Exploration and Practice of Data-Intelligent Talent Cultivation Model Based on CDIO-OBE Framework: A Case Study of the Literature Retrieval and Academic Writing Course

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Abstract: Confronting the disconnection between the demand for data-intelligent talents in the digital economy era and conventional higher education curricula, this study proposes an integrated CDIO-OBE framework through pedagogical reform of the Literature Retrieval and Academic Writing course. By synergizing the CDIO engineering education paradigm with OBE principles, a systematic framework for cultivating data-intelligent competencies was constructed. A competency framework encompassing systematic inquiry thinking, critical verification thinking, data-driven decision-making thinking, and ethical pre-evaluation thinking was established through the Delphi method. A three-phase cultivation pathway was designed as "problem definition-competency cultivation-value creation." During implementation, four supporting mechanisms-problem scenario repository, a cognitive toolkit, collaborative learning mechanisms, and a dynamic feedback network—were employed to enhance students' information retrieval proficiency, critical thinking, and scholarly writing capabilities. The implementation of this model is expected to significantly enhance students' research literacy and innovation capabilities in digital environments, providing practical and feasible guidance for promoting higher education reform.

Keywords: Conceive-Design-Implement-Operate; Outcome-Based Education; Data-Intelligent Talent Cultivation; Literature Retrieval and Academic Writing; Pedagogical Reform

1. Introduction

With rapid technological innovation and advancement, the digital economy has emerged as a critical driver of socio-economic transformation. Encompassing diverse domains such as big data, artificial intelligence, intelligent manufacturing, integrated circuits, and data security, the digital economy has imposed heightened demands for professionals with specialized expertise and interdisciplinary competencies. On April 17, 2024, nine governmental departments, including the Ministry of Human Resources and Social Security, jointly issued the Accelerating Digital Talent Cultivation to Bolster Digital Economy Development Plan (2024-2026). This policy explicitly outlined a three-year systematic initiative to enhance the independent innovation capabilities of digital talents and stimulate entrepreneurial vitality, thereby addressing the needs of industrial digitalization.

Recently, Wang et.al investigates the utilization of artificial intelligence (AI) for feature engineering in the education sector, highlighting its potential to enhance individualized learning and improve academic outcomes [1]. The incorporation of AI in education is changing the ways instructors teach, or students learn. Due to its automation of different responsibilities and real-time feedback, the learning environment has become more effective and inclusive [2].

Sanusi et.al employed semi-structured interviews to reveal the understanding of policymakers, teachers, and students regarding AI education, their identified priorities for integrating AI into the school system, related concerns, and the support needed for implementing AI education. It provides significant reference for further exploration on how to effectively incorporate AI into school curricula [3].

The increasing influence of artificial intelligence (AI) in nearly every aspect of human life has made it essential for everyone to understand the basic principles of how this technology operates [4,5]. As a result, introducing AI education at the compulsory education and high school levels

has been proposed as a critical strategy to prepare the younger generation for an AI-driven future [3]. The study by Annamalai et al. utilized PLS-SEM (Partial Least Squares-Structural Equation Modeling) techniques and, through Importance-Performance Map Analysis (IPMA), found that autonomy is the most important and highest-performing factor determining students' motivation for the continuous use of ChatGPT [6].

Amid the growing enthusiasm for ChatGPT, significant concerns have emerged, including issues related to academic integrity [7], plagiarism [8], and ensuring equitable access to resources [9]. The integration of generative AI into educational settings has sparked critical discussions about teaching methodologies, learning paradigms, authorship, and related challenges [10-11].

Data-intelligent talents, defined as high-caliber professionals with capabilities in innovation, application, and management within the realms of digitalization and intelligence, are pivotal to driving socio-economic transformation. Recent national-level strategic planning has underscored the imperative to accelerate the advancement of education, science and technology, and talent cultivation. Within this framework, promoting educational digitalization has emerged as a core focus and essential pathway toward building a modernized education system. Central to this transformation is the enhancement of students' digital literacy and the systematic cultivation of data-intelligent talents.

Under the policy framework of the digital economy, traditional pedagogical approaches have proven insufficient in addressing the needs of digital natives and fail to cultivate students' data-intelligent competencies [12]. In the latest research conducted in 2023, ChatGPT has demonstrated positive outcomes across various educational domains. For instance, Zou and Huang reported that ChatGPT has shown beneficial effects in enhancing academic writing [13]. As a core academic skills training course, Literature Retrieval and Academic Writing aims to enhance students' information literacy, research capabilities, and scholarly communication proficiency. Characterized by its interdisciplinary integration and practical orientation, this course comprehensively assesses undergraduates' holistic learning abilities, linguistic-logical skills, disciplinary synthesis, and an ideal implementation scenario for training data-intelligent competencies.

In conclusion, this study seeks to improve the educational outcomes of the Literature Retrieval and Academic Writing course by integrating the "CDIO+OBE" framework, thereby addressing the learning demands of digital natives and advancing the exploration of data-intelligent talent cultivation. The research is structured in three sequential phases. First, the foundational principles of CDIO (Conceive-Design-Implement-Operate) and OBE (Outcome-Based Education) are rigorously defined. Subsequently, a Delphi method is employed to develop a data-intelligent thinking competency framework, which aligns with the dual objectives of nurturing digital natives and cultivating data-intelligent talents. This phase further identifies the competencies required for talent development and refines practical teaching methodologies to enhance data-intelligent capabilities. Finally, the Literature Retrieval and Academic Writing course exemplifies designing a pedagogical framework and instructional strategies rooted in the "CDIO+OBE" paradigm while establishing a systematic model and implementation pathways for talent cultivation guided by data-intelligent thinking. The findings of this study are anticipated to contribute substantively to the advancement of data-intelligent talent development and provide theoretical and practical foundations for innovating higher education pedagogy and talent cultivation models.

2. CDIO and OBE Educational Frameworks

Amidst the new wave of technological revolution and rapid global economic development, higher education systems are increasingly required to meet heightened societal expectations for talent cultivation. The CDIO concept, proposed by institutions including the Massachusetts Institute of Technology (MIT) and the Royal Institute of Technology in Sweden, represents an engineering education model that emphasizes the cultivation of systemic engineering thinking through four stages—Conceive, Design, Implement, and Operate—to enhance students' interdisciplinary competencies. CDIO advocates for problem-driven pedagogical approaches rooted in real-world challenges, fostering systematic engineering logic, and has been widely adopted in engineering and technology-oriented disciplines [14]. CDIO can be synergistically integrated with Outcome-

Based Education (OBE) principles to further refine talent cultivation in higher education. OBE, pioneered by American scholars including Spady, prioritizes measurable learning outcomes and graduate competencies over traditional content-focused instruction [15]. OBE guides curriculum design and assessment frameworks by defining explicit learning objectives and ensuring pedagogical goals are transparent, quantifiable, and conducive to iterative optimization [16].

CDIO is an educational framework rooted in the "learning by doing" philosophy of American educator John Dewey. Initially developed by the Massachusetts Institute of Technology (MIT) and the Royal Institute of Technology in Sweden, the CDIO model emphasizes active, project-based learning that integrates theoretical knowledge with practical application, moving away from traditional passive learning approaches. It encourages learners to take an active role in their education, fostering creativity and initiative within a collaborative environment, while instructors act as facilitators rather than primary sources of information [17]. The CDIO framework has been widely adopted across various disciplines [18]. For instance, research by Su Xinyang demonstrated that nursing students in the intervention group, who were taught using the CDIO model, showed significant improvements in clinical practice skills, critical thinking, self-directed learning abilities, and both theoretical and practical performance, along with higher evaluations of clinical teaching quality compared to the control group [19]. Similarly, a study by Dong et al. applied an online training course based on the CDIO model to nursing students, revealing that the CDIO approach enhanced course interactivity and collaboration, which are critical for improving students' learning experiences and outcomes [18].

The hybrid education model based on the OBE concept holds the potential to achieve more efficient and higher-quality teaching outcomes. This is of significant importance in addressing the diverse learning needs of students and enhancing the overall quality of education [20]. Outcome-Based Education (OBE) is an educational philosophy centered on student learning outcomes. Its core principles emphasize a student-centered approach, outcome-driven objectives, and continuous improvement through teaching evaluation [21]. OBE focuses on whether students can acquire knowledge, skills, and appropriate values through learning, highlighting the central role and autonomy of students in the learning process, as well as the specific outcomes each student should achieve. Guided by the OBE framework, educators first define the expected learning outcomes for students. They then adopt a backward design approach, selecting appropriate teaching resources and designing effective learning activities and assessments to help students meet these predefined goals. The OBE model encourages students to actively engage in their learning journey, choosing paths and pacing that align with their individual characteristics and needs. In this context, teachers act as facilitators and coordinators, providing necessary support and guidance. Against the backdrop of global educational reform, the OBE teaching philosophy has gained widespread recognition for its clear goal orientation and proven effectiveness in achieving meaningful learning outcomes.

The integrated CDIO-OBE model has emerged as a predominant paradigm in contemporary engineering education reform. It combines CDIO's practical framework with OBE's outcome-driven orientation, offering a scientifically robust methodology for cultivating high-caliber talents [22]. While CDIO provides a holistic structure for engineering practice, OBE ensures goal-oriented curriculum alignment, establishing a closed-loop "objective assessment-improvement" system to maximize pedagogical efficacy.

Building upon the CDIO-OBE framework, a data-intelligent talent cultivation model can be constructed to establish a student-centered educational system that prioritizes the development of innovation capabilities and practical skills [23]. In the Literature Retrieval and Academic Writing course, the CDIO methodology emphasizes a problem-based pedagogical approach, enabling students to acquire domain-specific knowledge and technical competencies through engagement with real-world problem-solving contexts. Concurrently, the OBE methodology employs backward design and precision evaluation to ensure instructional processes align with predetermined outcomes, enhancing students' research literacy and academic writing proficiency.

3. Digital Natives and Data-Intelligent Talent Cultivation

3.1 Characteristics of Digital Natives

Digital Natives refer to the generation raised in digital technology environments, characterized by a high reliance on digital tools and distinct behaviors in information acquisition, processing, and application compared to previous learners [24]. Having been exposed to the internet, mobile devices, and multimedia resources early, Digital Natives are accustomed to acquiring knowledge through interactive learning methods and rely on social media and online platforms for information sharing and knowledge construction [12], demonstrating pronounced technology-dependent traits. However, despite their proficiency in technology usage and information retrieval, the learning behaviors of Digital Natives present new challenges. Traditional higher education curricula are often teacher-centered, lacking sufficient interactive and practical components, which limits students' engagement and intrinsic motivation [23]. Furthermore, the prevalence of information overload and fragmented learning patterns has led to deficiencies in critical thinking and systematic analytical skills, hindering the development of deep learning habits [25].

3.2 Competency Requirements for Data-Intelligent Talents

Driven by the digital economy and the advent of intelligent societies, data-intelligent talents have emerged as the core force for future industrial upgrading and technological innovation. Data-intelligent talents are high-caliber professionals capable of leveraging information technologies and data analytics competencies to resolve complex challenges in highly digitized and intelligent environments while demonstrating interdisciplinary integration capabilities, innovative thinking, and ethical awareness. According to the China Digital Economy Development White Paper (2023) and the Research Report on China's Digital Talent Development (2023), the digital economy is projected to account for over 50% of China's GDP by 2025, with global demand for high-end talents possessing data-intelligent competencies expected to grow exponentially. The Action Plan for Enhancing National Digital Literacy and Skills further emphasizes that data-intelligent talents must not only master domain-specific expertise but also cultivate core competencies in information processing, cross-domain integration, and ethical foresight. However, current higher education systems face significant challenges in cultivating such talents, including outdated curricula lagging behind technological advancements, knowledge-centric pedagogical approaches, insufficient training in critical thinking, and evaluation frameworks that fail to assess holistic competencies. Consequently, universities must re-examine the competency frameworks for data-intelligent talents and construct cultivation systems aligned with the demands of the digital economy era.

3.3 Construction of the Data-Intelligent Thinking Competency Framework

The Delphi method, initially developed by the RAND Corporation in the 1950s for military foresight, has evolved into a widely used tool across fields such as technology, health, and policy analysis. The development of the data-intelligent thinking competency framework in this study was conducted using the Delphi method, a systematic approach widely adopted for decision analysis and standard formulation in complex problem-solving contexts. This method ensures scientific rigor and operational feasibility by iteratively collecting and synthesizing expert consensus [26]. A panel of 12 experts from diverse domains was assembled—including educational technology, artificial intelligence, big data, and discipline-specific pedagogy. These experts, affiliated with renowned universities, research institutions, and domestic and international technology enterprises, collectively offered robust theoretical and practical expertise (Table 1).

Table 1. Descriptive Information about Expert Participants.

Participant No	Experience	Gender	Years of Work Experience
1	Artificial Intelligence Architect	M	16
2	Artificial Intelligence	W	12
3	Machine Learning Engineer	M	12
4	Machine Learning Engineer	M	11

5	Software Developer	M	4
6	Senior University Teacher, Associate Professor	M	4
7	Senior University Teacher, Professor	W	11
8	Big Data Analyst	W	10
9	Big Data Analyst	W	9
10	Research Assistant, Artificial Intelligence Research Institute	M	8
11	Researcher, Artificial Intelligence Research Institute	M	10
12	University Teacher	M	2

Three iterative Delphi rounds were implemented:

First Round: An open-ended questionnaire was designed to solicit experts' perspectives on the critical components of "data-intelligent thinking competencies," allowing unrestricted expression of insights. Textual responses were systematically categorized and subjected to content analysis, extracting core concepts and preliminary dimensions of data-intelligent thinking. The process continued until the construction saturation was achieved.

Second Round: Based on the first-round findings, experts were asked to rate each competency element's importance and feasibility. Results were aggregated to assess the degree of consensus among experts.

Third Round: Statistical summaries from the second round were shared with the panel, inviting experts to refine or reaffirm their judgments considering collective feedback. This iterative cycle continued until a high consensus level (≥80% agreement) was attained.

Through a three-round expert consensus process, this study established a data-intelligent thinking competency model comprising four core dimensions: Systematic Inquiry Thinking, Critical Verification Thinking, Data-Driven Decision-Making Thinking, and Ethical Foresight Thinking. These interconnected cognitive capacities collectively underpin university students' learning, research, and innovation capabilities in the data-intelligent era, constituting a holistic talent cultivation framework. Their implementation mapping within the Literature Retrieval and Thesis Writing course is detailed in Table 2.

Table 2. Dimensions of Data-Intelligent Thinking Competencies and Their Curricular Application Scenarios.

Dimension	Definition	Curricular Application Scenarios
Systematic Inquiry Thinking	The ability to deconstruct ambiguous requirements into actionable problems, refine research directions, and clarify logical relationships in complex issues.	Topic Selection Phase: Critical screening of AI-generated question repositories.
Critical Verification Thinking	The capacity to validate information sources and data-driven conclusions through logical scrutiny, identify potential biases, and enhance academic rigor.	Literature Review: Cross-verification and revision of AI-generated content.
Data-Driven Decision-Making Thinking	The competence to construct research logic through evidence chains, utilize data analytics for hypothesis derivation, and improve scientific decision-making.	Methodology Design: Data visualization tools for hypothesis validation.
Ethical Foresight Thinking	The awareness to anticipate technological risks, balance efficiency with ethical considerations, and maintain accountability in technology applications.	Thesis Writing: Ethical reflection reports on AI-assisted declarations.

4. CDIO-OBE Framework for the Literature Retrieval and Academic Writing Course Design

As a critical medium for cultivating digital literacy, integrating digital competencies into curricula is central to data-intelligent talent development. The Literature Retrieval and Academic Writing course, characterized by its interdisciplinary nature, is pivotal in enhancing students' information retrieval, filtering, and problem-solving capabilities. Firstly, in the information age, students must develop efficient literature retrieval and information screening skills to navigate vast and complex data ecosystems. Secondly, thesis writing requires

comprehensive critical evaluation and in-depth research, serving as a structured pathway for cultivating judgment, critical thinking, and analytical synthesis. Furthermore, to ensure research outcomes align with academic norms and societal relevance, competencies in data processing and technical ethics are systematically trained during academic writing practices.

In educational contexts, generative artificial intelligence (GenAI) has been demonstrated to accelerate pedagogical innovation, promote sustainable human well-being, enhance learning efficiency, and mitigate student anxiety [27]. Within the Literature Retrieval and Academic Writing course, intentional efforts to strengthen students' information literacy and data processing skills—coupled with training in mastering data-intelligent tools and clarifying the ethical boundaries of their usage—will significantly elevate students' digital proficiency and holistic competencies, equipping them with robust career adaptability and competitiveness [28].

Therefore, guided by the CDIO-OBE framework, the course's evaluation system is designed to deliberately steer students toward ethical and effective utilization of AI tools. This approach not only helps students master foundational literature retrieval and academic writing techniques but also fosters critical thinking and interdisciplinary research capabilities. By embedding information literacy and ethical discernment into the curriculum, the framework enhances students' comprehensive competitiveness, ensuring they possess enhanced adaptability and innovation capacity for future professional challenges.

4.1 CDIO-Based Curriculum Framework Design

The current Literature Retrieval and Academic Writing course predominantly emphasizes theoretical instruction with insufficient practical components. This pedagogical limitation has resulted in students' difficulties in efficiently retrieving, filtering, and managing scholarly information when confronted with academic research tasks. Furthermore, issues such as illogical argumentation, insufficient evidentiary support, and noncompliance with academic norms persist in the thesis writing. The CDIO educational philosophy (Conceive-Design-Implement-Operate) has been integrated into this curriculum reform to address these challenges. A project-driven and team-collaboration-oriented instructional model is constructed, organizing teaching activities into four iterative phases: conception, design, implementation, and operation. This framework enables students to master academic Literature Retrieval and Thesis Writing skills within authentic research contexts. Throughout this process, the curriculum prioritizes cultivating four core data-intelligence thinking competencies: systematic inquiry thinking, critical verification thinking, data-driven decision-making thinking, and ethical foresight thinking. This pedagogical design ensures that students acquire technical proficiency in literature retrieval and academic writing and develop the capacity to apply critical and innovative thinking in future scientific research and professional practice (Figure 1).

4.1.1 Conceived phase: topic selection based on authentic research problems

During the initial course phase, students are required to derive research topics from practical issues, integrate academic requirements, and develop literature retrieval plans. Instructors employ case-based demonstrations, AI-assisted topic exploration, and topic evaluation frameworks to cultivate systematic inquiry thinking, transforming ambiguous research interests into operationally defined academic questions. For example, AI-driven research cases in educational contexts are analyzed to guide students in dissecting topic rationale and contextualizing research backgrounds [29]. Students utilize academic visualization tools (e.g., VOSviewer or CiteSpace) to map research trends and screen topics through the "Social Value-Technological Feasibility Matrix" [28]. Iterative feedback is provided by instructors to validate the scholarly significance and operational viability of selected topics [30].

4.1.2 Design phase: formulating literature retrieval strategies and research frameworks

Upon finalizing the research topic, students are guided to acquire proficiency in efficiently retrieving and managing academic literature. The curriculum fosters critical verification thinking through training in database searches, the design of personalized retrieval strategies, and techniques for literature management and annotation. This ensures students develop the ability to evaluate and filter high-quality scholarly information. Instructors provide training on systematic literature searches using

academic databases such as Google Scholar, Web of Science, and CNKI. Specific emphasis is placed on applying Boolean logic operators and constructing advanced search syntax. Additionally, students learn to organize references through tools like Zotero or EndNote and employ concept mapping methods to synthesize core arguments from pivotal literature. During collaborative workshops, students present their peer review and cross-evaluation retrieval strategies. This iterative process refines search methodologies, optimizes strategy effectiveness, and validates the feasibility of proposed research frameworks.

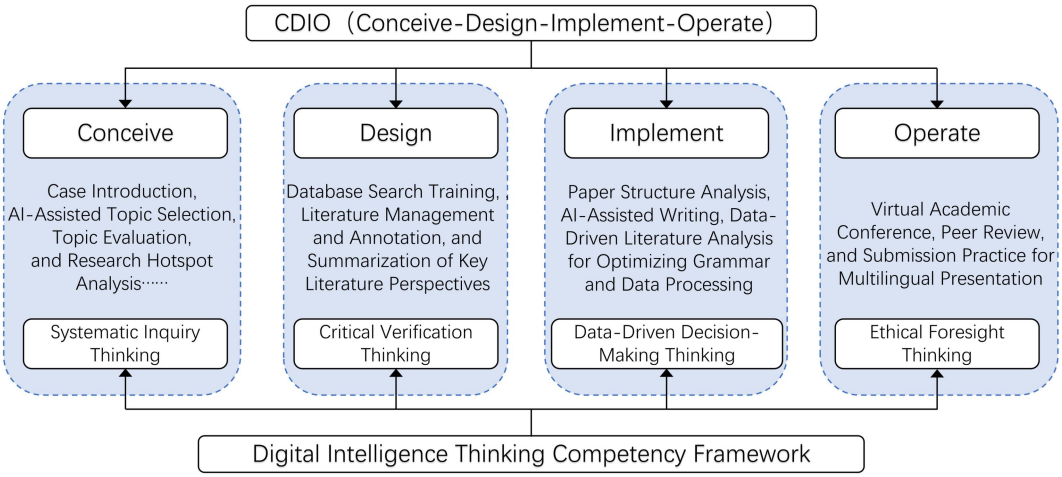

Figure 1. Schematic Diagram of the CDIO-Based Curriculum Framework and the Cultivation of Data-Intelligence Thinking Competencies

4.1.3 Implementation phase: thesis writing and data analysis

During the implementation phase, students are required to synthesize retrieved literature into systematic reviews and draft preliminary versions of their papers. The curriculum employs thesis structure deconstruction, AI-assisted writing, and data-driven literature analysis to cultivate students' data-driven decision-making thinking. Instructors guide students in analyzing the structural frameworks of exemplary academic papers and provide standardized thesis templates. Students leverage AI tools like ChatGPT, Deepseek, and Grammarly to refine grammatical accuracy and stylistic clarity throughout the writing. Paper content is iteratively adjusted based on feedback from instructors and peers. For studies involving data analysis, students must process datasets using Python Pandas or SPSS and then integrate analytical results into their manuscripts to substantiate research claims.

4.1.4 Operational phase: thesis defense and outcome application

In the course's final phase, students must present research outcomes and apply them to scientific or academic exchanges. The curriculum employs virtual academic conferences, cross-evaluation peer review, and submission practice to cultivate ethical anticipation thinking, enabling students to balance technological innovation with ethical accountability in academic and real-world contexts. Students deliver thesis presentations in simulated academic conferences, engage in double-anonymized peer review mechanisms for mutual critique, and iteratively refine their papers based on feedback.

Through integrating the CDIO framework, pedagogical activities shift from passive knowledge acquisition to active project-driven learning, forming a complete cycle of "problem-driven inquiry, solution design, practical validation, and outcome application." This course enhances students' information retrieval and academic writing skills and fosters core competencies such as systematic questioning, critical verification, data-driven decision-making, and ethical awareness. Ultimately, the curriculum establishes a robust foundation for cultivating high-caliber digital-intelligent talents equipped to meet the demands of the digital economy era.

4.2 Design Instructional Based on OBE Principles

Guided by the Outcome-Based Education (OBE) framework, the instructional design of the Literature Retrieval and Academic Writing course centers on students' learning outcomes, ensuring that teaching activities, course content, and assessment systems are tightly aligned with predefined educational objectives.

4.2.1 Four-dimensional support system for effective pedagogy

The course establishes a four-dimensional support system for the OBE model, comprising a problem scenario repository, cognitive toolkit, collaborative learning mechanisms, and dynamic feedback networks.

First, the problem scenario repository drives students' learning through authentic, real-world challenges. This repository curates research cases mapped to industry pain points and academic gaps, such as "knowledge management dilemmas in smart manufacturing" or "ethical issues in artificial intelligence," thereby enhancing the practical relevance and applied value of learning. Through Problem-Based Learning (PBL), students develop systematic inquiry thinking by engaging in contextualized tasks and cultivating competencies to address complex research problems.

Second, the cognitive toolkit equips students with a suite of non-technical methodological instruments, such as the SWOT analysis framework, logical fallacy checklist, and concept mapping methods. These instruments enable systematic problem analysis while reducing reliance on specialized software tools. By applying these tools, students strengthen critical verification thinking, enhancing rigor in literature retrieval, information filtering, and thesis logic construction.

Third, collaborative learning mechanisms are extensively implemented in group projects. Students are encouraged to form interdisciplinary teams and simulate real-world research workflows through role-playing (e.g., "technical expert + ethics consultant" models). This approach improves team communication skills and refines data-driven decision-making thinking via peer inspiration and iterative knowledge exchange.

Finally, the dynamic feedback network transforms instructors from "knowledge authorities" into cognitive coaches. Utilizing Socratic questioning, they guide students in self-reflecting and adjusting learning strategies. A multi-layered feedback system integrates instructor guidance, peer evaluation, self-assessment reports, and AI-powered learning platforms, fostering continuous strategy optimization. This structure amplifies the efficacy of cognitive training and reinforces ethical anticipation thinking throughout the learning cycle.

4.2.2 OBE-guided instructional design.

The OBE centers on designing pedagogies around students' learning outcomes. Through literature synthesis, 12 OBE principles are defined to guide instruction: clearly defined learning outcomes, backward curriculum design, high-level expectations, alignment between curriculum content and learning outcomes [31], alignment between teaching methods and learning outcomes, alignment between assessment methods and learning outcomes, transparent and clearly defined assessment criteria, student-centered active learning, provision of learning opportunities, continuous formative feedback [32], stakeholder-oriented approach, and continuous improvement cycle (Figure 2). These principles synergistically ensure that course objectives are tightly interlocked with final educational achievements. Instructors holistically apply these guidelines across all instructional stages—from defining goals and selecting content to designing assessments—with each step rigorously aligned to outcome requirements. This framework establishes a cohesive strategy for optimizing the Literature Retrieval and Academic Writing course, ensuring cultivated competencies remain entirely consistent with outcome-driven objectives.

Guided by the 12 OBE principles, the instructional methodology of the Literature Retrieval and Academic Writing course has been redesigned, with specific pathways detailed in the following Figure 3.

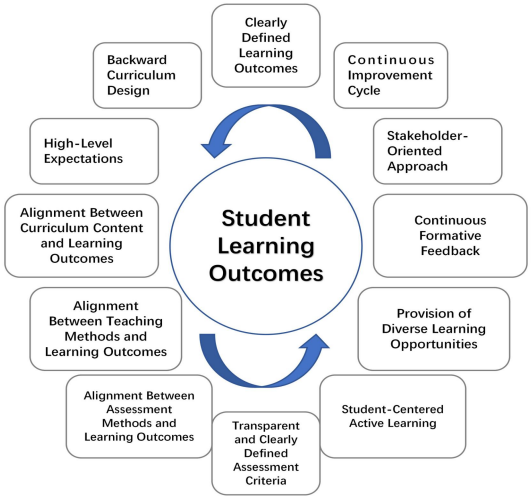

Figure 2. The 12 OBE Guiding Principles

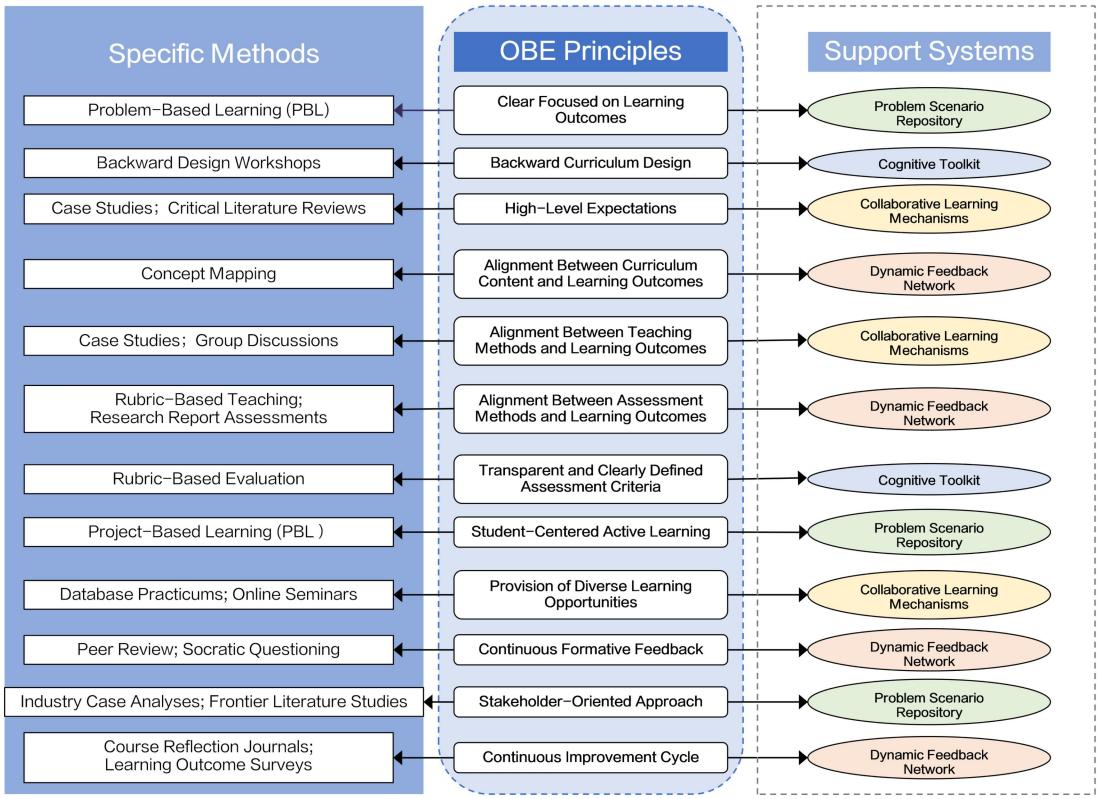

Figure 3. Instructional Methodology Pathways

4.3 Implementation Pathway of the Digital-Intelligent Thinking-Oriented Training Framework

In the digital-intelligent era, the core mission of higher education shifted from skill training to higher-order thinking cultivation, emphasizing the enhancement of comprehensive application capabilities and cognitive competencies. The integration of CDIO and OBE educational frameworks provides a scientifically grounded pathway for university curriculum reform. Under the digital-intelligent thinking paradigm, talent development models must evolve from traditional tool-based skill training to advanced cognitive capacity building, forming a pedagogical logic that progresses from "tool empowerment" to "cognitive evolution."

This course is structured around a three-phase cognitive progression framework—problem definition, competency development, and value creation—designed to establish a comprehensive epistemological system that transitions students from information retrieval through knowledge synthesis to scholarly innovation. Through the pedagogical integration of CDIO and OBE frameworks, students' digital-intelligent thinking abilities are incrementally advanced, culminating in research outcomes with practical significance. Specifically, the course adopts a problem-driven approach, guiding students through research question formulation, critical thinking refinement, and societal application of research outputs. This ensures alignment between learning objectives and real-world demands, effectively achieving the goal of cultivating digital intelligent thinking competencies (Figure 4).

Stage 1: Problem Definition and Competency Development

This phase focuses on cultivating students' ability to identify valuable research questions from complex information environments, ensuring their research directions demonstrate scientific rigor, innovation, and societal relevance. The primary challenge in academic research lies in selecting topics with scholarly merit. The course employs data-driven approaches to guide students in pinpointing key research trajectories and systematically deconstructing research problems.

Stage 2: Critical Thinking Refinement

This stage emphasizes advancing students' critical verification thinking and enhancing their proactive validation of information sources, analytical tools, and research conclusions. In digitalized contexts, the authenticity and reliability of information critically impact

academic quality. Students are trained in adversarial learning, data provenance tracking, and scientific peer review methods to strengthen academic discernment and bolster the credibility of their findings.

Stage 3: Value Externalization through Applied Research Translation

Following the completion of problem definition and critical verification thinking training, students transition to the value externalization phase, which prioritizes cultivating translational competencies to bridge academic findings with real-world implementation. High-caliber academic research should transcend theoretical discourse to demonstrate practical applicability and societal embeddedness. Consequently, this phase emphasizes systematic methodologies for deploying research outputs across three domains: industrial innovation prototyping, evidence-based policy co-creation, and multi-stakeholder impact assessment frameworks.

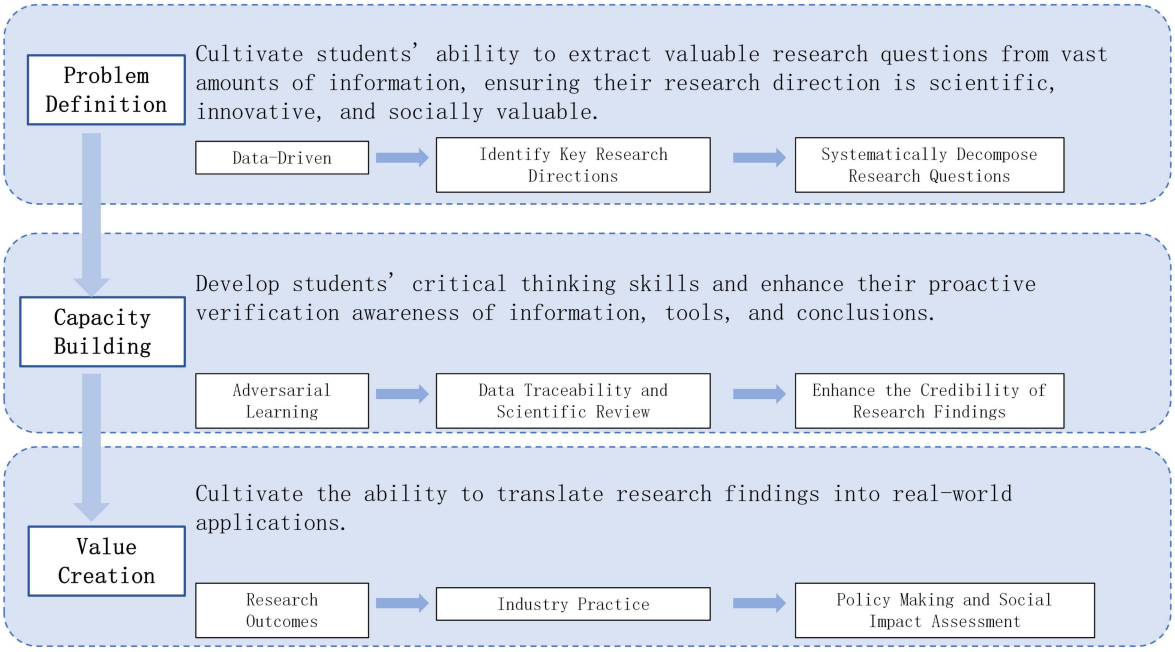

Figure 4. Schematic Framework of the Cultivation Model

5. Conclusion

This study was grounded in the CDIO-OBE integrated theoretical framework, through which a pedagogical reform was systematically implemented for the Literature Retrieval and Academic Writing course, culminating in proposing a digital-intelligent thinking-oriented talent cultivation model. By constructing a digital-intelligent competency architecture, the model explicitly defines four core competencies: systematic inquiry thinking, critical verification thinking, data-driven decision-making thinking, and ethics anticipation thinking. Throughout the instructional process, these competencies were operationalized via a four-dimensional support system comprising a problem scenario repository, cognitive toolkit, collaborative learning mechanisms, and dynamic feedback networks. The research contributions are twofold: 1) a systematized cultivation pathway for digital-intelligent talents was designed, addressing the fragmented approaches in traditional pedagogy; 2) persistent limitations in conventional teaching models—including overemphasis on knowledge transmission, insufficient practical training, and deficient cognitive skill development—were rigorously mitigated. Consequently, students' academic rigor, innovative capacity, and societal responsibility awareness were significantly enhanced, aligning with the strategic demands of the digital-intelligent era.

Guided by the practice-oriented CDIO framework, this course adopts phased pedagogical architecture. During the conceiving phase, authentic problem-driven approaches are emphasized to enable students to construct research questions based on societal demands and academic frontiers. Integrating data retrieval and literature management technologies in the design phase cultivates critical thinking and information literacy. The implementation phase introduces technological tools such as AI-

assisted writing, data analytics, and scholarly peer review to develop rigorous research logic within data-supported environments. During the operation phase, students engage in academic communication, research application, and ethical reflection to enhance their practical translation competencies of research outcomes. The backward design methodology inherent in the OBE paradigm ensures effective alignment among teaching objectives, instructional processes, and assessment systems. This allows learning outcomes to be quantifiably evaluated and continuously optimized via iterative feedback, promoting deep learning and competency transfer.

Furthermore, the three-phase progression framework—problem definition, competency development, and value creation—successfully addresses the limitations of traditional pedagogies that overemphasize technical tool dependency while neglecting higher-order thinking cultivation. Students progressively enhance logical thinking, problem-solving, and interdisciplinary integration capabilities across information retrieval, literature evaluation, data analysis, and academic writing. This framework provides transferable insights for pedagogical innovation in other disciplines.

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References

[1] Chao Wang, Tao Li, Zhicui Lu, Zhenqiang Wang, Tmader Alballa, Somayah Abdualziz Alhabeeb, Maryam Sulaiman Albely, and Hamiden Abd El-Wahed Khalifa. Application of artificial intelligence for feature engineering in education sector and learning science. Alexandria Engineering Journal, 2025, 110(1): 108–115.

[2] Firuz Kamalov, David Santandreu Calonge, and Ikhlaas Gurrib. New era of artificial intelligence in education: Towards a sustainable multifaceted revolution. Sustainability, 2023, 15(16): 12451.

[3] Ismaila Temitayo Sanusi, Friday Joseph Agbo, Oluwaseun Alexander Dada, Abdullahi Abubakar Yunusa, Kehinde D. Aruleba, George Obaido, Olayemi Olawumi, and Solomon Sunday Oyelere. Stakeholders' insights on artificial intelligence education: Perspectives of teachers, students, and policymakers. Computers and Education Open, 2024, 7: 100212.

[4] Duri Long and Brian Magerko. What is AI literacy? Competencies and design considerations. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20), New York, NY, USA, 2020: 1–16.

[5] David Touretzky, Christina Gardner-McCune, Cynthia Breazeal, Fred Martin, and Deborah Seehorn. A year in K-12 AI education. AI Magazine, 2019, 40(4): 88–90.

[6] Nagaletchimee Annamalai, Brandford Bervell, Dickson Okoree Mireku, and Raphael Papa Kweku Andoh. Artificial intelligence in higher education: Modelling students' motivation for continuous use of ChatGPT based on a modified self-determination theory. Computers and Education: Artificial Intelligence, 2025, 8: 100346.

[7] Enkelejda Kasneci, Kathrin Sessler, Stefan Küchemann, Maria Bannert, Daryna Dementieva, Frank Fischer, Urs Gasser, Georg Groh, Stephan Günnemann, Eyke Hüllermeier, Stephan Krusche, Gitta Kutyniok, Tilman Michaeli, Claudia Nerdel, Jürgen Pfeffer, Oleksandra Poquet, Michael Sailer, Albrecht Schmidt, Tina Seidel, Matthias Stadler, Jochen Weller, Jochen Kuhn, and Gjergji Kasneci. ChatGPT for good? On opportunities and challenges of large language models for education. Learning and Individual Differences, 2023, 103: 102274.

[8] John L. Rudolph. Why We Teach Science (and Why We Should) . Oxford Academic, 2023.

[9] Yiheng Liu, Tianle Han, Siyuan Ma, Jiayue Zhang, Yuanyuan Yang, Jiaming Tian, Hao He, Antong Li, Mengshen He, Zhengliang Liu, Zihao Wu, Lin Zhao, Dajiang Zhu, Xiang Li, Ning Qiang, Dingang Shen, Tianming Liu, and Bao Ge. Summary of ChatGPT-related research and perspective towards the future of large language models. Meta-Radiology, 2023, 1(2): 100017.

[10] Ben Williamson, Felicitas Macgilchrist, and John Potter. Re-examining AI, automation and datafication in education. Learning, Media and Technology, 2023, 48(1): 1–5.

[11] Michalinos Zembylas. A decolonial

approach to AI in higher education teaching and learning: Strategies for undoing the ethics of digital neocolonialism. Learning, Media and Technology, 2021, 48(1): 25–37.
[12] Marc Prensky. Digital natives, digital immigrants. On the Horizon, 2001, 9(5): 1–6.
[13] Min Zou and Liang Huang. To use or not to use? Understanding doctoral students' acceptance of ChatGPT in writing through technology acceptance model. Frontiers in Psychology, 2023, 14: 1259531.
[14] Ewelina Lacka and Tak Chi Wong. Examining the impact of digital technologies on students' higher education outcomes: The case of the virtual learning environment and social media. Studies in Higher Education, 2019, 46(8): 1621–1634.
[15] Quan Feng. Research on the cultivation of applied talents under the OBE education model. Journal of Anhui Polytechnic University, 2016,3(3):81–85.
[16] Kai Liu and Yanfang Sun.Research on the cultivation of university teachers is based on the concept of OBE education.Heilongjiang Higher Education Research,2017,6(6):59–61.
[17] Yu Chen, Heling Wen, Zheng Huang, Rui Zhang, and Lei Peng. Advancing arrhythmia education through the CDIO approach:A new paradigm in nursing student training. BMC Nursing, 2024,23:427.
[18] Xinyue Dong, Zhen Zhang, Xian Zhang, Minmin Lu, Yangyang Zhao,Ying Lin, and Yuxia Zhang. Effects of an online training program on cardiovascular health behavior modification on nursing students'health education competency. Nurse Education Today, 2023,127:105829.
[19] Xinyang Su,Huaxiu Ning,Fang Zhang, Li Liu, Xiaoling Zhang,and Hongmei Xu. Application of flipped classroom based on CDIO concept combined with mini-CEX evaluation model in the clinical teaching of orthopedic nursing. BMC Medical Education, 2023,23:219.
[20] Zhicui Yao, Yongqing Shen, Rong Wang, et al. Innovative construction of nursing education quality assessment system based on OBE concept in China. Teaching and Learning in Nursing, 2025. DOI: 10.1016/j.teln.2025.02.020.
[21] Feifei Li, Xuanyu Gong, and Shanhong Zhang. Research progress on outcome-based education in the field of nursing in China. China Continuing Medical Education, 2023,15(14):49–53.
[22] Xiaolan Du and Lei Zhang. Exploration and practice of higher vocational curriculum reform based on the OBE-CDIO concept.Technology Wind, 2025,3(3):16–18.
[23] Yihong Dai, Ching Sing Chai, Pei-Yi Lin, Morris Siu-Yung Jong,Yunwen Guo,and Jianhua Qin. Promoting students'well-being by developing their readiness for the artificial intelligence age. Sustainability, 2020,12(16):6597.
[24] Michael Henderson, Neil Selwyn,and Rachel Aston. What works and why? Student perceptions of'useful'digital technology in university teaching and learning. Studies in Higher Education, 2017,42(8):1567–1579.
[25] Don Passey. Digital technologies—And teacher wellbeing?. Education Sciences, 2021,11(3):117.
[26] Norman Dalkey and Olaf Helmer. An experimental application of the Delphi method to the use of experts. Management Science, 1963,9(3):458–467.
[27] Thomas K.F.Chiu and Ching Sing Chai. Digital learning and student anxiety:A review of ChatGPT in education. Journal of Computer Assisted Learning, 2020,36(5):837–851.
[28] Edward F.Crawley, Johan Malmqvist, SörenÖstlund, Doris R.Brodeur, and Kristina Edström. Rethinking Engineering Education: The CDIO Approach (2nd ed.). Springer,2014.
[29] Yan Chen, Rui Zhang, Zongkai Zhou, Mei Hong, Zhenyu Huang, Haifeng Wen, and Li Peng. Comparison of the conceive-design-implement-operate model and lecture-based learning in teaching the "healthcare-associated infections" course. Frontiers in Medicine, 2025,12:1505588.
[30] Hong-Xia Zhong, Po-Sheng Chiu, and Chin-Feng Lai. Effects of using CDIO engineering design in a flipped programming course on flow experience and cognitive load. Sustainability, 2021,13(3):1381.
[31] John Biggs. Enhancing teaching through constructive alignment. Higher Education, 1996,32(3):347–364.
[32] John Hattie and Helen Timperley. The power of feedback. Review of Educational Research, 2007,77(1):81–112.

