Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 21, No. 3, 2026

Exploring "Multi-disciplinary and Cross-domain" Integrated Teaching Reform for Frontier Graduate Courses Empowered by Digital Intelligence

-- A Case Study of the Course "Advances in Food Science Research"

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Abstract: To address challenges in frontier graduate courses—such as the rapid evolution of course content, significant disparities in students' foundational knowledge, and insufficient training in academic competencies—this study explores a "multi-disciplinary and cross-domain" integrated teaching reform, using the course "Advances in Food Science Research" as a case study. The reform focuses on three key areas: content organization, pedagogical methods, and process-oriented assessment. The curriculum employs interdisciplinary topics to bridge fundamental knowledge, cutting-edge research, and industrial applications, while integrating literature review, problem-based discussion, and academic inquiry into the thematic instruction. Digital tools, such as "Rain Classroom" (Yu Ketang), are utilized to gather student perspectives, allowing for instruction to be adjusted based on common issues. Furthermore, a smart course platform has been developed—featuring knowledge graphs, AI teaching assistants, resource recommendations, and intelligent assessment systems—to facilitate learning. This reform shifts the pedagogical focus from the delivery of isolated knowledge points to learning organized around frontier issues. It establishes a teaching model that combines thematic seminars with academic training, enriches extracurricular learning resources, and enhances feedback throughout the learning process.

Keywords: Graduate Education; Digital Intelligence Empowerment; Frontier Graduate Courses; Multi-disciplinary and Cross-domain Integration; Exploration of Teaching Reform.

1. Introduction

Course-based instruction is a vital component in the cultivation of high-level, innovative talent. As graduate education shifts its focus from quantitative expansion to qualitative enhancement, the priority of curricular reform has moved beyond mere knowledge dissemination. Instead, the focus is now on how to foster high-order competencies—such as problem identification, academic expression, interdisciplinary understanding, and the practical application of knowledge—within the curriculum [1]. The Ministry of Education's "Opinions on Further Promoting the Differentiated Development of Academic and Professional Graduate Education" emphasizes the need to "optimize the curriculum system, strengthen guidance on cutting-edge developments and methodological training, and enhance students' capacity for knowledge-based and practical innovation"—a directive that is particularly relevant to advanced, frontier-oriented graduate courses.

The course "Advances in Food Science Research"—an elective offered to students in fields such as biology, medicine, food science, and nutrition—is characterized by its focus on the academic frontier, a broad knowledge scope, a diverse student body, and comprehensive pedagogical objectives. Several recurring challenges have emerged in the delivery of this course: First, there is a tension between large-class instruction and in-depth academic inquiry; classroom interaction often remains limited to a "lecturer-speaks, student-listens" model, failing to facilitate genuine academic dialogue between faculty and students. Second, given the students' varied disciplinary backgrounds, some are able to engage with cutting-edge topics immediately, while others—particularly those from different fields—face significant barriers to understanding, leading to a scenario where some students find the material insufficiently challenging, while others struggle to keep pace. Third, because the course covers rapidly evolving frontier areas—such as food-omics, gut microbiota, novel proteins, and precision nutrition—traditional, static lesson plans struggle to keep pace with disciplinary advancements. This often results in a problematic situation characterized by an abundance of course materials, yet a lack of deep insight and only superficial discussion.

Existing research has explored areas such as graduate curriculum reform, blended learning, university-enterprise collaboration, and the application of digital-intelligent teaching tools [2-3]. For cutting-edge courses, further study—grounded in practical implementation—is required to determine how to effectively integrate content updates, interdisciplinary knowledge organization, teaching resources, and learning assessment [4]. Taking the course "Advances in Food Science Research" as a case study, this paper addresses two key questions: First, how can "multi-dimensional, cross-disciplinary integration" be used to organize cutting-edge knowledge and learning tasks to meet the needs of graduate students from diverse academic backgrounds? Second, how can teaching practices supported by the "Rain Classroom" (Yu Ketang) platform be aligned with the development of smart courses on the "Xuexitong" (Learning-to-Master) platform to further refine instructional strategies?

2. Approach to Curriculum Reform

2.1. Theoretical Foundations

2.1.1. Constructivist Learning Theory

The table 1 shows the arrangement of rotary kiln with accessories. Kiln can be used as a rotary dryer to remove water and moisture content from solid substances by introducing hot gases into a drying chamber. Kiln shell should be structurally strong with non-conductor lining and designed to withstand high temperature and prevent the thermal losses of the kiln. Construction and position alignment of the kiln is very important for all the process. In thermal processing of residual materials with a various origin and predominantly for fire treatment of hazardous wastes rotary kiln are employed, in thermal processing of residual materials with a various origin and predominantly.

2.1.2. Constructive Alignment Theory

Constructive alignment emphasizes the coherence between learning objectives, teaching activities, and assessment methods. In a graduate course, if the goal is to cultivate students' capacity for critical questioning, literature analysis, and academic expression, then classroom instruction cannot be limited to one-way lecturing. Similarly, assessment should not rely solely on final outcomes; instead, it must incorporate factors such as participation in discussions, the depth of insight, and specialized assignments throughout the entire learning process. Constructive alignment [6] provides a design framework for establishing the essential link between objectives, activities, and assessments required for this study.

2.1.3. Outcome-Based Education (OBE) Philosophy

The OBE philosophy [7-8] centers the design and implementation of a curriculum on student learning outcomes. In the context of a course focused on cutting-edge topics, this paper defines the intended learning outcomes as the ability to "think, speak, and write." Specifically, "thinking" refers to the capacity to identify a researchable question from emerging phenomena; "speaking" denotes the ability to articulate professional, evidence-based arguments regarding that question; and "writing" entails the ability to produce a well-structured paper with clear viewpoints and rigorous argumentation.

2.2. "Multi-Dimensional Integration" Instructional Design

In this paper, the term "multi-dimensional integration" encompasses the synthesis of interdisciplinary knowledge, the bridging of research and application, the incorporation of industry resources, and the combination of diverse pedagogical approaches. The course organizes knowledge from fields such as food science, biology, nutrition, and engineering technology around cutting-edge issues. It connects research with practical application through literature seminars and industry case studies, utilizing a mix of lectures, case analyses, task-driven activities, and peer assessment—all supported by digital and intelligent tools. This design is operationalized through the reconstruction of learning objectives, modularization of content, blended learning, ongoing process support, and comprehensive assessment, creating an instructional pathway that integrates content, resources, methods, and support mechanisms. The overall framework is illustrated in Figure 1.

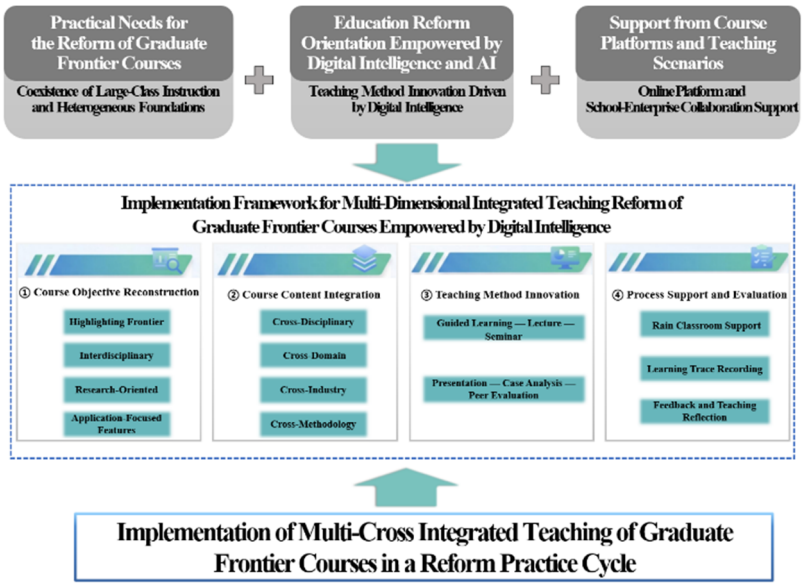

Figure 1. Digital-Intelligence-Enabled Cross-Disciplinary Integration Reform in Frontier Graduate Courses.

3. Research Design

3.1. Research Methodology

This study employs an action research approach. It focuses on the reconstruction of course objectives, modular organization, differentiated support, and process-oriented assessment—all facilitated by the "Rain Classroom" (Yu Ketang) platform. The implementation of the course is analyzed through classroom observation, records of the learning process, and pedagogical reflection. Building on this, a "smart course" has been developed on the "Xuexitong" (Learning Pass) platform, and an improvement plan for the next iteration has been formulated. This paper uses the completed teaching practice as the basis for a preliminary analysis; the smart course serves to illustrate the subsequent instructional design, with its application and comparative evaluation reserved for the next phase of implementation.

3.2. Research Participants

The study focuses on 112 graduate students enrolled in the

elective course "Advances in Food Science Research," comprising 74 students from the Biotechnology and Engineering program and 38 from the Food and Nutrition program. The majority of students (74.1%) hold undergraduate degrees in fields related to food science, biology, or pharmacy, while the remaining students come from disciplines such as environmental science, information technology, economics and management, and the humanities and arts. Given this diverse academic background, the course instruction balances the consolidation of foundational knowledge with the exploration of frontier issues, utilizing differentiated guidance and cross-disciplinary collaboration to support student learning.

3.3. Data Collection and Analysis

This study employs two types of data for descriptive analysis and qualitative induction: first, records from the "Rain Classroom" (Yu Ketang) platform—including check-ins, polls, student viewpoints, and interaction logs; and second, learning outputs such as thematic assignments, group reports, and in-class presentations. These data are cross-verified against classroom observations and the instructor's reflective notes. The analysis focuses on student engagement, performance on learning tasks, and the instructional adjustments made by the teacher; student satisfaction is not used as a primary metric for evaluating teaching effectiveness.

4. Reform in Practice: A "Multi-Domain Integrated" Pedagogical Approach Empowered by Digital Intelligence

4.1. Restructuring Course Objectives Toward Competency-Based Outcomes

Addressing the tendency in previous advanced-topic courses to "prioritize knowledge coverage over the manifestation of competencies," this study shifts the course objectives from merely "understanding research frontiers" to "comprehending frontiers, critically analyzing issues, articulating perspectives, and connecting theory to practice" [9]. In terms of knowledge, students are expected to master the developmental trajectories and research methodologies of key frontier topics in food science. Regarding competencies, the curriculum fosters skills in literature screening, problem distillation, viewpoint articulation, and academic writing. In terms of broader attributes, it emphasizes academic integrity, interdisciplinary thinking, and an understanding of the industry. This marks a transition from a focus on "what was taught" to "what students are ultimately able to produce."

4.2. Modular Content Reorganization Focused on Frontiers and Practical Application

Aligned with the objectives of enabling students to grasp disciplinary frontiers, analyze research problems, and apply knowledge to real-world scenarios, the course content is organized into eight thematic modules, incorporating advancements in digital intelligence and artificial intelligence. An introductory module outlines core propositions and frontier challenges in the food sector, while subsequent modules explore scientific mechanisms alongside evolving research methodologies. For instance, the module on flavor science bridges sensory experience with intelligent analysis; the module on personalized nutrition examines the relationship between data analysis and precision diets, accounting for individual variability—thereby highlighting the intersection of food science and information technology. Other modules—covering food safety, functional foods, novel proteins, and future foods—connect directly to practical applications, guiding students to holistically evaluate scientific evidence, safety, nutrition, cost, and sustainability requirements.

Each thematic module is structured around a problem-based introduction, an overview of frontier developments, case studies, and reflective discussion. For research cases involving digital intelligence and AI, instruction focuses on the problems that these technologies can address, while also exploring their scope of application and limitations. Through literature review and case discussions, students develop well-founded perspectives, integrating the study of digital intelligence and AI with the cultivation of comprehensive analytical skills.

4.3. Blended Teaching Organization Geared Toward Deep Engagement

In terms of instructional organization, this course employs a combination of three formats: lectures, seminars, and case studies [10]. Lectures are primarily used to outline cutting-edge developments and provide methodological guidance; seminars focus on the close reading of literature, the analysis of debates, and the articulation of viewpoints; and case studies introduce industry-specific examples to help students understand the practical contexts in which research questions arise. These components are weighted at approximately 40%, 35%, and 25%, respectively, ensuring a balance between systematic input and active output.

The course integrates pre-class preparation, in-class seminars, and post-class writing around specific thematic issues, embedding the development of academic skills throughout the entire learning process. Before class, preparatory materials—including core concept lists and discussion prompts—are distributed via the "Rain Classroom" (Yu Ketang) platform; this equips students for seminar participation while helping instructors identify areas where students may be struggling. During class, student groups present their arguments supported by evidence, with the robustness of their reasoning evaluated through peer feedback and follow-up questioning by the instructor. After class, assignments such as writing abstracts, short commentaries, or outlines for literature reviews guide students to synthesize course materials and discussion outcomes into written work. This structure bridges the gap between knowledge acquisition and academic training, with a particular emphasis on cultivating students' ability to analyze issues and substantiate their viewpoints using evidence.

4.4. Digital and Intelligent Support for Differentiated Learning

In this iteration of the course, the "Rain Classroom" (Yu Ketang) platform was utilized to facilitate guided learning and real-time interaction. A total of six guided learning sessions were conducted, yielding over 500 student contributions. Real-time feedback enabled instructors to identify common challenges among students and promptly adjust the focus of their explanations and discussion topics [11]. However, existing materials are primarily designed for pre-class guidance and in-class discussions; there remains a need for additional resources to support students' independent, out-of-

class learning.

To strengthen support for learning outside the classroom, the course has been developed into a "smart" curriculum on the "Xuexitong" (Learning Pass) platform. It employs a knowledge graph to organize fundamental concepts alongside cutting-edge developments, and incorporates features such as AI teaching assistants, resource recommendations, intelligent assessment, and learning analytics—addressing both the organization of study materials and the provision of Q&A and feedback throughout the learning process.

4.5. Integration of Industry-Based Teaching Resources for Real-World Contexts

The course incorporates expertise from industry professionals and real-world industrial case studies into its thematic instruction. Experts from prominent companies are invited to share insights and lead discussions on topics such as the regulatory approval of novel food ingredients and emerging industry trends, thereby situating the study of cutting-edge knowledge within practical, real-world contexts. By leveraging these case studies, the course guides students to examine research questions through the lenses of technical feasibility, application requirements, and the demands for practical implementation.

4.6. Establishing an Evaluation Closed-Loop for Continuous Improvement

To implement constructive alignment, the course evaluation incorporates data from both the process and the outcomes—such as classroom participation, seminar performance, group presentations, and thematic assignments. Through a combination of instructor assessment, peer review, and feedback, students are guided to refine their analytical perspectives and enhance their academic literacy. Based on platform records, learning outcomes, and pedagogical reflections, the research team adjusts the content, task design, and support mechanisms for subsequent iterations of the modules. Future assessments will utilize consistent rubrics for evaluating learning outcomes, integrating platform-based process data with task performance to examine the suitability of various instructional support strategies.

5. Implementation of Pedagogical Reform and Interim Observations

5.1. Implementation of the Current Course Cycle

The current iteration of the course exhibits several notable changes: First, the course organization has become more structured, with thematic modules centered on cutting-edge issues, and with lectures, seminars, and case analyses effectively integrated. Second, student engagement opportunities have expanded, incorporating tasks such as pre-class preparatory learning, small-group seminars, thematic presentations, and peer reviews. Third, data from the "Rain Classroom" (Yu Ketang) platform provides instructors with insights into students' perspectives and levels of classroom participation, enabling them to adjust the focus of their instruction and the structure of class discussions accordingly.

5.2. Positive Outcomes Observed During the Interim Period

Based on student thematic presentations, periodic assignments, in-class contributions, and instructor reflection records from this iteration of the course, several positive developments have emerged. First, students' understanding of cutting-edge topics has evolved; rather than merely listing materials or restating concepts, some students have begun to select relevant resources centered on specific frontier issues, synthesizing them and conducting preliminary analysis. Second, there is a heightened awareness regarding in-class communication. Compared to the beginning of the course, some student groups were able to present a clear research framework during their thematic presentations, structured as: "research background—core issue—key progress—personal reflections." Third, some students have begun to demonstrate an ability to make cross-disciplinary connections. Following the introduction of industry case studies and insights from corporate experts, some students have started to explore the intersections between academic frontiers, industry requirements, and technological applications.

5.3. Issues Encountered and Plans for Future Comparative Analysis

Certain challenges persisted during this iteration. In a large-class setting, the depth of group presentations and case discussions was constrained, with high-quality interaction largely concentrated among a subset of students. The use of the "Rain Classroom" (Yu Ketang) platform focused primarily on guided learning, interaction tracking, and instructor feedback; however, the link between data on the learning process and the assessment of student competencies requires further strengthening. Although the "Xuexitong" (Learning Pass) smart course platform has been developed, the effectiveness of its features—such as knowledge graphs and AI-powered teaching assistants—in supporting students with diverse backgrounds remains to be evaluated in an actual teaching environment.

For the next iteration, the "Xuexitong" smart course platform will be utilized to support instruction. While maintaining consistency in course objectives, key assignments, and assessment rubrics, an exploratory comparison will be conducted between this approach and the "Rain Classroom" support model used in the current iteration.

6. Conclusion

Taking the course "Advances in Food Science Research" as a case study, this paper explores a "multi-disciplinary and cross-domain" pedagogical reform empowered by digital and intelligent technologies. This approach addresses challenges such as large class sizes, diverse student academic backgrounds, and the rapid evolution of cutting-edge subject matter. The instructional design integrates interdisciplinary knowledge, bridges the gap between research and application, incorporates teaching resources from industry partners, and employs a variety of pedagogical methods. A full cycle of instruction—supported by the "Rain Classroom" (Yu Ketang) platform—was implemented; subsequently, based on reflections from this practice, a "smart course" was developed on the "Xuexitong" (Learning Pass) platform, establishing a phased pathway for continuous course improvement.

Observations of the classroom and analysis of student learning outcomes reveal progressive shifts in course organization, modes of student engagement, and the nature of discussions surrounding frontier topics. Moving forward, the "Xuexitong" smart course will be utilized to drive continuous

improvement, with a focus on enhancing student participation and learning outcomes, while the course design and evaluation framework will be further refined through iterative cycles of practical application.ure

Acknowledgments

This paper was supported by the Second Batch of Postgraduate Teaching Reform Projects of Zhejiang Province during the 14th Five-Year Plan period (Project No. JGCG2024361).

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