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Exploration of the Training Model for Excellent Scientific and Technological Innovation Talents in Software Engineering Bridging Undergraduate and Graduate Studies

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Abstract: Against the backdrop of the digital economy and the construction of emerging engineering disciplines, this paper proposes and constructs a training model for excellent scientific and technological innovation talents, bridging undergraduate and graduate studies in software engineering, characterized by "integrated objectives, project-driven learning, and the integration of science and education." This model aims to cultivate outstanding scientific and technological innovation talents as its overall goal, achieving seamless integration of undergraduate and graduate ability cultivation through the construction of a hierarchical and progressive objective system. It establishes a comprehensive five-level progressive project training system to bridge the gap between undergraduate practice and graduate research, and sets up a deeply integrated mechanism for the collaboration of science, education, and industry to promote the transformation of scientific research and industrial resources into teaching. Additionally, it improves the support system from three aspects: institutional frameworks, evaluation, and incentives. The study also outlines a five-stage practical path: "top-level design–resource integration–pilot operation–comprehensive promotion–dynamic optimization." This model effectively breaks down the barriers between undergraduate and graduate training, strengthens students' scientific research innovation and engineering practice abilities, and provides a replicable practical paradigm for the training of scientific and technological innovation talents bridging undergraduate and graduate studies in engineering disciplines.

Keywords: Bridging undergraduate and graduate studies; Software engineering; Excellent scientific and technological innovation talents; Integrated objectives; Project-driven learning; Integration of science and education

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1. Introduction

Currently, the global digital economy is flourishing, and software, as the core of information technology, is increasingly prominent in its strategic position. With the accelerated iteration of cutting-edge technologies such as artificial intelligence, big data, and cloud computing, the field of software engineering urgently demands "excellent scientific and technological innovation talents" with a solid theoretical foundation, outstanding engineering practice abilities, and strong scientific research innovation qualities. However, examining the current state of higher education in software engineering in China, the traditional segmented training model of "undergraduate education focusing on fundamentals and graduate education focusing on research" has led to fragmented training objectives, disjointed curricula, and discontinuous practical training between undergraduate and graduate levels, forming "barriers between undergraduate and graduate training" that restrict the high-quality development of talents [1,2]. How to break down these barriers and construct a new paradigm of integrated and progressive training for undergraduate and graduate students has become a focal issue in the reform of higher engineering education.

To address this dilemma, the national level has successively issued policy documents such as the *Outline of the Plan for Building a Strong Education Nation (2024–2035)*, explicitly promoting the transformation of talent training models from "segmented implementation" to "integrated training" [3]. The Ministry of Education has also made "integrated undergraduate and master's training" a core reform path in the Excellent Engineer Education and Training Program and the Special Project for the Reform of Engineering Master's and Doctoral Training [4]. In this context, some universities have already initiated pioneering explorations: Peking University has constructed a leading talent training system with deep integration of industry and education [5]; Yunnan University has created a dual-track model of "integrated undergraduate and master's academic chain + industrial practice chain" [6]; Qingdao University has formed a systematic talent training path of "goal-led, platform-supported, and integrated undergraduate and graduate training" [7,8]. These practices provide valuable references for this study, but existing explorations mostly focus on operational aspects such as curriculum connection and academic system integration, lacking a systematic construction plan from goal design, training carriers, integration mechanisms, to support systems [9,10].

Based on this, this study focuses on the software engineering discipline and proposes and constructs a training model for excellent scientific and technological innovation talents, bridging undergraduate and graduate studies characterized by "integrated objectives, project-driven learning, and the integration of science and education." It aims to provide a systematic solution to the problem of fragmented undergraduate and graduate training and offer beneficial references for the reform of bridging undergraduate and graduate studies in other engineering disciplines.

2. Core connotations and basic principles of model construction

2.1. Core connotations

This model takes "cultivating excellent scientific and technological innovation talents in the field of software engineering" as its overall goal and deeply integrates the three core elements of integrated objectives, project-driven learning, and the integration of science and education throughout the entire process of bridging undergraduate and graduate training. These three elements support and empower each other, forming an integrated talent training pattern of "goals leading the direction, projects carrying the training, and the integration of science and education improving quality."

Integrated objectives: Break down the fragmented state of undergraduate and graduate training objectives, formulate staged training objectives that are hierarchical, progressive, and organically connected around the laws of talent growth, clarify the key points of ability cultivation at each undergraduate stage and the graduate stage, and achieve a smooth transition from "foundational talents" to "applied talents" and then to "scientific and technological innovation talents," ensuring that undergraduate and graduate training objectives are aligned, ability requirements are connected, and growth paths are continuous.

Project-driven learning: Take "projects" as the core carrier, construct a progressive project training system throughout the entire undergraduate and graduate stages, integrate curriculum learning, practical training, scientific research innovation, and industrial applications into various projects, allowing students to consolidate their theoretical foundations, enhance their engineering abilities, and cultivate scientific research thinking through project practice, achieving "learning by doing and creating through research," and bridging the gap between undergraduate practice and graduate research.

Integration of science and education: Adhere to the principle of "scientific research nourishing teaching, teaching supporting scientific research, and industry-academia meeting demands," transform the scientific research resources of universities, the research topics of mentors, and the industrial projects of enterprises into teaching resources, promote the integration of scientific research methods, cutting-edge technologies, and industrial demands into undergraduate and graduate curriculum teaching and practical training, and achieve the "integration of teaching and research, theory and practice, and universities and industries," allowing students to enhance their scientific and technological innovation qualities in the process of coming into contact with cutting-edge scientific research and participating in real industrial projects.

2.2. Basic principles

Combining the characteristics of the software engineering discipline and the laws of talent training, bridging undergraduate and graduate studies, the construction and implementation of the model adhere to the following four basic principles to ensure scientificity, systematicity, and adaptability.

Progressive ability development with orderly connection: Based on the cognitive levels and ability foundations of students at different undergraduate and graduate stages, design an ability cultivation system that progresses from low to high levels, ensuring that ability cultivation at the undergraduate stage lays a solid foundation for the graduate stage, and ability cultivation at the graduate stage deepens and enhances that of the undergraduate stage, avoiding knowledge gaps and repetitive ability cultivation.

Integration of learning and application, research and innovation: Closely align with the highly practical nature of the software engineering discipline, integrate theoretical learning with practical application, and merge scientific research training with innovation cultivation, allowing students to deepen their theoretical understanding, master scientific research methods, and enhance their innovation abilities in the process of solving practical problems, achieving the "integration of learning, thinking, and application, and the unity of knowledge, belief, and action."

Resource integration and collaborative education: Integrate resources from multiple parties such as universities, enterprises, and research institutes, and construct a collaborative education mechanism of "university-led, enterprise-participated, and research-supported," achieving curriculum co-construction, platform sharing, faculty interchange, and project co-cultivation, allowing students to come into contact with cutting-edge scientific research achievements and real industrial demands, and broadening their training horizons.

Dynamic optimization and adaptive development: Keep pace with the iterative trends of software engineering technologies and the demands of industrial development, establish a dynamic optimization mechanism, and continuously adjust training objectives, project systems, and teaching content based on the practical effects of training, the dynamics of disciplinary frontiers, and the demands for industrial talents, ensuring that the training model always resonates with the development of the times and industrial demands.

3. Constructing a training model characterized by "integrated objectives, project-driven learning, and the integration of science and education"

This model takes integrated objectives as its top-level design, project-driven learning as its core carrier, and the integration of science and education as its implementation pathway. It constructs a comprehensive system for training excellent scientific and technological innovation talents, bridging undergraduate and graduate studies in software engineering from four dimensions: the training objective system, a progressive project system, an implementation mechanism for the integration of science and education, and a support system. This achieves an integrated advancement of undergraduate and graduate training.

3.1. Constructing a hierarchical and progressive integrated objective system to anchor the training direction for bridging undergraduate and graduate studies

With the overarching goal of "cultivating excellent scientific and technological innovation talents who possess a solid theoretical foundation in software engineering, outstanding engineering practice abilities, strong scientific research innovation capabilities, and a broad industrial perspective, and who can engage in cutting-edge research, technological development, and engineering management in software engineering and related fields," this model formulates staged training objectives that are hierarchical, progressive, and organically connected across three key stages: "lower undergraduate years–upper undergraduate years–graduate stage." It clarifies the knowledge, ability, and quality requirements for each stage, achieving a systematic integration of undergraduate and graduate training objectives. The staged training objectives for the software engineering major are illustrated in **Figure 1**.

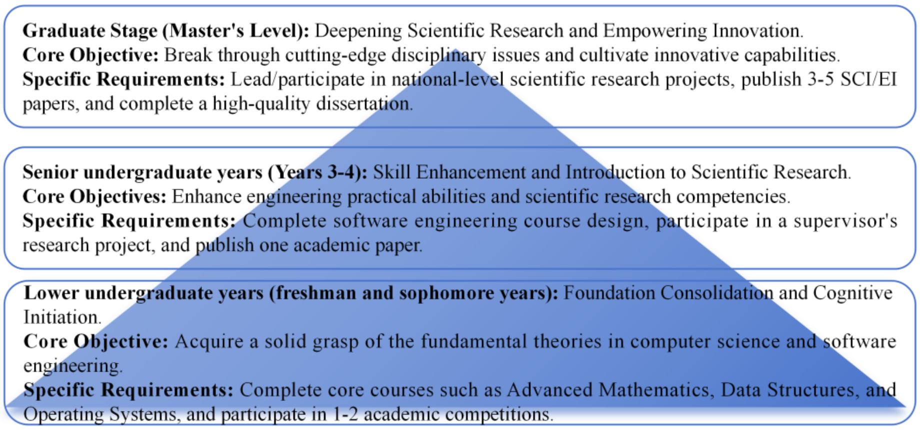

Figure 1. Phased training objectives for the software engineering major

To cultivate outstanding scientific and innovative talents who possess a solid theoretical foundation in software engineering, exceptional engineering practical abilities, strong scientific research and innovation capabilities, and a broad industrial perspective, enabling them to engage in cutting-edge research, technological development, and engineering management in software engineering and related fields.

3.2. Establishing a comprehensive project-driven system and building a practical bridge connecting undergraduate and graduate studies

Centered around “projects,” we aim to break down the barriers between undergraduate and graduate practical training and construct a five-tiered, progressive project training system: “Course Projects–Scientific and Innovation Competition Projects–School-Enterprise Collaboration Practical Projects–Scientific Research Projects–Achievement Transformation Projects” (see **Figure 2**). The difficulty, scale, and innovation level of the projects increase incrementally with the advancement of students’ academic stages, achieving seamless integration between undergraduate and graduate practical training and scientific research innovation. All projects adhere to the process of “theoretical support–practical implementation–scientific research exploration–summary and enhancement,” allowing students to simultaneously improve their knowledge, abilities, and qualities while completing the projects.

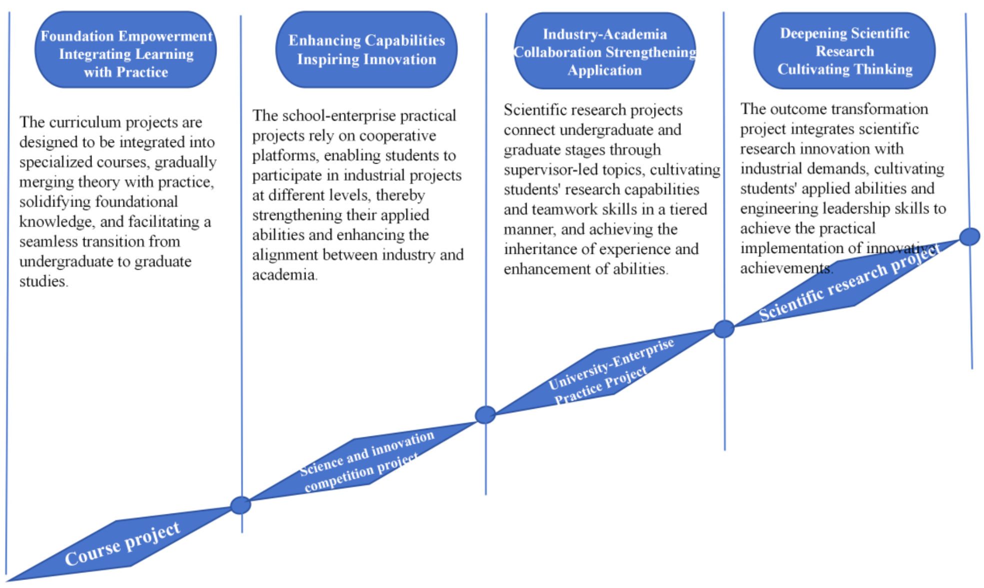

Figure 2. Five-level progressive project training system

The five-level project system progresses layer by layer, with each level interlocking with the next. It is structured with course projects as the foundation, science and innovation competition projects for enhancement, school-enterprise practical projects as a bridge, scientific research projects as the core, and achievement transformation projects for sublimation. This system ensures that students remain in a virtuous cycle of “project practice–ability enhancement–scientific research innovation” throughout their undergraduate and postgraduate studies, thereby establishing a clear pathway from “classroom learning” to “engineering practice” and then to “scientific research innovation.”

3.3. Establishing a deeply integrated implementation mechanism for the integration of science and education to activate the vitality of undergraduate-postgraduate continuum training

Adhering to the principles of “research nurturing teaching and industry-academia alignment with demand,” we have constructed a deeply integrated implementation mechanism for the integration of science and education from four aspects: curriculum system reconstruction, faculty development, platform resource sharing, and teaching method innovation (see **Figure 3**). This mechanism transforms scientific research and industrial resources into teaching resources, promotes the penetration of the integration of science and education, as well as industry and education, into the entire process of undergraduate-postgraduate continuum training, and achieves "teaching with scientific research depth and practice with industrial warmth."

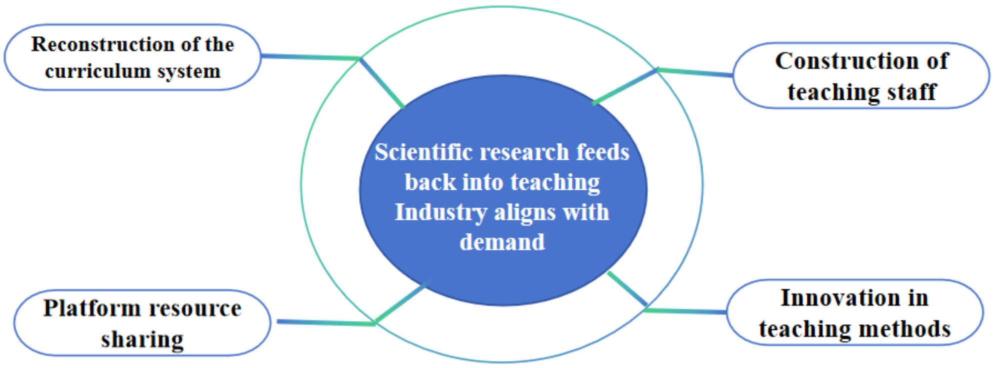

Figure 3. Implementation mechanism diagram for the integration of scientific research and education

(1) Reconstructing an undergraduate-graduate connected curriculum system for the integration of scientific research and education: Guided by the principles of "integrating cutting-edge scientific research into the curriculum and embedding industrial demands into teaching," a three-tier undergraduate-graduate connected curriculum system is established, consisting of the "basic level, enhancement level, and research level," along with a credit mutual recognition mechanism. The basic level solidifies professional foundations and initiates scientific research and industrial awareness; the enhancement level strengthens core competencies and incorporates scientific research projects and industrial initiatives; the research level focuses on cutting-edge research and innovative capacity building, achieving vertical integration of course content and the integration of scientific research and education.

(2) Building a faculty team for the integration of scientific research and education with "university mentors + enterprise mentors": A dual-mentor team is formed, comprising in-house research-oriented mentors and enterprise-based practical mentors, to facilitate faculty exchange and complementary skill sets, thereby achieving collaborative education that deeply integrates scientific research with industrial demands.

(3) Establishing a shared practice platform for the integration of scientific research and education among universities, government, and enterprises: By integrating university laboratories, research platforms, and enterprise engineering practice platforms and technology development platforms, a "Software Engineering Undergraduate-Graduate Connected Practice Platform for the Integration of Scientific Research and Education" is jointly constructed, including university-enterprise joint laboratories, engineering practice education centers, and scientific research innovation centers, among others, to enable shared platform resources among undergraduates and graduates, as well as between universities and enterprises. Graduate laboratories and scientific research innovation centers are opened to outstanding senior undergraduate students, allowing them early access to cutting-edge scientific research equipment and technological tools; enterprise development environments and toolchains (such as

MindSpore, Docker, and cloud-native development platforms) are introduced to the campus, creating a practice environment consistent with that of enterprises, enabling students to complete enterprise-level project development on campus; leveraging the platform, joint undergraduate-graduate scientific research and university-enterprise collaborative project development are conducted, maximizing the utilization of platform resources and providing hardware support for students' project practice and scientific research innovation.

(4) Innovating teaching methods for the integration of scientific research and education through "research-based teaching + project-based learning": The "research-based teaching + project-based learning" approach is innovatively adopted, breaking away from traditional lecture-based models. Research-based teaching cultivates students' scientific research thinking through project exploration, literature discussion, and experimental verification; project-based learning organizes teaching around projects, guiding students to acquire knowledge and skills through practice and enhancing their engineering innovation capabilities, thereby transforming students from passive recipients to active explorers.

4. Improving a multidimensional collaborative support system to safeguard the implementation of undergraduate-graduate connected training

To ensure the effective implementation of the "goal-aligned, project-driven, and research-education integrated" training model, a multidimensional collaborative support system is constructed from three aspects: institutional support, evaluation support, and incentive support, providing systematic and institutionalized support for undergraduate-graduate connected training.

(1) nstitutional support: Improving the management system for undergraduate-graduate connected training

A steering committee for undergraduate-graduate connected training is established, comprising leaders from the university's software college, academic leaders, key faculty members, enterprise technical executives, and education experts, responsible for the overall design, implementation supervision, and optimization adjustments of the training model; management systems such as the "Implementation Plan for Excellent Scientific and Technological Innovation Talent Cultivation in Software Engineering with Undergraduate-Graduate Connection," the "Management Measures for Mutual Recognition of Credits between Undergraduate and Graduate Programs," and the "Implementation Rules for the Dual-Mentor System" are formulated to clarify specific requirements, responsibilities, and implementation procedures for undergraduate-graduate connected training, ensuring orderly conduct of training activities; an organizational structure for undergraduate-graduate connected training is established, clarifying the responsibilities of departments such as teaching, research, and university-enterprise collaboration to achieve coordinated cooperation among departments.

(2) Evaluation support: Establishing a comprehensive evaluation system with multiple links

Breaking away from the single evaluation model based solely on scores and papers, a comprehensive evaluation system (see **Figure 4**) is constructed with "multiple indicators, process-based evaluation, undergraduate-graduate connection, and university-enterprise collaboration" to comprehensively measure students' knowledge, abilities, and qualities, with evaluation results serving as important references for students' advancement to graduate studies, merit awards, and project participation during the undergraduate-graduate phase.

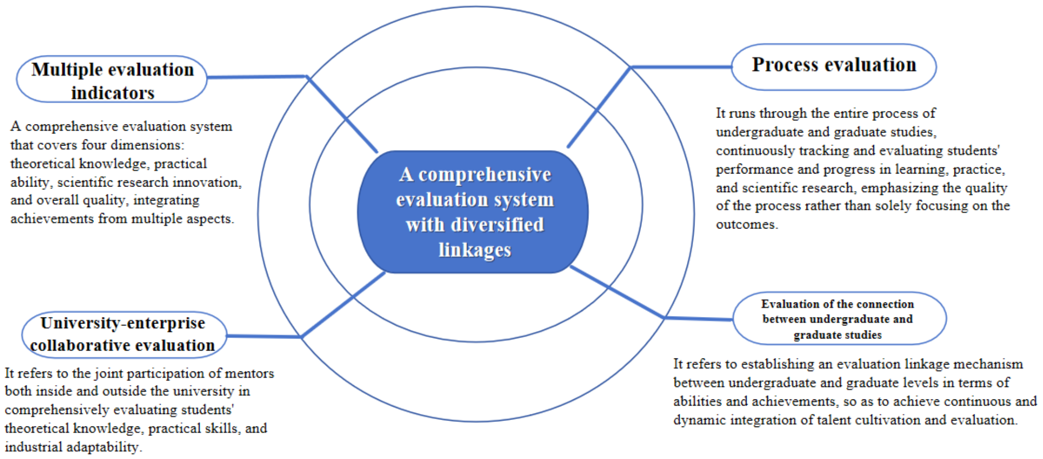

Figure 4. A comprehensive evaluation system with diversified linkages

The comprehensive evaluation system with diversified linkages aims to break away from a single evaluation model by constructing multiple evaluation indicators. It incorporates multidimensional performances such as theoretical knowledge, practical abilities, scientific research innovation, and overall qualities into the evaluation scope. This system implements process-oriented evaluation, tracking and assessing students' course learning, project practices, and scientific research training throughout their entire undergraduate-to-graduate journey. It strengthens the evaluation of undergraduate-to-graduate transitions by using undergraduate ability evaluation results as a basis for graduate student selection and cultivation, and linking graduate achievements with undergraduate cultivation outcomes. Additionally, it introduces collaborative evaluation involving schools and enterprises, where both internal and external mentors participate in the evaluation from different professional perspectives, thereby comprehensively and objectively measuring students' knowledge, abilities, and qualities.

(3) Incentive and support mechanisms: Establishing a multi-party linked incentive system

Establish a multi-party linked incentive system targeting students, teachers, and enterprises (see **Figure 5**) to fully mobilize the enthusiasm and initiative of all parties involved in undergraduate-to-graduate transition cultivation.

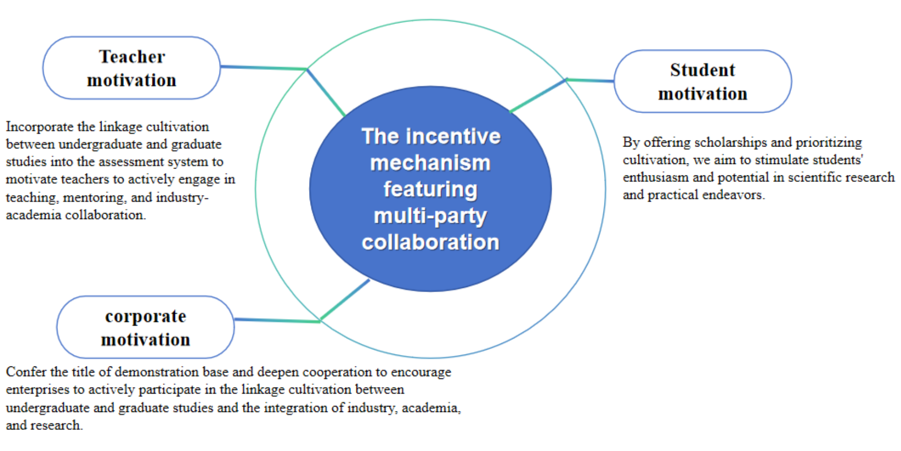

Figure 5. Multi-party collaboration incentive mechanism

An incentive mechanism featuring school-enterprise collaboration and multi-party collaboration should be established to stimulate the joint participation of students, teachers, and enterprises in the integration of undergraduate-graduate cultivation and industry-academia-research collaboration through scholarships, assessment rewards, and the awarding of demonstration base plaques.

5. Practical path of the cultivation model

Based on the actual situation of software engineering program at Dalian Jiaotong University, this study plans to systematically advance the implementation of the "goal integration, project-driven, and science-education integration" cultivation model in five stages: "top-level design–resource integration–pilot operation–comprehensive promotion–dynamic optimization," ensuring that the model can be scientifically implemented, gradually improved, and ultimately achieve the expected goals.

(1) Top-level design stage: The Undergraduate-Graduate Integrated Cultivation Steering Committee is proposed to take the lead in conducting systematic research on advanced cases of undergraduate-graduate integrated cultivation in software engineering, both domestically and internationally. Based on the university's disciplinary characteristics, faculty strength, and school-enterprise cooperation resources, a detailed cultivation implementation plan will be formulated. The plan will clarify the cultivation objectives, construct a project system, design a science-education integration mechanism, and plan safeguard measures, thereby establishing an overall framework for undergraduate-graduate integrated cultivation.

(2) Resource integration stage: It is planned to integrate internal university resources such as courses, faculty, laboratories, and scientific research projects to achieve efficient sharing of undergraduate-graduate resources. Simultaneously, cooperation with leading enterprises such as Huawei, Chinasoft International, and Neusoft Group will be deepened to jointly establish school-enterprise joint laboratories and practice platforms, introducing resources such as real enterprise projects, faculty, and advanced toolchains. Additionally, a dual-tutor team consisting of internal university tutors and enterprise tutors will be formed, and special faculty training will be conducted to enhance the tutors' abilities in undergraduate-graduate integrated teaching and project guidance.

(3) Pilot operation stage: It is proposed to select outstanding undergraduate students in their sophomore or junior years and new graduate students from the software engineering program to form a pilot class. Pilot teaching will be carried out strictly in accordance with the established cultivation implementation plan. During the pilot period, a dual-tutor system will be implemented, a five-level progressive project training will be promoted, and undergraduate-graduate integrated courses featuring science-education integration will be offered. Meanwhile, the improvements in the pilot students' learning outcomes, project practice abilities, and scientific research and innovation abilities will be tracked in real-time. Feedback from students, teachers, and enterprises will be collected to optimize the cultivation plan in a timely manner.

(4) Comprehensive promotion stage: After gaining experience and achieving results from the pilot operation, the cultivation implementation plan and management system will be further improved based on the problems identified during the pilot process. Subsequently, it is planned to extend the cultivation model from the pilot class to all undergraduate and graduate students in the software engineering program, ultimately achieving the normalized operation of undergraduate-graduate integrated cultivation. At the

same time, the core concepts and practical experience of this model will be extended to related majors such as artificial intelligence and big data technology, forming an educational pattern of "promoting overall development through key points."

(5) Dynamic optimization stage: Relying on the established comprehensive evaluation system, a comprehensive assessment of the implementation effects of the cultivation model will be conducted regularly. Based on the iterative trends of software engineering technology, changes in industrial talent demands, and feedback from cultivation evaluations, the cultivation objectives, project system, course content, and science-education integration mechanism will be continuously optimized to ensure that the cultivation model remains aligned with the times and industrial demands.

6. Conclusion

In response to the fragmented cultivation paradigm of traditional undergraduate-graduate education, this paper deeply integrates the three core elements of goal guidance, project carriers, and science-education integration, forming a systematic solution of "goal-path-mechanism-safeguard" that effectively fills the research gap in undergraduate-graduate integrated cultivation models in the field of software engineering. The implementation of this model is expected to significantly strengthen students' scientific research and innovation abilities and their abilities to solve complex engineering problems, improve the overall quality of software engineering talent cultivation, and provide useful references and replicable practical paradigms for other engineering majors to carry out undergraduate-graduate integrated scientific innovation talent cultivation.

In the future, we will conduct pilot applications in the software engineering program based on the practical path proposed in this paper, continuously testing and improving each link of the cultivation model through practice. At the same time, we will further explore new models of interdisciplinary undergraduate-graduate integrated cultivation and deepen international cooperation and exchanges to cultivate more outstanding software engineering talents with an international perspective and competitiveness, providing solid talent support for the high-quality development of China's digital economy.

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Disclosure statement

The authors declare no conflict of interest.

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