagogical effectiveness while avoiding real security risks.

Through these two practice platforms, students are able to transform theoretical knowledge into practical knowledge, explore the cutting-edge development and ethical challenges of AI technology in a controlled and feasible environment, and lay a solid foundation for their future career development.

4. Conclusion

The reform is faced with the challenges of accelerated technology iteration, interdisciplinary collaboration barriers, and insufficient resource input, which need to be broken through dynamic curriculum updating, dual-employee faculty mechanism, and diversified funding modes. This study focuses on the problem of disconnection between AI teaching system and industrial demand, and puts forward a complete set of teaching reform proposals, through the fusion of spintronics and neuromorphic computing, in-depth docking of China's industrial development of the actual needs of the university-enterprise cooperation and interdisciplinary education, and is expected to form a benign ecosystem of "teaching-industry-research," and promote the industrialization of AI technology. It is expected to form a benign "teaching-industry-research" ecology and promote the synergistic development of AI technology industrialization and talent training.

Through the implementation of the reform, students' knowledge has been greatly expanded, not only mastering the basic theory of spintronics, but also deeply understanding the working principle and design method of neuromorphic computing through laboratory operation. The creation of an algorithmic sandbox environment provides an experimental platform for simulating real-life scenarios, which enhances students' ability to deal with legal risks in AI applications. In addition, the combination of AI hardware design and legal compliance analysis addresses the students' ability to solve problems by comprehensively utilizing technology and regulations, and meets the contemporary society's demand for composite AI talents.

The introduction of spintronics is not only an expansion of subject content but also a renewal of educational thinking and teaching methods. Students will be able to learn in the classroom what is at the forefront of international science and technology, practice the design and manufacture of brain-like computing devices in the laboratory, and understand and apply intellectual property law in interdisciplinary projects. Ongoing training of the teaching team and the introduction of experts ensure that the faculty can keep up with the pace of technological and legal updates, and promote the reform of education from the inside out.

In the field of AI, the teaching reform program of this study provides an innovative demonstration effect and provides effective research and practice samples for the corresponding curriculum and teaching mode change in universities. In the face of the booming development of AI technology in the future, this program is more capable of cultivating composite talents who can adapt to the market changes, comply with the national intellectual property law norms, and master advanced technology, so as to contribute to the power of the national industrial innovation, and it also provides ideas and experiences for the reform of AI education in colleges and universities and opens up a new way of talent cultivation. Aiming at the problem of the disconnection between AI education and social demand, this education reform program constructs an AI education system with the deep integration of "theory-practice-frontier." Through curriculum reconstruction, interdisciplinary experiments, university-enterprise collaboration, and resource integration, the comprehensive ability of students in neuromorphic computing and industry scenarios is significantly enhanced.

Disclosure statement

The authors declare no conflict of interest.

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