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Strategies for Teaching Reform of Metal Materials and Heat Treatment Courses Driven by AI

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Abstract: Against the background of Emerging Engineering Education construction, artificial-intelligence technology provides technical support for curriculum innovation of materials-related majors. *Metal Materials and Heat Treatment* is a core course for materials majors with complex knowledge content. Based on the actual teaching status of the course, this paper analyzes existing problems in AI-empowered teaching of this course. Reform implementation strategies are proposed from four dimensions: digital reconstruction of knowledge systems, construction of human-machine collaborative classroom modes, cultivation of students' high-order engineering capabilities, and establishment of diversified teaching-evaluation mechanisms. It aims to build a curriculum-teaching paradigm matching the training objectives of application-oriented talents, promote the transformation of the course from knowledge-memorization-oriented teaching to competence-oriented teaching featuring human-machine collaboration, and offer references for intelligent-teaching reform of similar science-and-engineering courses.

Keywords: Artificial intelligence; Metal materials and heat treatment; Teaching reform; Human-machine collaboration; Emerging engineering education

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1. Existing problems in teaching of *Metal Materials and Heat Treatment* courses driven by AI

1.1. Superficial technology stacking, insufficient integration between artificial intelligence and curriculum-teaching scenarios

When promoting intelligent teaching, disconnection between technical tools and curriculum teaching tends to occur. Some teaching practices merely treat artificial intelligence as an auxiliary means for information retrieval and courseware generation, and simply add intelligent functions onto original traditional teaching workflows. This represents superficial technology stacking instead of reconstructing teaching workflows relying on artificial intelligence. The course itself possesses rigorous internal logic, and its primary teaching objective is to enable students to understand the intrinsic correlations among composition, process, microstructure and properties [1]. Current applications fail to design intelligent teaching scenarios in accordance

with the core knowledge logic of the course. Light-weight teaching resources and data sets that satisfy curriculum-teaching demands are lacking. Functions of AI tools are not targeted at inherent pain points of course teaching. Intelligent resources are disconnected from the original curriculum-knowledge system, and intelligent tools can hardly penetrate key teaching links including concept comprehension, process deduction and logical speculation. Thus, technical advantages cannot be well converted into teaching and educational outcomes [2].

1.2. Hidden risks to educational equity in the implementation of personalized intelligent teaching

One merit of artificial-intelligence technology lies in its capacity to push differentiated learning content according to learners' cognitive levels and realize personalized learning guidance. Nevertheless, implementing personalized teaching brings new balance-related challenges. Objectively, students differ in their acceptance and usage habits of intelligent tools. Some students can reasonably leverage intelligent tools to expand their thinking dimensions, while others cannot proficiently operate digital tools and thus fail to benefit fully from intelligent teaching. If learning paths are entirely determined by artificial intelligence, gaps among different learners will be further widened, resulting in polarization of learning outcomes. Specialized courses involve professional operations such as material-process-parameter setting and property deduction, and complex intelligent models impose high operation thresholds. Without teaching-oriented encapsulation of technical interaction interfaces, complicated model-operation logics will increase students' learning burden. Technical barriers in turn become obstacles for some students, which runs counter to the basic requirements of educational equity [3].

1.3. Blurred boundaries between teachers' and students' roles, risks of weakening students' independent critical-thinking ability

After artificial intelligence intervenes in classrooms, traditional teacher-student relationships are broken, and role positioning among teachers, students and intelligent systems is prone to misalignment. Some teachers hold an inadequate understanding of artificial intelligence and delegate massive work such as knowledge explanation, Q&A, and analysis to intelligent tools, which weakens their core functions, including teaching-design, value guidance, and thinking enlightenment. For students, readily-available AI-generated tools can rapidly output exercise answers, scheme texts and process-analysis results. Some students directly adopt AI-generated content to finish assignments without engaging in independent thinking and logical deduction [4]. In the absence of corresponding constraint mechanisms, students tend to become overly dependent on artificial intelligence. They no longer actively deduce the action mechanisms of alloying elements or the changing logic of heat-treatment processes, and their capabilities for independent analysis and critical judgment fail to be trained. Besides imparting professional knowledge, course teaching shall cultivate engineering-speculative competence. Outputs from artificial intelligence may contain deviations. If students lack awareness of manual verification, their engineering-judgment ability will gradually degrade and fall short of competence standards for Emerging-Engineering-Education talent training.

1.4. Lagging teaching-evaluation system hardly adaptable to human-machine-collaborative talent-cultivation objectives

Traditional curriculum evaluation mostly takes written-examination scores as the major judging criterion and

emphasizes how much theoretical knowledge students have memorized. As artificial intelligence penetrates every learning link, students' learning behaviors and forms of competence output change accordingly, exposing deficiencies of original evaluation systems. On the one hand, traditional evaluation approaches cannot measure students' ability to solve problems via human-machine collaboration. They fail to examine students' thinking processes while using intelligent tools and their competence to identify and critically judge AI-generated outputs, and cannot distinguish whether academic deliverables stem from students' independent thinking or artificial-intelligence generation. On the other hand, full-process data, including students' online-learning behaviors, virtual-exploration procedures, and engineering-scheme deduction processes, are insufficiently mined and utilized. Quantifiable multi-dimensional evaluation indicators cannot be formed. Evaluation still focuses on final learning outcomes while ignoring students' in-depth learning processes and development of higher-order thinking [5]. Meanwhile, evaluation indicators for the effects of AI-driven teaching reform are absent. The practical performance of intelligent-teaching modes cannot be objectively reflected, which hinders continuous updating and improvement of teaching modes.

2. Teaching-reform strategies for *Metal Materials and Heat Treatment* courses driven by AI

2.1. Reconstruct digital curriculum-knowledge system and promote in-depth integration of AI technologies into teaching workflows

First of all, adhere to the basic principle that technologies serve teaching. Carry out digital reconstruction of the curriculum-knowledge system based on the intrinsic knowledge logic of *Metal Materials and Heat Treatment*, and avoid formalistic stacking of technical tools. Sort out all core concepts of the course. Based on key knowledge points such as alloying elements, heat-treatment processes, microstructures and mechanical properties, construct a visual knowledge graph for the course. Break the linear layout of textbook chapters, establish logical connections among scattered knowledge points, and link knowledge, problems and capabilities. Meanwhile, incorporate curriculum-ideological-and-political contents to build a multi-dimensional digital knowledge-resource system [6]. Relying on online-teaching platforms, realize linkage among teaching courseware, case resources, exercises, extended materials and knowledge graphs. Achieve intelligent associated push of learning resources via knowledge graphs, and fully present the logical chain of "composition-process-microstructure-properties" of the course.

Secondly, carry out teaching-oriented transformation of intelligent technologies according to classroom-teaching demands, and build light-weight applications satisfying curriculum-teaching requirements. Encapsulate functions including material-property prediction and process-simulation-based exploration into simple interactive forms. Students are not required to master complex-model-training operations. They can complete simulation-deduction of heat-treatment processes and alloy compositions merely by inputting parameters and adjusting controls. Cutting-edge material-prediction technologies are thus converted into inquiry-oriented teaching tools available for classrooms.

Furthermore, embed intelligent tools into the complete teaching chain covering pre-class preview, in-class seminars and post-class consolidation. Design corresponding intelligent-teaching scenarios centering on key and difficult points of the course, so that artificial intelligence serves core teaching links including concept comprehension, process deduction and problem-oriented inquiry. Carry out overall reconstruction of teaching workflows starting from curriculum-teaching objectives, so as to achieve genuine in-depth integration between

technologies and curriculum contents [7].

2.2. Build a teacher-student-machine tri-party collaborative classroom mode and balance personalized learning and educational equity

First, establish a tri-party collaborative teaching mode featuring teachers as guides, students as subjects, and intelligent tools acting as learning companions and auxiliary carriers, and reconcile the relationship between personalized-learning development and educational equity. Teachers undertake the major work of teaching design, classroom organization, thinking guidance, and value-oriented education. Artificial intelligence serves as a teaching-aid learning companion and undertakes knowledge retrieval, simulation deduction and learning-situation feedback. Students act as learning subjects to conduct inquiry-based thinking. The three parties perform their respective duties to complete classroom-teaching activities jointly.

Secondly, prevent outcome polarization while implementing personalized teaching. Simplify and encapsulate intelligent interactive functions to lower the operational difficulty of intelligent tools. Make simulation-and-emulation functions accessible to students via intuitive parameter input and slider adjustment, and mitigate impacts of underlying complex technical logics on students [8]. Dynamically profile students' learning situations based on learning-behavior data collected by platforms. Identify students' knowledge weaknesses with knowledge graphs and push corresponding learning resources. Nevertheless, overall learning planning and explanation of key and difficult points remain under teachers' control. Provide in-class guidance and support for underachieving students who have difficulties adapting to digital tools to eliminate learning barriers caused by technical thresholds. Combine online intelligent autonomous learning with offline classroom seminars. Online sessions adopt intelligent tools for learning basic knowledge points and inquiry via process simulation; offline classrooms are organized by teachers for in-depth seminars and discrimination of problems emerging from simulation-deduction, so that auxiliary functions of intelligent tools complement teachers' guidance.

2.3. Formulate AI usage norms and strengthen cultivation of students' independent-thinking and critical-engineering-thinking competence

To address students' over-reliance on artificial intelligence, formulate in-course AI-usage specifications, stipulating that intelligent tools can only serve as aids instead of substitutes for independent thinking. Treat critical verification of AI-generated outputs as an important component of curriculum-competence cultivation. For course assignments and scheme-design tasks, require students to submit AI-contribution statements and manual-verification records, distinguish contents originating from intelligent tools and self-derived contents, judge the rationality of AI-generated process conclusions and analytical results combined with specialized theories, and conduct manual verification of outputs. Direct copying of AI-generated deliverables to finish assignments shall be prohibited.

Secondly, shift teaching priorities in teaching processes. Transform curriculum-educational objectives from mere memorization of specialized factual knowledge points to cultivation of students' competence to conduct engineering analysis, judgment, and decision-making with the assistance of artificial intelligence. Leverage intelligent tools to expand inquiry boundaries, and guide students to adopt AI for literature sorting and auxiliary conception of experimental schemes, while logical deduction and mechanism analysis of schemes must be completed by students themselves. Conduct inquiry-oriented learning via virtual-simulation functions: students adjust alloy compositions and heat-treatment-process parameters by themselves, observe

simulated property changes, and sort out changing rules between process and properties. Teachers design discriminating seminar tasks in classrooms, organize students to identify and correct biased specialized conclusions generated by artificial intelligence, cultivate students' critical-thinking awareness, and develop their capability to tackle complex engineering problems through human-machine collaboration [9].

2.4. Construct a multi-dimensional quantifiable evaluation system and realize closed-loop iterative optimization of teaching modes

First, break the mode that takes final written-examination scores as the sole evaluation criterion. Establish a multi-faceted and quantifiable teaching-evaluation system compatible with AI-driven teaching modes, which takes both learning processes and learning outcomes into consideration, and attaches importance to both knowledge-mastery level and comprehensive human-machine-collaboration competence. Evaluation contents cover mastery of theoretical knowledge, inquiry-based learning processes, and human-machine-collaborative engineering capabilities. It assesses students' memorization and comprehension of alloy principles and heat-treatment theories, as well as their inquiry processes using intelligent tools, critical-verification of AI outputs, and logical deduction of engineering schemes [10].

Secondly, fully mine full-process learning data collected by teaching platforms. Take knowledge-graph learning trajectories, virtual-simulation inquiry procedures and AI-contribution statements of academic tasks as evaluation references to record students' in-depth-learning processes objectively. Differentiate evaluation priorities for various course tasks: written examinations mainly assess comprehension of basic theories, while scheme-design assignments focus on students' logical-deduction competence and their capacity to identify and verify AI-generated results. Build a closed-loop mechanism for teaching reform. Feed back practical effects of teaching reform through multi-dimensional evaluation, continuously collect various problems arising in teaching, and keep improving digital knowledge resources, intelligent-teaching scenarios and classroom-organization forms following the "design-implementation-assessment-updating" mindset.

3. Conclusion

Artificial intelligence brings brand-new development opportunities for the teaching reform of *Metal Materials and Heat Treatment*. However, intelligent-teaching reform is not simply adding intelligent-software tools into courses, but reconstructing the educational system of the curriculum with technologies. We shall reconstruct the digital knowledge system of the course to achieve real-world implementation of technologies in teaching, build a collaborative classroom integrating teachers, students and machines to realize personalized development and educational equity, perfect AI-usage specifications to safeguard students' independent critical-thinking capabilities, and construct a multi-dimensional evaluation system to form a teaching closed-loop. In this way, the course can be transformed from the traditional knowledge-imparting mode to a human-machine-collaborative competence-cultivation mode. The educational quality of materials-major courses will be improved, and compound engineering talents satisfying digital-development requirements of the new-material industry can be cultivated.

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