AI-Enabled Research on Competency-Oriented Interdisciplinary Split-Track Task-Driven Instruction

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***Abstract*—Aiming at the problems of insufficient task suitability and a single evaluation dimension in personalized teaching, this paper proposes an Artificial Intelligence (AI)-empowered competency-oriented interdisciplinary split-track task-driven teaching framework. The framework takes the background of super-discipline integration education, uses AI empowerment and causal analysis to achieve precise matching of task competence and elimination of confounding variables, and realizes the goal of multidimensional competence enhancement through assessment and evaluation optimization. In the case of information security teaching implementation, the F-test results show that the variance of students' competence is significantly reduced from 20.97 to 10.41, reflecting the effectiveness of the framework. The framework provides a new methodological paradigm and useful reference for AI-enabled personalized teaching.**

***Keywords*—personalized teaching, causal analysis, Artificial Intelligence (AI)-enabled, split-track task design, competency-oriented**

I. Introduction

The rapid development of Artificial Intelligence (AI) technology has brought about profound changes in the field of education, promoting the transformation of the education model from scale to personalization. The engineering education accreditation system emphasizes the need for in-depth integration of course objectives with AI technology, while the evaluation standard for national first-class courses explicitly requires the use of digital intelligence tools to achieve "learning-centered" blended teaching and to strengthen the cultivation of students' comprehensive ability through diversified evaluation. The background of the times and policy requirements shows that AI-enabled personalized teaching is not only a technical development trend but also an inevitable requirement for education reform in the new era.

However, the current practice of personalized teaching at home and abroad still faces many problems. For one thing, the task design is in a single form, which is difficult to adapt to the development needs and learning motivation of different students. At the same time, although AI can improve learning efficiency, there is also the risk of AI abuse [1], and there is an urgent need to effectively balance the boundaries between AI assistance and independent thinking. Secondly, confounding factors in the process of task design and process assessment are often overlooked, leading to limited effectiveness in the implementation of teaching strategies [2]. Third, AI technology has lowered the threshold of knowledge acquisition, and the importance of ability cultivation is becoming more and more prominent; the traditional evaluation system overly relies on knowledge assessment and lacks the validation of the synergistic development of students' multidimensional abilities [3]. These problems urgently need to be solved through instructional design innovation.

The structure of this paper is organized as follows: first, a competence-oriented interdisciplinary task-driven teaching framework empowered by AI is proposed, and the design logic and core elements of the framework are systematically elaborated. Second, the information security course is used as a case study to carry out practical verification, analyze the problems encountered in the teaching process, and how to use the framework proposed in this paper to carry out teaching reforms, and conduct a case effect analysis. Finally, the work of this paper is summarized, and future research directions are proposed. This study aims to provide theoretical support and practical examples for the deep integration of AI technology and personalized education, and help to efficiently achieve the goal of talent cultivation in the new era.

II. AI-Enabled Competency-Oriented Interdisciplinary Tracked Task-Driven Instructional Framework

The AI-enabled competency-oriented interdisciplinary split-track task-driven teaching and learning framework is contextualized by hyperdisciplinary integrated education. Integration education is a hyperdisciplinary teaching model driven by complex social problems, which constructs systematic solutions by integrating multidisciplinary knowledge [4]. Teachers design the

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teaching content through the method of transdisciplinary integration design, so that the task design has the attribute of multidimensional competence development. Students complete task learning through the method of hyperdisciplinary integration design to better enhance multidimensional competence.

The framework introduces causality analysis as a method for teaching strategy optimization. Based on the front door criterion in causality science, unobservable confounding variables between the intervening variable and the outcome variable are first identified, and then the influence of confounding variables can be effectively eliminated by setting mediating variables and assessment observation points [5]. Through this method, the interference of confounding variables can be eliminated in advance at the stage of instructional design to ensure the effective implementation of teaching strategies.

AI assumes a dual enabling role in the framework. On the teacher's side, AI assists in completing the design of split-track tasks, realizing an accurate match between task topics and competence orientation; at the same time, with the help of AI's causality analysis, it can improve the optimization efficiency of teaching design. On the students' side, AI can help students shorten the knowledge acquisition cycle and devote more time to multi-dimensional ability cultivation.

The framework implementation process consists of three major parts: sub-track task design, process assessment optimization, and competency evaluation innovation (Fig. 1).

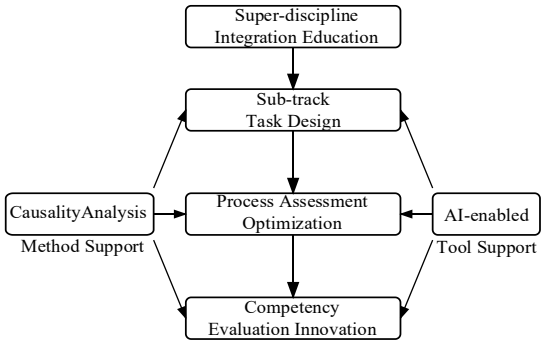

Fig. 1. Flowchart of the framework implementation.

At the stage of task design, based on the background of super-discipline integration education, AI assists in selecting interdisciplinary topics and designing tasks, ensuring that different tasks cover multidisciplinary knowledge and accurately meet the multidimensional ability cultivation needs of students. In the process assessment optimization stage, we focus on the identification of confounding variables in the teaching process, and establish a causal conduction path through the introduction of mediating variables and quantitative assessment observation points, so as to effectively strip away the inhibitory effect of interfering factors on the enhancement of abilities. In the stage of final competence evaluation innovation, we break through the drawbacks of traditional knowledge assessment, and guide students to shift from knowledge memorization to comprehensive competence internalization through an innovative competence-oriented assessment mode.

III. Curriculum Reform Case Studies

A. Split-Track Task Design for Hardware Acceleration of Cryptographic Algorithms

In the teaching of the Information Security course in 2023 at a school, it was found that the examination students had problems with low class participation and insufficient learning. For this reason, the teaching improvement strategy that was applied in the previous year for the graduate school students, i.e., the introduction of cutting-edge topics to design project-based teaching, was migrated to the group of graduate school students in 2024. Meanwhile, the causal analysis revealed that there were two key confounding variables for the exam students compared to the research students, which influenced the effect of the cutting-edge topics on learning outcomes (Fig. 2).

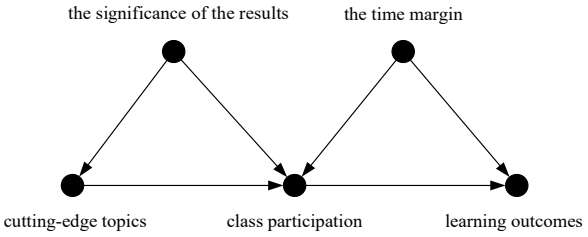

Fig. 2. Cause and effect diagram of students who took the exam.

First, the significance of the results, the opportunity for the examination students to show the results of the program in the review session is significantly less than the formal scene of the summer camp participation of the graduate students, and some of the students do not have enough cognition of the value of the display, resulting in a weak motivation to participate. Second, the time margin, graduate school students need to concentrate on preparing for the examination, and the conflict between course tasks and review time, which limits the time and depth of course tasks.

In order to enhance the adaptability of the migration strategy, the 2024 teaching improvement measures focus on two aspects: first, the content of the cutting-edge topics is set as the practical application of mathematics in cryptography, which strengthens the realistic correlation between the results and the developmental needs of the students; and second, the differentiated division of tasks through the design of supra-disciplinary integration aims at enabling the students to enhance their learning efficiency through the integration of multidisciplinary knowledge and the intersection of competencies. However, the results inferred through the counterfactual in the science of causality show that the enhancement of the learning outcomes of the students who took the exams is only 42% of the enhancement of the students who took the exams in the previous year, which is a significant gap. In-depth analysis showed that the root of the problem was that the task design was not sufficiently aligned with the

goal of supra-disciplinary integration. On the one hand, the improvement measures only target a single group of graduate students, resulting in increased time costs; on the other hand, the cutting-edge topics designed are centered on the application of mathematical knowledge, which involves a single dimension of knowledge domains and ability cultivation, restricting the synergistic development of multidimensional abilities of the students in a limited period.

Therefore, in the 2025 information security curriculum reform, in order to more effectively eliminate the confounding influence of the meaning of the outcomes, it is planned to focus on the cutting-edge topic in the area of cryptographic algorithmic hardware acceleration. This topic requires the integration of three core competency literacies: mathematical competency, hardware implementation competency, and interdisciplinary analysis competency, aiming to enable students to achieve their competency development goals more efficiently through interdisciplinary integration, while enhancing learning motivation. To eliminate the confounding effect of time margin, the split-track tasks are designed for three groups of students with respect to the core competencies required for hardware acceleration of cryptography algorithms. For students with strong mathematical ability or the need for mathematical ability, the mathematical transformation of cryptography algorithms task is set; for experimental talents who are good at hardware practice, the hardware selection task is designed; and for students who pay attention to comprehensive development, such as those who plan to take the examination for public office and the editorial board, the multidisciplinary analysis and discernment task is designed. These three types of tasks not only completely cover the technical chain of cryptography hardware acceleration, but also accurately dock different ability development-oriented student groups, through the design of sub-track tasks and a series of subsequent assessment measures, it is expected to realize the cultivation goal of the synergistic development of students' multidimensional ability.

In the mathematical transformation task, three assessment observation points are designed based on mathematical competence requirements: depth of mathematical theory (A1), bottleneck of the original method (A2), and innovation of the new method (A3). The depth of mathematical theory requires an in-depth understanding of the basic mathematical principles and their core role in the algorithm; the bottleneck of the original method requires the precise identification of the key defects of the original method and its impact on the efficiency of the system; and the degree of innovation of the new method requires the use of mathematical transformation to optimize the design and to evaluate the advantages of the new method in comparison with the original method. Taking the coordinate system transformation as an example, the following two tracks have also been completed, but will not be described for space reasons. The depth of mathematical theory can be reflected in the mastery of the point operation rules of the affine coordinate system and the chi-square coordinate representation principle of the projective coordinate system, as well as the understanding of the mathematical characteristics of the modulo-inverse operation and the multiply-add operation. The bottleneck of the original method can be manifested as the frequent modulo inverse operation in the point-addition operation of the affine coordinate system, which leads to a surge in hardware implementation delay. For example, Eq. (1) calculates the slope, and (x, y) represents the coordinates of the point.

$$\lambda = \frac{y_2 - y_1}{x_2 - x_1} \tag{1}$$

The modulo-inverse computation of the denominator requires hundreds of hardware cycles and becomes a performance bottleneck. The new method, Degree of Innovation, then converts the division to a multiplicative-additive chain by means of a projective coordinate system, e.g., Eq. (2) calculates the slope, and $(X: Y: Z)$ (e.g., $x = X/Z$, $y = Y/Z$) denotes the chi-square coordinates.

$$\lambda = \frac{Y_2 Z_1 - Y_1 Z_2}{X_2 Z_1 - X_1 Z_2} \tag{2}$$

By absorbing the denominator in chi-square coordinates and reconstructing the point operation formula to eliminate the mode inverse operation, meanwhile, using a hardware parallel pipeline to enhance the throughput and significantly reduce the power consumption, to realize the double breakthrough of theoretical innovation and engineering optimization.

In the hardware selection task, three assessment observation points are designed based on the requirements of hardware realization ability: theoretical depth of hardware selection (A4), comparison of technical solutions (A5), and cost scenario analysis (A6). The theoretical depth of hardware selection needs to understand the arithmetic characteristics of the hardware platform and the algorithm adaptation logic; the comparison of technical solutions needs to analyze the performance, resource consumption, and development complexity differences of different solutions; and the analysis of cost scenarios needs to integrate the economic costs and application scenarios, and weigh the technical advantages and deployment feasibility.

In the multidisciplinary analytical thinking task, three assessment observation points are designed based on the demand for interdisciplinary analytical ability: social hotspot relevance (A7), interdisciplinary problem analysis (A8), and comprehensive solution (A9). The relevance of social hotspots requires close attention to the social impact of real events and public concerns; interdisciplinary problem analysis requires the integration of technical, legal, ethical, and other perspectives to analyze the problem; and the comprehensive solution requires the proposal of a systematic strategy that takes into account both technical feasibility and social value.

B. Introducing Process Assessment for Exam Question Design

In the process assessment optimization design, the introduction of exam question design is primarily based on two reasons. First, it requires students to independently design five review questions around the split-tracking task theme, covering core disciplinary knowledge and its engineering applications, while specifying the question logic, assessment dimensions, problem-solving approaches, and grading criteria. This transforms knowledge output into competency development. Second, the confounding factor of learning motivation exists between split-tracking tasks and learning outcomes (Fig. 3a). Traditional assessment models, where process assessments and final exams are disconnected, lead to insufficient student engagement. By establishing exam question design as a mediating variable (Fig. 3b), outstanding classroom presentation topics are integrated into the final exam scope, while abolishing the outdated practice of uniformly distributing review materials. This effectively strengthens intrinsic motivation, eliminates confounding factors, and enhances learning outcomes (Fig. 3c).

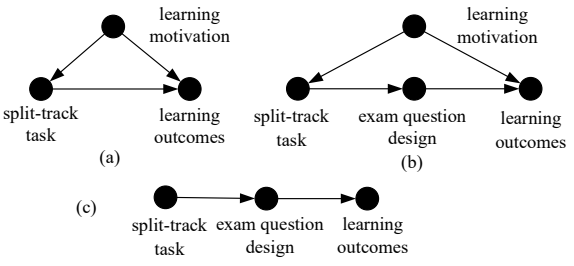

Fig. 3. Cause and effect diagram of exam design.

For the process assessment of examination question design, three assessment observation points are designed: the completeness of examination questions (B1), the relevance of disciplinary core knowledge (B2), and the integration of engineering problems (B3). The completeness of the examination questions requires that the design of the questions cover the complete elements of the question stem, the logic of the questions, the assessment dimensions and the scoring criteria, reflecting the logical self-consistency; the degree of relevance of the core knowledge of the discipline requires that the core theoretical knowledge of the cryptographic algorithms and hardware acceleration of the information security course be closely followed; the degree of integration of the engineering problems requires that the questions be mapped to the practice of complex engineering to check the comprehensive application and problem solving ability of the students.

C. Introduce Role-Playing Process Assessment

In the role-playing process assessment design, we innovatively introduced a group debate mechanism based on controversial social issues, requiring each group to pre-design a structured debate script from disagreement to consensus, designing a process of alternating presentation, cross-examination and common point refinement of the pro and con sides, and recording a group debate video to form a consensus conclusion, with the outstanding works selected for classroom display. This design has a double effect optimization: on the one hand, compared with the limitations of traditional classroom display of works which can only cover a few students, the assessment form of group debate video as a carrier can significantly enhance the breadth of students' participation, and achieve the goal of all-member capacity cultivation under resource constraints; on the other hand, in response to the current dilemma of the failure of the traditional mode of reporting due to the misuse of AI tools, the mandatory exchange of views and consensus building process not only deepens students' understanding of the topic, but also improves students' understanding of the topic and its implications. On the other hand, in view of the current dilemma of the failure of the traditional reporting mode due to the abuse of AI tools, through the mandatory exchange of views and consensus building process, not only to deepen the students' understanding of the connotation of cryptographic algorithms and hardware acceleration technology, but also to systematically train their critical thinking and collaborative integration ability, to effectively achieve the closed-loop of the teaching of the internalization of knowledge and the development of multidimensional capabilities, the cause and effect diagram is shown in Fig. 4.

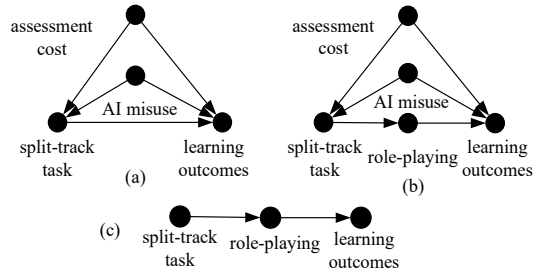

Fig. 4. Role-playing cause and effect diagram.

For the process assessment of the role-play, three assessment observation points were designed: completeness of debate (C1), relevance of social hotspots (C2), and cross-disciplinary relevance (C3). The completeness of the debate requires that the debate process covers the presentation of viewpoints, cross-examination and consensus refinement, and that the logic is rigorous and clear; the relevance of social hotspots requires that the debate should be closely related to controversial real-life technological or ethical issues, and that it should reflect the social concern and value of the event for discussion; and the relevance of interdisciplinary relevance requires that it should integrate the perspectives of multiple fields, such as technological principles, ethical risks, and legal policy, so as to promote students to analyze the issue from multiple perspectives and finally reach a consensus. The interdisciplinary relevance requires the integration of technical principles, ethical risks, legal policies and other perspectives, so as to encourage students to analyze the

issue from multiple perspectives and eventually reach a consensus.

D. Competency Assessment Design

By introducing a mediating variable to eliminate confounding with the appraisal observations, the causal diagram shown in Fig. 5.

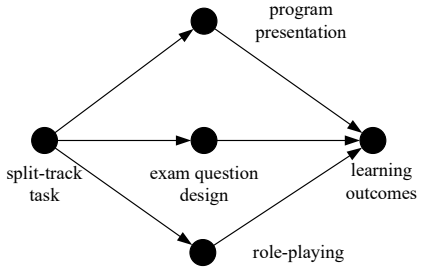

Fig. 5. Final cause and effect diagram.

Prior to the final competency assessment, an optimal group is first evaluated from each of the three tracks of tasks based on all the previously designed assessment observation points, and the specific scoring criteria are as follows. The total task completion score of each group includes the program presentation score A, the examination question design score B, and the role-playing score C. The program presentation score A of the group for the mathematical transformation task is the summation of A1, A2, and A3, similarly, the A for the group for the hardware selection task is the summation of A4, A5, and A6, and the A for the group for the multidisciplinary analytical and discursive task is the summation of A7, A8, and A9. The exam design scores B for all groups were B1, B2, and B3 added together, and the role-playing scores C were C1, C2, and C3 added together.

In the final competency assessment design, in order to comprehensively assess the multidimensional competency of students after learning through the task and to verify the effect of teaching reform, the classroom quiz was used for comprehensive evaluation. First of all, according to the three optimal groups selected above, with reference to their group works, mainly the design content of the examination questions, respectively, the first three questions are set, each accounting for 20% of the total grade of the classroom quiz, although the questions originated from the students' works lead to limitations of the investigation, but they have covered the needs of the three core competencies of mathematical competence, hardware realization ability, and cross-disciplinary analytical ability. In order to break through this limitation and deepen the competency assessment, the fourth question, which accounts for 40% of the total grade of the classroom quiz, was set up, and a metacognitive protocol [6] was innovatively introduced to require students to critically analyze and improve the design of the best works of the first three groups based on the steps of Awareness, Diversification, and Disruption. This design not only strengthens students' critical thinking ability, but also promotes students' deep understanding of the knowledge core and ability logic of the first three questions and the corresponding works of the three groups through reflective learning, which not only makes up for the insufficiency of independent propositioning, but also realizes the synergistic enhancement of multidimensional ability, fully reflecting the comprehensive nature of the goal of teaching reform.

IV. Case Effect Analysis

In order to verify whether the teaching reform measures can promote students' multidimensional competence improvement, this study selected two years of students' task learning ability dispersion for research, 2024 did not adopt personalized split-track task learning, designed for all students the same task, the sample size of 115, the ability score variance of 20.97, 2025 adopted personalized split-track task learning, the sample size of 158, the ability score variance was 10.41. The variance was 10.41. The F-test was used to compare the difference in variance ability scores between the two years, and the F-value was calculated to be 2.01, with degrees of freedom of (114, 157), taking the significance level of $\alpha = 0.05$, and a two-tailed test with a critical value of approximately 1.37. Since the F-value was greater than the critical value of 1.37, the original hypothesis of $p < 0.05$ was rejected, which indicates that the difference in the two years' variance was statistically significant, as shown in Table I.

TABLE I. ANOVA F-Test Results

F-value	Degrees of freedom	α	threshold value
2.01	(114, 157)	0.05	1.37

This result preliminarily confirms that AI-enabled competency-oriented interdisciplinary split-track task-driven teaching significantly reduces the degree of dispersion in students' competency scores, reflecting the positive effect of the teaching strategy on the balanced development of competencies. The split-track task-driven accurately matches students' needs and improves students' classroom participation, while further strengthening students' intrinsic motivation through process assessment and competency assessment, realizing the teaching goal of synergistic enhancement of knowledge internalization and multidimensional competency.

V. Summary and Outlook

Aiming at the current personalized teaching problems, such as single-task design and lagging evaluation system, this paper proposes an AI-enabled interdisciplinary split-track task-driven teaching framework, which accurately matches the students' ability needs through split-track tasks, optimizes the process assessment to eliminate confounding factors, and strengthens the multidimensional ability verification through ability evaluation innovation. At the same time, the information security course is used as a case study for specific program implementation, and the statistical analysis shows that the variance of students' ability scores is significantly

reduced, which verifies the effectiveness of the framework on the balanced development of abilities. In the future, counterfactual inference will be used to deeply analyze the mechanism of action of teaching strategies and promote the continuous optimization of teaching programs.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Yongxiang Yu primarily conducted task and assessment design, Bin Duan mainly provided classroom support and improvement recommendations, and Yao Xiao focused on assisting process implementation and data collection. All authors had approved the final version.

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