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Artificial Intelligence Empowers Botany Field Course in Higher Education: Model Exploration and Practical Pathways

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Abstract: With the in-depth advancement of the educational digitalization strategy, artificial intelligence (AI) technology provides crucial support for the reform and innovation of botany internship teaching in higher education. Focusing on the theme of "AI empowering botany field course," this paper systematically explores the application models and practical pathways of AI technology in botany field course. It analyzes the limitations of traditional botany field course in terms of teaching content, resources, methods, and assessment, and elaborates on how AI technology, through various forms such as intelligent recognition, knowledge graphs, virtual simulation, electronic specimens, QR code learning, and intelligent assessment, promotes the transformation of botany internship teaching towards intelligence, personalization, and efficiency. Drawing on practical cases from multiple universities, the paper summarizes the implementation pathways and principles of AI-empowered botany field course and analyzes its role in enhancing teaching effectiveness, optimizing resources, and reforming assessment. Simultaneously, it points out current challenges in AI application, including high student dependency, insufficient teacher digital literacy, and high technical costs, proposing corresponding solutions. Future development directions involving multi-technology integration and adaptive learning systems are also discussed. Research indicates that the deep integration of AI technology and botany field course helps construct a new internship teaching model characterized as student-centered, combining virtual and real experiences, and fully intelligentized throughout the process, providing theoretical reference and practical guidance for the digital transformation of botany practical teaching in higher education.

Keywords: Artificial Intelligence, Botany Internship, Digitalized Teaching, Practical Pathway, Teaching Model.

1. Introduction

Botany internship, as a vital and essential practical course, plays an extremely important role in the teaching process of various disciplines such as botany, horticulture, forestry, and ecology. It aims to cultivate students' ability to integrate theory with practice and develop professional skills primarily through field observation, specimen collection and preparation, and plant classification and identification. However, traditional botany internship teaching has long faced numerous challenges: Firstly, the teaching content is significantly constrained by geography and season, making it difficult to ensure the diversity and representativeness of plant species students encounter. Secondly, teaching resources are scarce, with teaching aids and tools (specimens, equipment) being outdated and insufficient to meet practical needs. Thirdly, teaching methods are singular, predominantly following a "teacher explanation - student recording" pattern, which fails to fully stimulate students' initiative in learning and exploratory interest. Fourthly, assessment methods overemphasize outcomes, neglecting the comprehensive evaluation of students' learning processes and ability development [1].

With the in-depth advancement of the educational digitalization strategy, artificial intelligence technology provides a significant opportunity for the reform and innovation of botany internship teaching. AI possesses technical advantages such as image recognition, big data analysis, and virtual simulation, which can effectively break through the temporal, spatial, and resource limitations of traditional internships. Through intelligent recognition, personalized recommendation, and whole-process tracking, AI can drive systematic changes in the content, methods, and assessment mechanisms of botany field course [2, 3]. In recent years, an increasing number of universities have attempted to introduce AI into course teaching, achieving notable results in various disciplines [4-6]. However, in the field of botany field course, existing explorations mostly focus on the application of technical tools [7-10], lacking systematic innovation at the teaching model level, thus failing to fully leverage AI's overall empowering effect on internship teaching. Therefore, based on practical cases from multiple universities, this paper systematically explores the integration pathways and innovative models of AI in botany field course. It aims to construct a new internship teaching model that is student-centered, combines virtual and real experiences, and is fully intelligentized throughout the process, from the perspectives of teaching philosophy, implementation pathways, and evaluation systems. This provides theoretical support and practical reference for promoting the digital transformation and upgrading of botany practical teaching.

2. Exploration of Application Forms of Ai Technology in Botany Field Course

2.1. Exploration of Intelligent Recognition Tools in Plant Classification

Plant classification and identification are key focuses of botany field course. Traditionally reliant on teachers' accumulated expertise and practical experience, the learning process can now be augmented by using image recognition

APPs based on deep learning, such as "Flower Companion," "Xingse," "Baidu Image Search," etc. [11]. Additionally, professional software like Biotracks is an important means to help students complete plant observations and record relevant data [1]. Students can use their mobile phones to photograph representative structures of plants, such as flowers, fruits, and leaves, and immediately obtain possible species identifications and learn about key taxonomic characteristics, achieving the simple goal of "identifying objects by photograph."

Based on this, a progressive learning procedure of "Intelligent Recognition - Authoritative Verification - Manual Judgment" can be established: Use APPs like "Flower Companion" or "Xingse" for rapid plant identification on campus and in the field, and use professional software like Biotracks to record plant habitat and distribution data; subsequently, guide students to use authoritative databases like "iPlant.cn" to compare and verify identification results, forming a dual mode of "technology-assisted, human-judged" learning. Discrepancies or ambiguities in identification results encountered during learning can be resolved by consulting dichotomous keys and seeking guidance from teachers. Practice at the Beijing Academy of Agriculture and Forestry Sciences has proven that this approach helps improve students' autonomous learning ability. Teachers in the "Botany" course organized a "Plant Treasure Hunt" activity where students used mobile devices to explore the campus, capturing images of various plants and instantly obtaining identification results for comparative learning [12]. This interactive model transforms traditional passive listening into active exploration, greatly stimulating students' learning interest.

While AI recognition tools can quickly provide answers and spark interest in discovery and exploration, they may also lead some students to over-rely on the technology, neglecting the accumulation and understanding of basic concepts [12]. Therefore, in practical exploration using such tools, it is essential to adhere to the guiding principles of plant morphological terminology and taxonomic fundamentals, treating technology as an auxiliary, instrumental tool. Students should recognize that while mastering the technology, they must also deepen their understanding and grasp of relevant theoretical knowledge to prevent deficiencies in the foundational knowledge base due to the convenience offered by technology.

2.2. Exploration of Knowledge Graph and Ai Teaching Assistant System Construction

To help students construct a systematic botanical knowledge graph, AI technology can be employed to build a botany knowledge graph, connecting scattered, point-like botanical knowledge points into a clear hierarchical network structure, thereby assisting students in better mastering and learning related knowledge. Experience from Southwest University shows that in the teaching of core plant protection courses, a three-tier construction model from "knowledge point - course knowledge graph - course group knowledge graph" was established. A "knowledge-problem-objective" three-dimensional visual graph supports the construction of multi-modal course resources and guides students' personalized learning path selection and adaptive learning [4]. The approach of the Hubei Normal University Botany Teaching and Research Office can also be referenced. Utilizing the Superstar Smart Teaching System and employing semantic analysis and natural language processing (NLP), they built a "Knowledge Brain." This Knowledge Brain not only supports on-demand retrieval and autonomous jump learning for students but also provides feedback to teachers on the course design logic during course construction, thereby promoting the transformation of teaching from a linear, indoctrination-based process to a systematic construction process [2]. Furthermore, regarding AI teaching assistants, the integrated toolchain of "Intelligent Assistant + Virtual Tutor + Learning Assistant" explored by Southwest University can be considered. In each core course at Southwest University, an intelligent teaching assistant is, integrating functions like learning supervision, online Q&A, and knowledge retrieval, enabling course content iteration based on AIGC. This forms a new ternary interactive teaching paradigm of "AI Tutor + Professional Teacher + Student." Utilizing the AI teaching assistant to deliver "Basic - Advanced - Expanded" three-level teaching can enhance teaching efficiency [3].

2.3. Exploration of Virtual Simulation and Digital Twin Technology Applications

Virtual simulation technology is an excellent solution to the seasonal and geographical constraints of botany field course. For example, Shenyang Agricultural University developed a "Virtual Teaching System for Botany Classification Internship" based on plants on its campus. Using 720° panoramic materials and other scene-specific recordings, it categorizes plants in various scenes by species, annotates typical plant morphologies and applications on maps, and includes voice explanations [13]. Such virtual reality learning platforms allow students to learn about various plant knowledge through familiar campus scenes in a virtual environment, regardless of their physical location. Additionally, digital twin technology can be tentatively used to establish plant growth process models. Introducing matching digital twin sandboxes to simulate plant growth environments, as explored in the "Data-Driven - Intelligent Decision-Making - Virtual-Real Combination" whole-process smart agriculture teaching reform at the College of Agriculture, Ningxia University, where digital twin sandboxes simulate plant ecosystems, allows students to observe the impact of environmental factors on plant growth [14]. This is an important way to systematize and visualize teaching and an effective means to achieve differentiated and more characteristic teaching models.

2.4. Exploration of Data Collection and Electronic Specimen Production Models

In traditional botany field course, the production of herbarium specimens is time-consuming, and the resulting specimens are easily damaged, difficult to preserve long-term, and inconvenient to share. With the development of AI technology, electronic specimens can now be used for related teaching. The method involves students using mobile phones or digital camera systems to photograph the entire plant, determine the specific location via GPS, and create an electronic specimen by combining the photo with a brief introduction to the plant [15]. These are then uploaded to the teacher via online platforms like "Learning Tong." This electronic specimen collection model not only significantly reduces the cost of producing and preserving physical specimens and effectively improves the efficiency and quality of field internships but also cultivates students' ability to collect and organize digital information [16].

A typical case is Zhongkai University of Agriculture and Engineering. In their practical teaching, they used Biotracks software to guide students in photographing the comprehensive characteristics of trees and creating electronic specimens during the practical teaching process of "Landscape Dendrology." They systematically recorded various morphological characteristics, growth environment, geographical coordinates, and other data of the plants. Finally, the software organized the obtained information to form a complete database, allowing for easy retrieval and viewing of the data. This facilitates long-term preservation and widespread sharing and can serve as an important basis for further data analysis and scientific research work [1].

Further practice by the School of Life Sciences, Qinghai Normal University, confirmed the effectiveness of this model. During their practice, the team used digital means such as mobile APPs and DSLR cameras to conduct a plant resource survey in Xining Botanical Garden, establishing electronic files for over 300 plant species in the garden, containing basic information, growth dynamic data, high-definition pictures, and other dimensions [17]. This digital attempt not only helps students better understand professional knowledge but also greatly enhances their information integration and data processing abilities, fully reflecting the development direction of botany internship teaching in the AI era.

2.5. Exploration of Plant Labeling and QR Code Learning System Construction

In the construction of campus plant internship bases, applying plant labeling and QR code learning methods establishes a seamless learning environment connecting "physical plants - digital resources." By placing labels with QR codes on trees, students can scan them with their phones to directly access introductions including plant name, family and genus, morphological characteristics, ecological habits, and garden uses. Clicking the specific link can open a page with detailed textual information. This model effectively breaks the spatiotemporal limitations of traditional internships, enabling students to conduct cognitive learning anywhere on campus beyond the classroom, achieving truly ubiquitous teaching where "learning can happen anytime, anywhere" [18-19].

2.6. Exploration of Artificial Intelligence Assessment System Construction

Using artificial intelligence technology transforms the single outcome evaluation method, adopting process-oriented evaluation across multiple dimensions. For instance, an online plant identification examination system with functions like random test paper generation and automatic scoring can be established using the "Learning Tong" teaching platform. It can randomly display plant pictures or specimens, require species identification within a time limit, and save and feed back key information such as response time and accuracy rate to the teacher for understanding students' situations.

Furthermore, based on multi-form data from students throughout the entire internship process, such as the quality of electronic specimens, the completeness of virtual experimental operations, and the frequency of interaction with the AI teaching assistant, further exploration can be conducted to summarize and refine knowledge mastery, skill operation, and learning participation. An interconnected and mutually corroborating teaching evaluation system covering these three aspects can be created, laying a solid foundation for subsequent personalized teaching guidance and precise teaching intervention for students.

The exploration of the various AI application modalities discussed above demonstrates that artificial intelligence technology has deeply permeated all aspects of botanical fieldwork practice, driving systematic reform in field instruction. The core functions, representative tools/platforms, and pedagogical value of these seven application forms are summarized for reference in Table 1.

Table 1. Application Forms and Functions of AI Technology in Botany field course

Application Form	Main Functions	Representative Tools/Systems	Teaching Value
Intelligent Recognition Tools	Rapid plant identification, feature analysis	Flower Companion, Xingse, Baidu Image Search, Biotracks	Improve learning efficiency, cultivate exploration ability
Knowledge Graph System	Knowledge systematization, personalized learning paths	Superstar Smart Teaching System, Course Knowledge Graph	Promote knowledge construction, support autonomous learning
AI Teaching Assistant System	Intelligent Q&A, Learning Supervision, Content Recommendation	Learning Assistant System on Superstar Platform	Provides personalized guidance, reduces instructor workload.
Virtual Simulation System	Break spatiotemporal limits, simulate observation	Virtual Teaching System for Botany Classification Internship	Expand teaching scenarios, compensate for seasonal limits
Electronic Specimen System	Digital recording, data analysis	Biotracks, Custom Databases, Learning Tong Submission System	Cultivate information literacy, facilitate resource sharing
QR Code Learning System	Plant information query, extended learning	Plant Label QR Codes, iPlant.cn links	Support ubiquitous learning, strengthen extracurricular cognition
AI Assessment System	Process evaluation, intelligent test generation, learning analysis	Learning Tong Online Exams, Behavioral Data Analysis	Achieve multi-dimensional evaluation, improve assessment efficiency

3. Exploration of Implementation Pathways For AI-Empowered Botany Internship Teaching

3.1. Pathways for Integrating AI Into Botany Internship Teaching

This pathway uses the closed-loop framework of "Knowledge Input - Experience Transformation - Innovation Output" to systematically promote the deep integration of AI and botany field course. In the knowledge input stage, dynamic knowledge graphs help students master theoretical foundations like plant classification and physiology. In the experience transformation stage, students are guided to use AI recognition tools and authoritative databases for on-site species identification and verification, strengthening practical understanding. In the innovation output stage, students are encouraged to engage in creative practices like ecological design and virtual specimen production, achieving the leap from cognition to application [12]. Simultaneously, a full-process intelligent internship system covering "Identification - Verification - Assessment - Archiving" is constructed. Combined with the plant QR code system to expand learning scenarios, and through a data-driven multi-dimensional evaluation model integrating data from identification tests, electronic specimen quality, and learning behaviors, it comprehensively reflects students' achievement levels in knowledge, skills, and literacy.

3.2. Implementation Principles and Safeguards for the Pathways

To achieve sustainable integration of AI and botany field course, three core principles should be followed: First, technology integration should be gradual, adhering to the path of "from auxiliary to main, from point to system," avoiding technological stacking, and ensuring alignment with teaching objectives. Second, uphold the philosophy of "Tradition as Foundation, AI as Empowerment," retaining traditional internship methods like specimen making and field observation while integrating new methods like AI recognition and digital reconstruction to achieve complementary advantages. Third, strengthen data drive. Based on multi-source data such as students' learning behaviors on AI platforms and task completion quality, establish scientific evaluation and feedback mechanisms to promote the transformation of internship teaching from experience-based to precise and intelligent.

To uphold these principles and enable the informed selection of technological tools, a meticulous evaluation of the pedagogical effectiveness and applicability of various AI applications is necessary. Table 2 provides a detailed comparison of mainstream AI tools across multiple dimensions—including suitable application stages, advantages, limitations, and practical recommendations—offering a systematic reference for educators in their selection process.

Table 2. Teaching Effects and Applicability of Different AI Tools in Botany field course

AI Tool Type	Applicable Internship Stage	Advantages	Limitations	Application Suggestions
Plant Recognition APPs	Field investigation, Plant identification	Immediate feedback, stimulates interest	Limited accuracy, potential dependency	Recommend as auxiliary tool, needs combination with traditional taxonomy methods
Knowledge Graph System	Theoretical learning, Internship preparation	Systematizes knowledge, supports personalized learning	High development cost, requires professional team	Suitable for pre-internship preview and theoretical reinforcement
AI Teaching Assistant System	Full-process Support	Personalized tutoring, reduced faculty workload	Limited interaction depth	Suitable for Q&A and foundational guidance; complex topics still require teacher explanation.
Virtual Simulation Platform	Internship preview, Supplementary teaching	Breaks spatiotemporal limits, repeatable operation	Gap with real-field experience	Recommend as supplement to field internship, cannot fully replace it
Electronic Specimen System	Specimen making, Data management	Easy preservation & sharing, supports data analysis	Requires certain technical support	Can explore gradually replacing part of traditional specimen making
AI Teaching Assistant System	Whole-process support	Personalized tutoring, reduces teacher burden	Limited interaction depth	Suitable for Q&A and basic guidance, difficult points still need teacher explanation
AI Assessment System	Learning evaluation, Effect assessment	Automated grading, enables process evaluation	Difficult to assess higher-order thinking skills	Recommend as important part of assessment

4. Analysis of Teaching Effectiveness of AI-Empowered Botany Field Course

4.1. Enhancement of Student Learning Outcomes

AI empowerment in botany field course significantly enhances student learning outcomes. Firstly, it increases students' learning interest and initiative. Experiments at Beijing University of Agriculture showed that after using AI in the "Plant Treasure Hunt," student participation increased, shifting from passive knowledge reception to active learning and exploration, demonstrating markedly heightened curiosity, indicating a substantial improvement in learning initiative [5]. Using intelligent recognition tools and QR code learning systems, information about plants can be obtained conveniently and quickly both inside and outside the classroom, liberating students' enthusiasm for active learning to a certain extent. According to relevant practice reports from Zhongkai University of Agriculture and Engineering, after using Biotracks software, students' abilities in identifying landscape trees, outdoor observation, and recording all improved [1]. Secondly, it enhances students' understanding and grasp of professional knowledge. Through the visual display of AI knowledge graphs, students can more intuitively understand the internal connections within plant classification systems, thereby better mastering professional knowledge.

4.2. Optimization of Teaching Resources and Improvement of Teaching Efficiency

Using AI technology to enhance teaching efficiency and optimize resources has largely transformed the original internship model. In past internships, teachers had to spend significant time and energy repeating similar tasks. Now, using AI teaching assistant systems can automatically assist students with related operations, reducing the teacher's burden and allowing them to focus on more meaningful personalized instruction and in-depth problem-solving for students. Using virtual simulation systems to supplement limited internship resources allows students to conduct virtual internship operations in advance, familiarize themselves with the internship procedures and specific operational essentials, and lay a good foundation for subsequent offline internships, greatly improving the overall teaching efficiency of the internship [13].

Using online exams on platforms like "Learning Tong" for online identification assessments can standardize and streamline the assessment process. Functions like random test paper generation and automatic scoring significantly reduce teachers' grading workload, eliminate result distortions due to human factors, and ensure fair assessment for students of different levels. Furthermore, it facilitates the accumulation of complete exam data for subsequent precise process evaluation and the construction of comprehensive AI evaluation models. – Taking the botany internship at Lingnan Normal University as an example.

Electronic specimens are easier to preserve long-term and share widely compared to traditional herbarium specimens, and they integrate information more completely. The collection of student electronic specimens submitted as per internship requirements serves not only as an important basis for evaluating their internship outcomes but can also be accumulated into a complete teaching resource database. Examples like the plant electronic archive database established by the Qinghai Normal University Xining Botanical Garden practice team are models of multi-dimensional development of teaching resources. These resources can be used for university teaching and also enable the botanical garden to serve multiple functions such as science popularization, scientific research, and ecological monitoring [17].

5. Challenges and Countermeasures in AI Application

Despite the broad application prospects of AI technology in botany field course, certain difficulties exist in its promotion process.

5.1. High Student Dependency and Weakening of Basic Skills

Although AI plant recognition tools are very convenient, they may reduce students' emphasis on mastering basic principles and skills, which is detrimental to their genuine understanding and mastery of knowledge itself. Associate Professor Tian Yelin from Beijing University of Agriculture observed that when AI tools are uncertain, they often provide multiple possible answers. Without a solid foundation in morphology, any judgment might seem plausible, potentially leading to serious misjudgments in practical work. During internships, it was also found that some students over-relied on APP identification results, neglecting the observation of key classification characteristics of plants [12]. Solutions are sought by constructing a teaching philosophy centered on "technology as an aid," defining the boundaries of AI use, and complementing both methods: prioritize classroom teaching and knowledge systems that inspire student thinking, focusing on building students' professional foundation; establish the teaching philosophy of "technology as aid, cultivating basic ability as the core," delineate and correctly use the boundaries of AI tools. Integrate traditional classification methods and AI methods in teaching design, requiring students to verify AI results using dichotomous keys and explain the reasons, interpreting key classification characteristics. Furthermore, the strategy of "AI preliminary judgment combined with manual review and verification" can be institutionalized and integrated into teaching design and assessment. Specifically, students can be required to submit both the preliminary AI identification results and the process records of manual verification based on authoritative resources like dichotomous keys and floras, along with the final interpretation of key classification characteristics for comparison and identification tasks. This should be a key component of the internship report and a core assessment basis.

5.2. Insufficient Digital Literacy of Teachers

Enhancing the digital literacy of the teaching staff is a crucial condition for applying AI technology to education and teaching. Currently, many botany teachers in universities are not familiar with AI technology, making it difficult to apply it in daily teaching. Solution: Establish systematic teacher training mechanisms to improve teachers' digital literacy through workshops, training courses, etc. The Hubei Normal University Botany Teaching and Research Office regularly organizes experience exchange activities for "AI + 'Botany' Course Construction," helping teachers master the application skills of AI teaching tools through case demonstrations, technical analysis, and interactive discussions [2]. Simultaneously, experts in the field of artificial intelligence can be invited to participate in teaching reforms, forming interdisciplinary cooperation mechanisms to jointly develop teaching resources.

5.3. High Technical Costs and Resource Sharing

The development and maintenance of AI teaching systems require significant technical support and funding, posing considerable obstacles for some universities. The following approaches should be considered: Firstly, inter-university cooperation and resource sharing should be promoted. Based on the actual conditions of regional institutions, efforts should be made to establish shared teaching resource centers that enable cross-institutional access and utilization. Secondly, encourage universities to seek school-enterprise cooperation, adopt a combination of industry, academia, and research to tackle challenges jointly, co-develop, and share the construction cost burden. The College of Agriculture, Ningxia University, in its teaching reform oriented towards smart agriculture, proposed building a "Regionally Shared" Plant Protection Smart Learning Center to provide AI teaching services for surrounding universities, achieving optimized allocation of resources [14].

6. Future Prospects

With the advancement of artificial intelligence technology, AI-empowered botany field course has vast development space.

6.1. Multi-technology Integration and Intelligent Platforms

The future development trend of botany field course lies in the integration of more technologies. Therefore, botany field course should move towards combining multiple technologies. During the internship process, technologies like 5G, the Internet of Things (IoT), and big data can be integrated to build more intelligent botany internship platforms. For example, installing sensor network equipment in internship bases can monitor environmental parameters of plant growth in real-time and use AI algorithms to analyze the relationship between plants and environmental factors, providing students with a better inquiry-based learning environment.

6.2. Personalized Learning and Adaptive Systems

Personalized learning and adaptive systems leverage AI to tailor the most suitable learning paths and internship plans for individual students based on their learning behaviors, knowledge mastery, and personal ability characteristics, truly achieving personalized education. The data obtained from assessments using platforms like Learning Tong, after accumulation over time, can be mined for deeper value. Establishing learning early warning and personalized recommendation systems on such platforms is also feasible. The "Life Sciences and Artificial Intelligence" Cross-Innovation Training Camp at East China Normal University proposed a personalized learning path design model [20], realizing tailored education for students with different aptitudes and cultivating high-level talents, enhancing students' inquiry thinking, self-regulation ability, and fostering independent innovation awareness and capability. As algorithms and models continue to be updated and optimized, future AI will be better able to monitor student learning status and provide more targeted learning guidance.

7. Conclusion

Artificial intelligence technology is disrupting the educational and teaching methods and patterns of botany field course in higher education with unprecedented breadth and depth. Applications including intelligent plant identification, knowledge graph construction, virtual simulation training, and intelligent assessment evaluation are all innovating teaching under the empowerment of AI, breaking resource constraints, overcoming spatiotemporal barriers, and promoting teaching efficiency. Using multiple universities as examples, this paper discusses the feasible methods, pathway choices, and practical techniques for integrating AI into botany internship practice. Success in AI-empowered practice is not merely a patchwork of technologies but a systematic transformation integrating updates in educational philosophy, transformation of teaching models, and integration and innovation.

While continuously promoting the application of new technologies, we must not forget our original intention, nor the essence of education, clearly understanding that our purpose is to use technology to teach, not to teach technology itself. Only by adhering to the "student-centered" principle in botany internship teaching practice and clarifying the fundamental purpose of botany field course – to cultivate students' core literacy and professional abilities – can we develop correctly amidst the tide of the digital era. As AI technology continues to deepen its practical application in classroom teaching, universities will certainly establish a new ecology for botany field course in the AI era, thereby driving botany teaching towards a more intelligent, personalized, and efficient direction, ultimately becoming fertile ground for cultivating more, higher-level, and stronger interdisciplinary talents for the digital age.

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