Deepening the Integration of Science and Education to Cultivate Future Leaders in Science and Technology (Postprint)

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Abstract

The new era has set forth new and higher requirements for innovation and entrepreneurship talents regarding moral character, knowledge structure, and professional competence. Against this backdrop, global practices in cultivating such talents demonstrate emerging trends including the convergence of multidisciplinary intersections, integrated and fused cultivation processes, open collaboration among multiple stakeholders from education, research, and industry, and empowerment through digital transformation. Building on the Chinese Academy of Sciences' strengths in innovation and entrepreneurship education, the University of Chinese Academy of Sciences conducts in-depth research into the cultivation patterns of high-caliber innovation and entrepreneurship talents, particularly science and technology leadership talents. The university actively explores new models and pathways for talent cultivation through education-research integration, including innovations in cultivation and organizational models, reform of the curriculum and teaching system, improvement of the "Grand Ideological and Political Education" work system, as well as ideas and measures for strengthening faculty development to support talent cultivation goals.

Full Text

Preamble

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Deepening Integration of Research and Education, Cultivating Future Leading Talents in Science and Technology

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The new era has imposed new and higher demands on innovative and entrepreneurial talents in terms of moral character, knowledge structure, and professional competence. Against this backdrop, global practices in cultivating such talents are evolving toward several key trends: the convergence of multiple disciplines, integrated and coherent training processes, open collaboration among education, research, and industry stakeholders, and empowerment through digital transformation. Leveraging the Chinese Academy of Sciences' (CAS) distinctive strengths in innovation and entrepreneurship, the University of Chinese Academy of Sciences (UCAS) has undertaken in-depth research into the cultivation patterns of high-quality innovative talents, particularly leading scientific and technological talents. The university is actively exploring new models and pathways for talent cultivation through the deep integration of research and education, focusing on innovations in training and organizational models, reforms to curriculum and teaching systems, and the improvement of comprehensive ideological and political education frameworks, all while strengthening faculty development to support these educational objectives.

Keywords: University of Chinese Academy of Sciences (UCAS), integration of research and education, leading talents in science and technology, talent cultivation model

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Abstract: The new era has put forward new and higher requirements for innovative talents in terms of their moral qualities, knowledge structure, and professional abilities. In this context, the practice to cultivate innovative talents in science and technology world-wide has presented new trends, including multidisciplinary collaborations, coherent processes, open coordination among education, research and industry sectors, and empowerment through digital transformation. Relying on the advantages of the Chinese Academy of Sciences (CAS) in scientific and technological innovation, University of the Chinese Academy of Sciences (UCAS) is exploring educational laws to cultivate high-quality innovative and entrepreneurial talents, especially leading talents in science and technology, actively searching for a new path and mode of talent cultivation through the integration of research and education, in respect to creating organizational models, reforming curriculum and teaching systems, and

improving ideological and political work, and faculty development to achieve its educational goals.

The world today is undergoing unprecedented changes not seen in a century, with accelerating evolution in the global landscape. Issues such as pandemic prevention and control, geopolitical conflicts, food security, and climate change have intensified global instability, while competition and cooperation among major powers in economy, science and technology, military, and culture are taking on new dimensions. Simultaneously, a new round of scientific and technological revolution and industrial transformation is deepening. Breakthroughs in key core technologies and disruptive innovations, grounded in original research, are continuously expanding new frontiers and opening new tracks, becoming strategic high ground in great power competition. Talent lies at the core of this competitiveness. Meanwhile, the rapid development of artificial intelligence is accelerating the transformation of research paradigms and fundamentally reshaping human production and lifestyles. All these developments pose new challenges and demands for cultivating innovative and entrepreneurial talents, particularly leading scientific and technological talents. China's higher education must not only meet the urgent needs for talent in key domains but also adopt forward-looking and systematic planning to cultivate future scientific and technological leaders and a large cohort of high-quality innovative talents who can spearhead the building of a strong science and technology nation. This requires assessing new trends in talent cultivation and actively exploring new models.

New Requirements and Trends for Future Innovative Talent Cultivation

New Requirements for Future Innovative and Entrepreneurial Talent Cultivation Today's world is experiencing profound transformations characterized by complexity, volatility, uncertainty, and ambiguity, with complex common challenges awaiting solutions. Great power competition demands more original, disruptive, and breakthrough innovations that can be rapidly transformed into industrial advantages. The deep interaction and accelerated co-evolution of scientific revolution and industrial transformation have given rise to obvious trends of interdisciplinary integration in scientific research and innovation development, significantly shortening innovation chains. Large-scale, cutting-edge scientific research and technological breakthroughs require division of labor and cooperation across disciplines, organizations, industries, and regions [1]. The development of new-generation artificial intelligence is accelerating the transformation of research paradigms. These trends have imposed new and higher requirements on future innovative and entrepreneurial talents in terms of ideals and convictions, spiritual qualities, knowledge structure, thinking ability, and digital literacy.

In terms of ideals, beliefs, and spiritual qualities, future innovative and entrepreneurial talents must possess profound patriotism, a strong sense of mission, and awareness of a global community with a shared future, along with international vision and global competence. The complexity of research problems and the uncertainty of scientific exploration require these talents to have self-confidence and perseverance. Given that all-round development forms the foundation for sustainable innovation, humanistic literacy, aesthetic appreciation, and physical health all serve to empower their innovative and creative capabilities.

Regarding interdisciplinary knowledge and thinking ability, future talents must not only master deep knowledge in a single discipline but also possess a convergent knowledge vision, familiar with research paradigms and languages across multiple disciplines, and capable of integrating theory with practice to identify and solve problems from complex phenomena. Original innovation requires curiosity, an exploratory spirit, and critical thinking—the ability to step outside cognitive frameworks, make bold hypotheses, and grow into innovators through the joy of discovering nature's mysteries.

In digital literacy, future innovative and entrepreneurial talents must rapidly adapt to the disruptive changes brought by surging artificial intelligence to human production, life, learning, and research, exploring scientific laws through new paradigms. For scientific and technological leaders, strategic thinking, systematic thinking, decision-making judgment, resource integration ability, and leadership are particularly essential [2].

Emerging Trends in Innovative Talent Cultivation In response to these new requirements, higher education worldwide is undergoing reforms that reveal several common trends. First, talent cultivation pathways are shifting from single-discipline approaches to multidisciplinary convergence. Discipline construction forms the foundation of talent cultivation. In the new era, disciplinary differentiation and integration proceed in parallel, with increasingly close connections between higher education reform and economic-social development. To cultivate future innovative talents, universities must coordinate basic disciplines, applied disciplines, and emerging interdisciplinary fields to promote disciplinary convergence. This requires adjusting traditional linear, discipline-based organizational structures and adopting matrix and network organizational forms that combine physical and virtual elements to achieve cluster development of disciplines and majors.

Second, fragmented talent training processes are transitioning toward integrated and coherent models. The training process is key to achieving cultivation goals. In response to new requirements for future innovative talents, the international higher education community is beginning to focus on coherent training stages, conducting systematic planning and top-level design across curricula, teaching, research training, internships, and quality assurance.

Third, the closed separation among education, research, and industry is transforming into multi-stakeholder open collaboration. High-level innovative talent cultivation requires high-quality scientific research [3]. Currently, the innovation chain from original research to industrial application has significantly shortened, and the research path of identifying important scientific questions from industrial development has become increasingly important. This demands breaking down the closed separation among education, research, and industry to build an open, shared, and collaborative education system that deepens the integration of research and education and industry and education, forming a coherent training system that integrates coursework, research practice, and internships to cultivate innovation and entrepreneurship capabilities [4].

Fourth, traditional classroom teaching models are shifting toward digital empowerment. The rapid development of new-generation artificial intelligence challenges traditional teaching and learning content and methods, making digital transformation a crucial force for reforming future innovative talent cultivation models. In this strategic action, teachers serve as the bridge and key link between education and digital technology [5], requiring universities to empower faculty with core competencies for educational digital transformation.

UCAS's Exploration in Cultivating Future Innovative Talents through Research-Education Integration

Facing the talent needs for building a world science and technology power, UCAS will focus on the goal of "taking the lead in building a national innovative talent highland" and actively explore new models for cultivating high-level innovative talents.

Innovating Talent Cultivation Models for Categorized Development
UCAS will explore cultivation models for scientific and technological leaders under a new national system, following the patterns and requirements of different types of scientific talent. By leveraging major missions to pool resources and through systematic institutional design for research-education integration, UCAS will transform the advantages of organized research—featuring large tasks, large platforms, and large teams—into advantages for high-level talent cultivation. This will enable future scientific and technological leaders to continuously emerge from large-scale, cross-disciplinary, cross-organizational, and cross-regional innovation and entrepreneurship activities, with the elite among them growing into strategic scientists through "large-scale collaborative combat" in major mission research.

Inheriting CAS's tradition of "using tasks to drive disciplines," UCAS will construct talent training sequences in fields such as carbon neutrality, deep space and deep-sea exploration, aerospace engineering, new materials, new energy, integrated circuits, artificial intelligence, and cybersecurity, driven by major missions. Through frontier technology forecasting and mission analysis, the university will establish an interdisciplinary, cross-industry, cross-organizational

multi-stakeholder governance system for talent cultivation, coordinating and implementing training programs, evaluation systems, support conditions, and collaboration mechanisms for different sequences.

Deepening Industry-Education Integration through Major Projects Project-based learning is crucial for cultivating outstanding engineering and technical talents. Under the joint guidance of mentor teams, students "learn by doing," strengthening engineering and technical capabilities through integrating theory with practice. Meanwhile, through various forms and channels such as elective courses, minor degrees, and certificate programs, UCAS supports students in personalized expansion of knowledge domains based on their interests and abilities, fostering transferable competencies and comprehensive quality enhancement. The university will improve the precision of talent cultivation for industry needs, overcome potential constraints in project-based training, and enhance students' innovation and entrepreneurship capabilities.

Connecting Educational Stages for Long-Term, Personalized Cultivation UCAS will break barriers between basic and higher education by extending its rich research-education resources to primary and secondary schools, opening laboratories to teachers and students, organizing summer schools, and encouraging faculty and graduate students to participate in science education at the K-12 level. Concurrently, the university will utilize research findings from cognitive science and psychology to identify, select, and cultivate gifted and highly motivated secondary school students. On the other hand, leveraging its abundant research-education resources and large mentor pool, UCAS will achieve integrated cultivation across "undergraduate—doctoral student—special research assistant" stages. While building an independent talent cultivation system, the university will emphasize deep internationalization, develop localized international programs, improve flexible talent introduction mechanisms, and create a diverse and open educational ecosystem. By establishing stable support and incentive mechanisms, providing a relaxed research environment, and improving evaluation systems, UCAS will ensure that "extraordinary," "specialized," and "unconventional" talents are not overlooked, promoting early identification and cultivation of top innovative talents so they can grow into future scientific and technological leaders through sustained high-level innovative practice.

Exploring New Organizational Models for Education UCAS will inherit CAS's tradition and advantage of using major missions as drivers to conduct organized research and talent cultivation in an institutionalized manner. Relying on major platforms such as comprehensive national science centers and national key laboratories, the university will gather and cultivate future scientific and technological leaders through multidisciplinary and multi-institutional integration.

Building Research-Education Communities Based on Physical Na-

tional Science Centers. UCAS will establish isomorphic research-education communities based on national science centers and other major platforms to further promote interdisciplinary integration, faculty merging, and cultivation model innovation, exploring new models for cultivating scientific and technological leaders through high-level innovation practice. Taking the Material Science Center at the Beijing Huairou Comprehensive National Science Center as an example, it brings together multiple related disciplines including physics, chemistry, nuclear science and technology, materials science and engineering, and environmental science and engineering, gathering several CAS institutes such as the Institute of Physics, Institute of Chemistry, and Institute of High Energy Physics. UCAS will explore building a research-education community based on this material science center, establishing a new educational governance system with specialized committees for admissions, teaching, degree preliminary review, and student affairs, integrating resources from all participating parties, and constructing unified and efficient operational mechanisms to form an interdisciplinary talent cultivation organizational model and sequence based on major scientific research tasks in the material science field.

Establishing Discipline Alliances to Create Virtual Research-Education Communities. Targeting major common scientific problems and talent needs in specific fields, UCAS will unite relevant universities and research institutions to aggregate resources scattered across different regions, industries, and organizations, building virtual platforms to drive interdisciplinary discipline construction and talent cultivation through organized research. Taking planetary science as an example, in 2019, UCAS, as the initiator and leading unit, jointly established the Chinese University Planetary Science Alliance with 27 domestic universities to address important issues in planetary science talent cultivation, frontier research, and development strategy. In the future, UCAS will further pool platforms and resources from all parties, using major missions such as deep space exploration as talent cultivation units to nurture future scientific and technological leaders and strategic scientists through organized collaborative research.

Integrating Social Resources to Advance Deep Industry-Education Integration. UCAS will target major urgent needs for national industrial security, pool multi-party forces, and deepen industry-education integration to cultivate innovative and entrepreneurial talents capable of leading complex engineering projects and driving industrial transformation. Focusing on core technology breakthroughs in key national fields, the university will establish specialized integrated industry-academia-research platforms with leading technology enterprises, exploring new multi-stakeholder collaborative education models to promote deep integration of innovation chains, industrial chains, and value chains. Jointly developing "order-based" training programs with industry leaders will significantly enhance students' technological innovation and engineering practice capabilities for solving complex problems, achieving batch production of personalized outstanding engineering talents.

Deepening Curriculum and Teaching Reform to Support Holistic Student Development

Curriculum and teaching constitute crucial aspects of talent cultivation. UCAS will continuously explore curriculum system reforms, develop high-quality teaching materials, promote diversified teaching methods, break temporal and spatial boundaries, and create an all-time, all-space educational ecosystem to strongly support the cultivation of future innovative talents' competencies and qualities.

Deepening Curriculum Reform to Build a "Five-Dimensional Education" System. UCAS has long built a curriculum system oriented toward meeting students' needs for cross-college, cross-disciplinary, and on-demand course selection, comprising core professional courses, general courses, seminars, and science frontier lectures, supplemented by advanced intensive courses and summer lecture series. Looking ahead, UCAS will reform and innovate course content and forms to create a "five-dimensional education" curriculum system . The university will strengthen connections between graduate and upper-level undergraduate courses, explore diversified curriculum plans, break semester restrictions, and achieve personalized precision teaching. It will enhance the value-leading role of moral education courses, strengthen physical education, improve the quality of public courses on excellent cultural heritage, aesthetic appreciation, and classical education, and integrate creative labor with professional and innovation-entrepreneurship courses.

Advancing "New Infrastructure for Education" to Accelerate Digital Transformation. UCAS will high-quality promote the construction of digital teaching scenarios including smart classrooms, libraries, and laboratories, create integrated media platforms, break spatial-temporal limitations, and foster a learning environment accessible anytime and anywhere. The university will enhance teachers' ability to apply new educational technologies and cultivate students' autonomous learning capabilities. By coordinating multi-party research-education resources, UCAS will achieve remote synchronous classrooms and sharing of high-quality courses, providing rich and diverse digital research-education resources to promote holistic student development.

Accelerating Development of High-Quality Textbook Systems with Chinese Characteristics. Committed to vigorously developing teaching materials, UCAS has had multiple textbooks adopted as primary course materials by numerous universities and won several awards. For example, *Introduction to Cryosphere Science* won the first National Excellent Textbook Special Prize. In the future, UCAS will establish school- and college-level textbook research bases, focusing on national core textbooks, basic discipline classics, interdisciplinary and emerging discipline characteristic textbooks, and new-form textbooks integrating information technology, strictly controlling political and academic standards to form a high-quality, multi-disciplinary, multi-variety Chinese characteristic textbook system centered on high-quality graduate textbook series.

Improving the "Great Ideological and Political Education" System to Cultivate Students with Core Socialist Values

To answer the fundamental educational questions of "for whom to cultivate, what kind of people to cultivate, and how to cultivate them," UCAS will deepen student ideological and political education, striving to cultivate and practice core socialist values and consolidate students' ideals and convictions.

Improving the "Great Ideological and Political Education" Institutional Mechanism. Under the unified leadership of the CAS Party Group, UCAS will effectively play the role of Party committee leadership and student Party organizations and members, continuously strengthening the "Great Ideological and Political Education" system covering centralized teaching and research training processes. The university will improve evaluation systems, strengthen full-time counselor and part-time ideological-political work teams, enhance the construction of research-ideological-political systems, and form a clear responsibility, effective university-institute "Great Ideological and Political Education" closed-loop work system. Meanwhile, it will coordinate the synergistic efforts of ideological-political courses and "curriculum-based ideological-political education," integrating ideological-political course content, innovating teaching methods, optimizing textbook systems, and strengthening ideological-political teaching faculties. The university will also formulate implementation plans for "curriculum-based ideological-political education," improve assessment and supervision mechanisms, and integrate ideological-political construction into classroom teaching.

High-Quality Development of "Large Campus" Cultural Construction. UCAS will continuously explore effective paths of "cultivating people through culture." The university will strengthen coordination between campus and institute youth leagues, enhance cultural and sports activity platforms, create cross-organizational and cross-regional academic exchange and cultural activity brands, and organize diverse activities. It will jointly build labor education practice bases with institutes and conduct diversified scientific research labor practices through mentors and research teams. By enriching excellent traditional culture courses and lectures and leveraging cultural construction sites such as the "CAS and 'Two Bombs, One Satellite' Memorial Hall," UCAS will inherit and promote excellent traditional Chinese culture and the "Two Bombs, One Satellite" spirit and scientist spirit, strengthen innovative campus culture, cultivate students' innovation and entrepreneurship awareness, and continuously enhance cultural confidence among faculty and students.

Strengthening Faculty Development to Consolidate the Foundation for Talent Cultivation

UCAS will focus on talent cultivation needs, gather high-level faculty globally, improve faculty development systems, strengthen talent evaluation and incentive mechanisms, and build a new-era faculty team that integrates "professional

expertise" and "moral integrity," providing strong support for cultivating future innovative and entrepreneurial talents.

Multiple Measures to Gather First-Class Faculty. UCAS will widely attract top global scientists and outstanding young talents, gathering a high-level faculty team combining research-education integration, enterprise-education integration, and full-time and part-time members. The university will strengthen the special research assistant system, making postdoctoral and full-time research positions important channels for gathering, cultivating, and selecting young talents, achieving dual improvement in "quality" and "quantity" to build a talent pipeline. It will improve flexible talent introduction mechanisms and promote close integration between mobile talent pools and faculty development.

Improving a "Full-Cycle, Full-Coverage, Categorized and Layered, Personalized" Faculty Development System. UCAS will establish sound dynamic adjustment mechanisms for full-time faculty positions and mentor selection and appointment systems. The university will implement a series of talent cultivation programs, promote advisory systems for young teachers, accelerate the cultivation of scientific and technological leaders and high-level innovation teams, and establish a world-class faculty with reasonable structure. It will promote faculty research on talent cultivation patterns, enhance the systematicness and effectiveness of mentor training, establish master teacher cultivation programs, strengthen consciousness of moral cultivation, and improve teaching and mentoring levels.

Improving Talent Evaluation, Incentive, and Service Guarantee Systems. UCAS will highlight moral cultivation effectiveness, establish multidimensional evaluation systems, deepen categorized evaluation, and comprehensively consider faculty performance, contributions, and academic impact in serving national major strategies. The university will also incorporate teaching quality, textbook compilation, education research, and talent cultivation effectiveness as important indicators. By optimizing resource allocation and fully mobilizing teacher enthusiasm, UCAS will explore establishing evaluation and appointment systems for "teaching-oriented" faculty. The university will vigorously address research platform construction for introduced talents and adopt various measures to solve talent concerns, enabling them to focus on research and education.

Conclusion

Facing the world's profound changes, China's urgent demand for high-level innovative and entrepreneurial talents continues to grow. UCAS will further research the growth patterns and cultivation models of scientific and technological leaders and high-quality innovative talents. Continuing to be oriented toward serving national strategic needs and relying on CAS's strong research capabilities and distinctive research-education integration system, UCAS will explore new pathways and models for efficiently transforming national first-class research

platforms, talent teams, and research achievements into educational resources through multi-stakeholder collaborative construction. The university is committed to promoting educational development, driving scientific and technological innovation, accelerating talent aggregation, cultivating future scientific and technological leaders and high-quality innovative talents with both moral integrity and professional competence, and building a national innovative talent highland and a world-class university with unique characteristics.

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"Five-dimensional education" refers to the comprehensive development of moral, intellectual, physical, aesthetic, and labor education.

"Three-all education" refers to all-personnel, whole-process, and all-round education.

Note: Figure translations are in progress. See original paper for figures.