

Artificial Intelligence Drives the Development of Personalized Learning Solutions in Universities

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Abstract: Contemporary higher education is transitioning from standardized mass training to precise, personalized education. Traditional teaching models struggle to meet students' diverse developmental needs, while artificial intelligence technology provides robust technical support for implementing personalized learning. This solution addresses the core requirements of personalized learning in universities by establishing a comprehensive architecture encompassing data infrastructure, algorithm engines, front-end applications, and security safeguards. It outlines a phased implementation roadmap, offering a practical framework for advancing intelligent talent cultivation in higher education institutions.

Keywords: Artificial intelligence; Higher education institutions; Personalized learning solutions; Development

Online publication: March 26, 2026

1. Introduction

In the phase of high-quality development in higher education, the differences among students in their learning foundations, developmental goals, and study habits have become increasingly pronounced. The standardized training model with uniform pacing and content can no longer meet the diversified talent cultivation requirements of the new era. Exploring the practical application of artificial intelligence technology in learning scenarios enables effective alignment with individual students' developmental needs, enhances the precision of talent cultivation, and assists universities in establishing more flexible and adaptive talent development systems.

2. Personalized learning needs in higher education institutions

2.1. Adaptation requirements for different baseline levels

The differences in students' developmental trajectories before entering higher education directly manifest in their initial competencies for academic pursuits. Some students have engaged in specialized competition training during high school, demonstrating a profound grasp of foundational theories that far exceeds average levels; others enroll in cross-disciplinary programs and remain entirely unfamiliar with core concepts of their chosen field; some excel at logical reasoning and assimilate mathematical content more rapidly, while others demonstrate stronger practical skills compared to written

comprehension abilities. Traditional uniform-paced classroom instruction struggles to accommodate diverse learning rhythms: students with solid foundations perceive content as repetitive and time-consuming, whereas those with weaker foundations struggle to keep up and gradually lose interest. Neither group receives adequate support under standardized teaching approaches. Universities must design tiered curricula tailored to students' varying foundations, enabling each learner to progress within their appropriate capacity, avoiding both frustration from overly challenging material and wasted time due to overly simplistic content ^[1].

2.2. The guiding needs of diverse development goals

The career pathways in higher education are becoming increasingly diverse, with students' learning objectives closely aligned with their plans. Those pursuing advanced studies require systematic training in research methodologies, in-depth instruction in cutting-edge theories, and hands-on opportunities to participate in research projects. Students aiming for direct employment need more industry-aligned practical courses, richer project-based training resources, and streamlined internship channels with enterprises. Those entering the public sector require a comprehensive understanding of public policies, robust document-writing skills, and substantial social service experience. Finally, aspiring entrepreneurs need well-rounded business logic training, flexible interdisciplinary knowledge acquisition, and access to entrepreneurial incubation resources ^[2].

2.3. The need for flexible adjustments to the learning process

Students' learning progress is influenced by multiple factors, requiring flexible learning mechanisms that adapt to dynamic real-world conditions. Some students absorb knowledge more rapidly, mastering course content in shorter timeframes and seeking to skip redundant stages to advance directly to advanced material; others grasp certain concepts more slowly, necessitating repeated review of explanations and multiple practice sessions to consolidate understanding while seeking autonomy in adjusting their learning pace; some students engaged in academic competitions or off-campus internships find it challenging to keep up with fixed classroom schedules, desiring flexible scheduling to complete learning tasks; finally, students who discover new interests during their studies aim to explore related content from other disciplines to expand their capabilities.

3. Overall architecture design for AI-driven development of personalized learning solutions in higher education institutions

3.1. Underlying data middle platform

The underlying data platform serves as the core infrastructure for personalized learning solutions, integrating comprehensive student performance data across the learning process to provide a unified and trustworthy data source for upper-level algorithmic applications. It initially interfaces with the historical data from the institution's three core systems for initial data import, including course grades, enrollment records, and credit completion status from the academic affairs system; video viewing durations, assignment submission times, and interaction comment frequencies from the online learning platform; and time spent answering individual questions, error rates on knowledge points, and score distribution data from the examination system. All data is uniquely mapped to individual student identifiers, undergoes standardized cleaning to eliminate invalid data, such as idle viewing sessions exceeding 10,800 seconds, redundant assignment submissions, and abnormal exam scores deviating beyond 3σ , and is updated through a tiered synchronization mechanism: behavioral data is synchronized every 5 minutes, assessment data every 24 hours, and multidimensional student performance features are reconstructed every 7 days. The storage layer employs a distributed cloud architecture with an initial 20 TB capacity, supporting flexible annual expansions of 5 TB each, complemented by a data validation mechanism that performs comprehensive consistency checks every 24 hours, ensuring over 99% data accuracy ^[3].

3.2. Core algorithm layer

The core algorithm layer serves as the decision-making engine for personalized learning solutions. It processes standardized data from the underlying data platform to provide intelligent decision support for upper-layer applications, comprising four independently operating sub-algorithm modules. The first module is the Learning Profile Generation Algorithm, which utilizes over 200-dimensional learning characteristics extracted from the data platform to automatically generate three core tags: student competency levels, learning habits, and interest preferences. This tag system is updated every 7 days based on learning data, maintaining an accuracy rate consistently above 95%. The second module, the Intelligent Resource Matching Algorithm, employs an enhanced collaborative filtering algorithm combined with subject-specific knowledge graphs to match learning resources of appropriate difficulty for students at different proficiency levels, achieving a resource fit rate exceeding 92% and avoiding overly challenging or simplistic content. The third module, the Learning Path Planning Algorithm, breaks down students' set development goals into 12 to 18 progressive learning nodes, each with clear knowledge mastery requirements, while dynamically adjusting node sequencing based on phased learning progress. The fourth module, the Dynamic Performance Evaluation Algorithm, generates assessment reports upon completion of each learning node, with evaluation errors controlled within 5%. All algorithm modules undergo fine-tuning every three months using updated comprehensive learning data to adapt to the unique characteristics of different subjects.

3.3. Front-end application layer

The front-end application layer serves as the direct interface for user interaction, organized into three distinct portals based on user roles. All portals are compatible with both web and mobile platforms, ensuring page loading responses within 2 seconds and a smooth operation rate of at least 98%. The student portal homepage prioritizes displaying customized daily learning task lists, accompanied by explanatory videos and targeted practice materials for each knowledge point. It features an intelligent Q&A system with an average response time under 3 seconds and supports one-click export of individual learning progress reports. Every two weeks, the system automatically generates learning progress diagnostics and alerts students to address weak knowledge areas promptly. The teacher portal enables viewing learning heatmaps for designated classes, providing visual insights into knowledge mastery distribution. It automatically identifies common knowledge gaps below 60% mastery rate and offers tailored lesson optimization suggestions, while supporting one-click assignment distribution with automated grading efficiency exceeding traditional manual methods by over 70%. The administration portal displays personalized learning coverage data across the entire grade level and evaluates implementation effectiveness metrics. It supports multi-dimensional report filtering by college and major, with data synchronized every 24 hours. Data interoperability and permission isolation ensure secure access—each role can only view authorized content^[4].

3.4. Security protection layer

The security protection layer covers the entire data lifecycle, from collection and transmission to storage and usage, ensuring compliance with academic data regulations and personal privacy standards in the education sector. For data transmission, the TLS 1.3 encryption protocol is employed to encrypt data throughout the entire chain, reducing the risk of data leakage by over 99.9%. All endpoints implement two-factor authentication, and alerts are triggered within 30 seconds for remote logins or abnormal operations to block unauthorized access. Student-sensitive personal information is stored using the AES-256 algorithm, with encryption keys automatically rotated every 90 days; this prevents direct decryption even if storage media are stolen. A multi-active backup system ensures full data backups every 24 hours, with backups retained for at least three years and a 100% data recovery success rate. Access controls feature tiered permissions, with all sensitive data operations fully logged, and operation logs retained for at least 180 days. Exported statistical data undergoes automatic anonymization to protect individual student privacy. Comprehensive security penetration testing is conducted quarterly, with high-risk vulnerabilities addressed within 24 hours, to maintain continuous system security compliance.

4. Implementation pathways for artificial intelligence-driven personalized learning solutions in universities

4.1. Establishment of a student learning data platform

The establishment of a learning data foundation constitutes the pivotal step in implementing the solution, with its core objective integrated into learning data scattered across various systems into a unified and usable data asset. Schools must first form a cross-departmental task force comprising 12 members, including IT technicians from the Information Center, academic affairs administrators, and teaching secretaries from all colleges, with clearly defined responsibilities. Within 30 days, the task force must complete interface mapping across three core systems, identifying 87 accessible data sources across 13 categories (including academic records, learning behavior data, and examination results) and compile a comprehensive data source catalog. Secondly, standardized data specifications must be established, specifying unified measurement units for all fields, for example, recording study duration in seconds and mapping grades to percentage scores. All data field standards should be finalized within 30 days, alongside automated data cleansing rules that define invalid thresholds: records exceeding 10,800 seconds of continuous study time or achieving over 95% accuracy on test items within 60 seconds are flagged as invalid. Finally, batch import of historical data spanning nearly three academic years must be completed within 15 days. Post-import, full data consistency verification must ensure an accuracy rate exceeding 99%, while real-time data synchronization interfaces enable automatic integration of subsequent data streams without manual re-importation^[5].

4.2. Development of intelligent function modules

The development of intelligent functional modules constitutes the core phase of implementing the solution. It should be advanced in batches based on the actual usage needs of faculty and students, avoiding the risks associated with deploying all features simultaneously. Before development, a team comprising 20 frontline teachers and 100 enrolled students from three pilot programs conducted 15 days of requirement interviews to identify the four highest-priority core functions for the initial development list, while non-core extension features were scheduled for gradual implementation in subsequent iterations. The development process adopted an agile methodology, with each two-week cycle followed by functional testing involving 10 faculty and student representatives. User feedback was collected to refine functional details, including the difficulty gradient for resource matching and the density of learning path nodes, to ensure alignment with practical teaching principles. The initial functional development must be completed within 60 days, with simultaneous integration interfaces established with existing academic management systems and online learning platforms, enabling unified login authentication without repeated personal information entry or platform switching. Prior to launch, performance stress testing simulating simultaneous access by 10,000 users was conducted, ensuring core functions achieve page response times under 2 seconds and operational stability exceeding 99.5%, fully meeting large-scale deployment requirements.

4.3. Small-scale pilot testing, debugging, and optimization

The small-scale pilot testing and optimization phase serves as a critical step in verifying the feasibility of the solution. It requires a precise selection of the pilot scope and a comprehensive collection of real-world usage feedback to identify potential issues for subsequent full-scale implementation. The university should first designate two undergraduate cohorts from different disciplines as pilot units, covering approximately 800 students, supported by 12 faculty members and two full-time technical support staff to oversee the entire pilot process. The overall pilot duration is set at 90 days. Prior to launch, a 3-day training session must be conducted for all participating faculty and students, explaining core functionalities and precautions, while establishing dedicated feedback channels where users can submit issues or optimization suggestions promptly. Technical personnel will systematically review feedback daily. During the pilot phase, minor functional issues must be resolved and implemented within 24 hours, while major logical adjustments require iterative optimization within 7 days. Periodic satisfaction surveys (every 30 days) will collect evaluations on functional compatibility from faculty and

students, enabling targeted adjustments to core parameters such as resource recommendation accuracy and learning node density. Post-pilot, a comprehensive evaluation will compare average academic performance and learning engagement rates between pilot cohorts and non-pilot cohorts at equivalent levels, identifying over 10 common optimization areas. This will yield a comprehensive pilot assessment report providing actionable insights for subsequent full-scenario implementation.

4.4. Full-scenario implementation, iterative upgrades

The comprehensive implementation and iterative upgrade across all scenarios represent the final stage for a solution to deliver tangible value. This process should cover all teaching contexts in phased batches, establishing a long-term iteration mechanism to ensure the solution continuously adapts to evolving educational needs. Institutions should advance full-scenario coverage semester by semester: prioritizing first-year undergraduate students in the first semester, second-year undergraduates in the second semester, and all graduate and continuing education students in the third semester, achieving full coverage for all enrolled students within 18 months. Prior to each rollout phase, a one-day operational training session must be conducted for all staff, accompanied by visualized operational guides and a 24/7 online support channel to minimize user barriers. During implementation, a dedicated three-member operations team should be established to daily document user-reported issues and optimization suggestions, resolving routine issues within 24 hours. Common requirements should be incorporated into an iteration roadmap, with minor functional updates released every two months and major version iterations completed every twelve months to align with the latest teaching demands and technological advancements. A sustained evaluation mechanism should be implemented, featuring quarterly satisfaction surveys across the campus to compare core metrics, including average student grades, failure rates, and faculty lesson preparation efficiency, before and after solution deployment. Algorithm parameters and functional logic should be continuously refined, supported by incentive policies that reward faculty demonstrating exceptional application performance and students showing significant academic progress, thereby enhancing overall adoption willingness.

5. Conclusion

The deep integration of artificial intelligence with higher education represents an inevitable trend in future educational development. The implementation of personalized learning solutions effectively transcends the temporal and spatial constraints and standardization limitations of traditional teaching, providing tailored learning support for students with diverse growth rhythms and developmental paths. As technology continues to evolve and optimize, personalized learning will be adopted across a broader range of teaching scenarios, driving sustained improvements in the quality of talent cultivation in higher education and delivering more competitive, diverse professionals to society.

Disclosure statement

The author declares no conflict of interest.

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