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A Collaborative Undergraduate Education Model for Mathematics-Related Programs amid Digital Transformation: Shared Foundations and Differentiated Pathways

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Abstract

The rapid expansion of artificial intelligence and big-data industries has renewed attention to the strategic importance of mathematics-related disciplines. Focusing on undergraduate program curricula and training plans, this study combines document analysis, questionnaire surveys, and in-depth interviews to examine current arrangements and challenges concerning the alignment of educational objectives, resource sharing across programs, the progression of practical training, and the evidence used to assess learning outcomes. The study finds that the programs have begun to establish distinct educational profiles, but that further improvements are needed in integrating emerging technologies and developing coherent sequences of practical learning. It therefore proposes a three-tier curriculum structure, a progressive project-based training mechanism spanning all four academic years, and the development of interdisciplinary teaching teams. These proposals are intended to provide a reference framework for cultivating practice-oriented graduates in mathematics-related fields at regional undergraduate institutions.

Keywords: Mathematics-related undergraduate programs; curriculum structure; undergraduate education; outcome-based education (OBE); practical training; digital transformation

1. Introduction

Against the backdrop of China's New Engineering and New Liberal Arts initiatives, traditional mathematics education is undergoing a substantial shift in orientation. Historically, undergraduate programs in mathematics-related fields have largely followed a discipline-centered approach, emphasizing the coherence of theoretical knowledge and the rigor of mathematical reasoning. As digital transformation progresses, however, labor-market expectations are increasingly shaped by application-oriented needs. Whether the task involves digitizing mathematics instruction in primary and secondary schools, developing the underlying algorithms of large-scale models, or applying statistical models to economic decision-making, graduates are expected not only to understand mathematics but also to translate mathematical knowledge into practice.

This study examines the mathematics-related undergraduate programs at one university, with a detailed focus on its 2026-entry training plans, including educational objectives, matrices linking courses to graduation requirements, curriculum schedules, and credit distributions. Questionnaire surveys were conducted with students enrolled in Applied Statistics in 2025, Information and Computing Science in 2026, and mathematics teacher education in 2024. In-depth interviews were also conducted with full-time faculty members in the relevant teaching units. The interviews focused on program orientations, the modular organization of curricula, the appropriateness of credit allocations, alignment between courses and graduation requirements, the sequencing of practical training, and opportunities for individualized development.

2. An Analysis of Current Undergraduate Education Arrangements

2.1. Program Profiles

Comparative analysis reveals distinct orientations among the three undergraduate programs. The Mathematics and Applied Mathematics program, which prepares future mathematics teachers, is organized around the integration of mathematical foundations, teacher education, and data technologies. Beyond mastery of mathematical theory, it emphasizes pedagogical transformation: the ability to make abstract mathematical concepts accessible to primary and secondary school students, supported by AI-assisted instructional approaches. The Information and Computing Science program integrates mathematics, computer science, and artificial intelligence.

It aims to prepare graduates for algorithm design, software development, and AI-agent development, with particular attention to turning mathematical models into executable programs. The Applied Statistics program combines statistics, data science, and economics and management. It emphasizes sensitivity to data and the use of statistical software for data cleaning, modeling, interpretation, and decision support in settings such as finance, economics, and social surveys.

2.2. Credit Distribution and Curriculum Structure

The curriculum documents show that the three programs have broadly comparable total credit requirements (154–155 credits), but differ in how credits are allocated across their main components.

Table 1. Comparison of Credit Allocations across the Three Programs

Curriculum component	Mathematics teacher education	Information and Computing Science	Applied Statistics
Disciplinary foundations (required)	42	41	32
Program foundations (required)	11	13	20
Core program courses (required)	18	14	16
Integrated practical training (required)	24	26	25
Total elective credits	12	12	14
Theoretical instruction	114.5	109.75	112
Laboratory and practical instruction (combined)	40.5	44.25	43

As shown in Table 1 and the program training plans, Mathematics and Applied Mathematics and Information and Computing Science share a substantial set of foundational mathematics courses, including a 17-credit sequence in Mathematical Analysis. This common core provides a basis for coordinating faculty resources and establishing shared teaching standards within the school. Applied Statistics allocates fewer credits to disciplinary foundations (32 credits), but more to program foundations (20 credits) than the other two programs. This reflects the distinct

disciplinary positioning of statistics and its emphasis on integrating economics, probability, and statistical principles. Practical instruction accounts for more than 26% of credits in all three programs, with Information and Computing Science recording the highest share (28.73%), consistent with its emphasis on hands-on programming and algorithm development.

2.3. The Organization of Practical Training

All three programs combine course-based training, concentrated practical activities, and final-year requirements, although their priorities differ. Mathematics and Applied Mathematics draws on training in handwriting and spoken classroom communication, school observations, teaching internships, and reflective teaching practice to connect simulated teaching with experience in actual classrooms. Information and Computing Science emphasizes database projects, mathematical modeling competitions, numerical analysis exercises, and applied projects involving large-scale AI models. Applied Statistics organizes practical work around survey design, statistical forecasting and decision-making, and econometric exercises, thereby covering the principal stages of the data analysis process.

3. Challenges in Curriculum Development

3.1. Balancing Shared Foundations with Program-Specific Needs

All three programs treat Mathematical Analysis, Advanced Algebra, and Probability and Mathematical Statistics as common disciplinary foundations. However, the analysis identifies tensions between common course provision and program-specific requirements. Mathematics teacher education requires greater attention to the history and culture of mathematics and to explanations of how mathematical concepts originated, in preparation for school teaching. Information and Computing Science requires stronger applications of matrix theory and numerical error analysis. Applied Statistics places relatively less emphasis on proofs of convergence but requires rigorous understanding of the logic of statistical inference. Moreover, the teaching units responsible for the programs currently operate with considerable independence. Mechanisms for sharing case repositories and experimental data remain limited, and faculty may develop comparable courses, such as Python Programming, separately rather than collaboratively.

3.2. Translating Emerging-Technology Objectives into Learning Outcomes

Although the 2026-entry training plans explicitly refer to emerging areas such as AI-agent development and large-scale AI-model applications, difficulties remain in translating these aims into curriculum delivery. Some advanced courses are located within elective modules and may therefore be taken by only a limited proportion of students. This arrangement can make it difficult to substantiate a graduation

requirement that all students acquire AI application skills, leaving gaps in the evidence of attainment.

Conventional written examinations are also poorly suited to assessing students' practical ability to develop AI agents. Assessment arrangements have yet to incorporate systematic evidence of such capabilities, for example through version-controlled code repositories or videos of project demonstrations.

3.3. Fragmentation and Limited Flexibility in Elective Pathways

Electives are currently organized into fixed tracks, including cross-program study, employability and entrepreneurship development, and pathways linking undergraduate and postgraduate study. Students are not permitted to select courses across these tracks. Although this restriction helps maintain a coherent focus within each pathway, it can constrain interdisciplinary development. For example, a mathematics student wishing to take Data Visualization in the Applied Statistics program may encounter restrictions arising from the track-based rules, thereby limiting opportunities to develop cross-disciplinary problem-solving skills.

3.4. Discontinuities across Practical Learning Activities

Despite the relatively high proportion of credits assigned to practical instruction, the individual activities are not consistently linked in a developmental sequence. Basic programming in the first year, modeling exercises in the second, applied projects in the third, and the capstone project in the fourth can remain disconnected, rather than forming a coherent four-year progression in which the complexity of expected competencies increases over time.

4. Recommendations for Curriculum Development and Quality Enhancement

4.1. Establish a Three-Tier Curriculum Structure

The three programs should move beyond institutional divisions and develop a coordinated, tiered curriculum map.

Tier 1: Shared disciplinary foundations. Foundational courses such as Mathematical Analysis, Advanced Algebra, and Analytic Geometry should be coordinated across programs. A combination of large-group lectures and small-group seminars could be adopted: lectures would cover widely applicable theory, while seminars would introduce applications relevant to mathematics teacher education, computing, or statistics.

Tier 2: Program-specific competency clusters. In mathematics teacher education, proposed new required courses include Mathematical Core Competencies and Textbook Studies and Applications of Modern Educational Technology. Information and Computing Science should strengthen courses such as Algorithm Design and

Analysis, Fundamentals of Machine Learning, and Embedded Systems and AI Agents. Applied Statistics should consolidate a core sequence in Statistical Computing, Multivariate Analysis, and Nonparametric Statistics.

Tier 3: Interdisciplinary extension modules. Restrictions on combining elective tracks should be relaxed. After completing their program's core requirements, students could be allowed to select 5–8 credits across different tracks, facilitating individualized pathways such as mathematics and AI or statistics and finance.

4.2. Develop a Progressive Four-Year Project-Based Learning Sequence

Drawing on the CDIO approach to engineering education, practical learning should be organized as a continuous four-year sequence.

Year 1: Orientation and tools. Students would learn to set up their working environments and use foundational tools. Weekly exercises could develop skills in LaTeX document preparation, MATLAB visualization, and introductory Python programming, while fostering awareness of data-related questions.

Year 2: Specialized training and modeling. Mathematical modeling would serve as the organizing theme for problem identification and model construction. Courses such as Ordinary Differential Equations and Probability Theory could be linked to specialized modeling activities lasting two to three weeks, with particular emphasis on identifying problems and formulating models.

Year 3: Systems and integration. Students would undertake integrative projects spanning multiple courses. In mathematics teacher education, a Digital Instructional Design Project could require students to develop instructional presentations using AI tools and evaluate their performance through simulated teaching. In Information and Computing Science and Applied Statistics, a Data Lifecycle Management Project could cover data acquisition through web scraping, cleaning, modeling, and visualization, integrating the main stages of applied work.

Year 4: Outputs and evaluation. Final-year projects and theses should be more closely aligned with practice. A dual-supervisor arrangement involving university and industry mentors could be introduced, and students could be encouraged to address real-world problems and integrate their internship reports with their final projects or theses.

4.3. Strengthen Assessment of Emerging-Technology Competencies

For newly emphasized competencies, including AI-agent development, assessment should establish a clear link between intended outcomes and demonstrable evidence of attainment. Reliance on conventional written examinations should be reduced, with a greater role for project presentations, code review, and video recordings of simulated teaching. Data on course-level learning-outcome attainment should be collected annually. If a particular graduation requirement, such as interdisciplinary integration, repeatedly shows low attainment, the corresponding syllabi and assessment weights should be revised.

4.4. Coordinate Teaching Resources and Develop Interdisciplinary Teams

Separate laboratories could be brought together in a Center for Mathematical Foundations and Artificial Intelligence, with designated facilities for mathematical modeling, statistical computing, and AI-agent development, and round-the-clock access for students. Joint lesson planning by faculty in mathematics and computer science should also be encouraged. In Advanced Algebra, for example, computer science instructors could contribute applications of matrix operations in image processing, making the relevance of mathematical content more visible to students. A three-way feedback mechanism involving alumni, employers, and current students should support regular curriculum revision. School principals, IT-sector human resources professionals, and financial data managers could be invited to contribute, helping programs remain responsive to professional needs.

5. Implementation Arrangements and Anticipated Outcomes

5.1. Organizational and Institutional Support

To support implementation, a Teaching Reform Steering Group should be established to coordinate courses across the three programs. Faculty performance and workload arrangements should also recognize contributions to interdisciplinary curriculum development and the creation of shared case repositories. These measures could facilitate a shift from knowledge-centered to competency-oriented undergraduate education. Clearer professional pathways could help students understand the applications of their mathematical studies. After four years of progressively more demanding projects, graduates would be able to present a portfolio comprising code repositories, teaching videos, and survey or research reports.

The three programs could thereby function as a mutually reinforcing educational system. AI-supported teaching would expand the professional capabilities of mathematics teacher education graduates; a stronger mathematical foundation would deepen the algorithmic competencies of Information and Computing Science graduates; and cross-disciplinary applications would broaden opportunities for Applied Statistics graduates. Together, these strengths could better support both the preparation of teachers for regional basic education and the provision of algorithmic expertise for local high-technology enterprises.

6. Conclusion and Outlook

This study considers how regional undergraduate institutions can reform mathematics-related programs under digital transformation by strengthening foundations, clarifying specialized pathways, connecting practical learning, and

emphasizing evidence of learning outcomes. Curriculum reform is not simply a matter of adding or removing courses; it entails rethinking the logic of undergraduate education, integrating resources across programs, and changing approaches to assessment. As generative AI becomes increasingly widespread, mathematics education will face further opportunities and challenges. Educators should therefore look beyond students' ability to calculate, prove, and write, and also cultivate higher-order capacities to formulate questions, develop models, and interpret results. A sustained student-centered approach to curriculum development is needed to prepare graduates who combine a sound mathematical foundation with the ability to use modern digital technologies.

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