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Curriculum Optimization for Big Data Majors: Enhancing College Students' Professional Capabilities through Mathematical Modeling Course Improvement

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Abstract: Acknowledging the significance of big data and its technology, an increasing number of colleges and universities in China, as with colleges and universities worldwide, have established majors related to this field. With experience in educating these majors and facing emerging challenges, optimizing the curriculum for big data-related majors has become essential. To enhance students' readiness for the job market, colleges and universities in China have collectively agreed to implement curriculum optimization strategies, at the same time, they found that enhancing key courses is a highly effective approach to achieving this goal. As a consequence, examining strategies to enhance the curriculum for big data-related majors by improving key courses is highly important. This paper explores and analyzes strategies for optimizing the curriculum of Data Science and Big Data Technology by enhancing key courses, using Mathematical Modeling as an example. Our goal is to strengthen college students' professional capabilities. Based on our research, we introduce a set of strategies to improve and optimize the Data Science and Big Data Technology curriculum. These strategies aim to align educational objectives with industry demands, thereby promoting the development of essential technical and analytical capabilities in data science and big data analytics among college students. An empirical study is carried out through a quantitative analysis of teaching data in Data Science and Big Data Technology. The results validate the effectiveness of the proposed strategies.

1. Introduction

Over the past decade, the role of big data and its associated technologies has grown substantially, with its importance becoming more evident over time[1-4]. A growing number of colleges and universities in China, as with educational institutions worldwide, have introduced majors focused on big data. For example, Suqian University, where we are affiliated, has introduced the Data Science and Big Data Technology major[1]. As higher education institutions accumulate experience in teaching these subjects and encounter new challenges, optimizing the curricula of big data-related majors becomes essential[1,2,4]. In this paper, inspired by emerging trends in big data education and the experience gained by our teaching team, we continue exploring strategies to optimize the curriculum of the Data Science and Big Data Technology major.

Recent studies have explored various strategies for optimizing curricula in the Data Science and Big Data Technology major to align with industry needs and pedagogical innovations[1-4]. Wang et al. [1] demonstrated the effectiveness of Improving the course of Mathematical Modeling in enhancing students' professional competencies. Li et al. [2] investigated the integration of ideological and political education with innovation and entrepreneurship training in mobile big data courses. Chen [3] adopted an Outcome-Based Education (OBE) perspective to redesign the Data Science and Big Data Technology curriculum. Zhang et al. [4] addressed interdisciplinary training in new engineering disciplines, advocating for foundational courses in Data Science and Big Data Technology. This study investigates effective strategies for optimizing the curriculum of big data-related majors by adopting an approach centered on enhancing key courses. Specifically, it examines the Data Science and Big Data Technology major, analyzing and exploring various methods to improve the educational framework. By reviewing the afore-mentioned references, we conclude that among the various approaches to curriculum optimization, enhancing key courses is one of the most effective strategies. Furthermore, among the objectives of curriculum optimization, the most prominent is the improvement of college students’ professional competence. Therefore, the primary goal in this paper is to strengthen students’ professional capabilities. Wang et al. [5] investigated curriculum optimization in Mathematics Education by improving key courses, such as Elementary Mathematics Research, and linking them to innovation literacy. Inspired by this, we take Mathematical Modeling as a case study to explore strategies for optimizing curriculum of Data Science and Big Data Technology aimed at enhancing college students’ professional capabilities.

The rest of the paper is organized as follows. In Section 2, we explain in detail the curriculum’s role in fostering the professional competencies of college students. In Section 3, we propose several strategies for optimizing the curriculum of the Data Science and Big Data Technology major through Improving the course of Mathematical Modeling. In Section 4, we perform an empirical study based on our teaching team’s experience. In Section 5, we present several concluding remarks.

2. Existing curriculum challenges in the major of Data Science and Big Data Technology

In this section, our main aim is to explain several key challenges in the academic training of students majoring in Data Science and Big Data Technology. Despite growing industry demand, the current curriculum often fails to fully support students in developing the essential skills needed for real-world data science tasks. Specifically, many students demonstrate deficiencies in foundational mathematical competencies, such as linear algebra, probability, and optimization. Additionally, the curriculum often lacks applied, project-based learning experiences, limiting practical skill development. Lastly, there is insufficient integration of real-world big data applications, reducing students’ exposure to relevant tools, datasets, and industry practices.

2.1. Deficiencies in foundational mathematical competencies for students majoring in Data Science and Big Data Technology

Students majoring in Data Science and Big Data Technology often exhibit deficiencies in foundational mathematical competencies, limiting their ability to develop and apply advanced analytical models. Key gaps include Linear Algebra, Probability Theory, Statistics, and Optimization, which are fundamental for machine learning, data mining, and large-scale data analysis. Many students struggle with mathematical abstraction, formal reasoning, and algorithmic thinking, which impairs their ability to construct and validate predictive models. Additionally, inadequate exposure to numerical methods, mathematical modeling, and computational optimization weakens their problem-solving capabilities. Strengthening these areas through curriculum enhancements, project-based learning, and interdisciplinary integration is essential for improving professional competency and fostering innovation in data-driven industries.

2.2. Limited engagement with applied, project-based learning approaches

Based on our experience and revealed by surveying the collected data, Students majoring in Data Science and Big Data Technology often experience limited engagement with applied, project-based learning approaches, which are essential for bridging the gap between theoretical knowledge and real-world applications. Traditional curricula frequently emphasize mathematical theories, statistical models, and algorithmic principles without providing sufficient opportunities for hands-on implementation. As a result, students may struggle with data pre-processing, feature engineering, and model deployment, which are critical for industry applications. Furthermore, the lack of structured problem-solving exercises, case studies, and real-world datasets reduces students' ability to develop practical intuition and analytical thinking when handling complex data-driven challenges. Many courses rely on standardized assignments rather than open-ended projects, limiting students' exposure to exploratory analysis and decision-making under uncertainty. Additionally, insufficient collaboration with industry partners or cross-disciplinary project-based coursework hinders students from understanding real-time data processing, cloud computing environments, and large-scale machine learning frameworks. Incorporating project-based learning, internships, and interdisciplinary collaborations into the curriculum is essential to cultivate problem-solving abilities, innovation, and job readiness in the evolving data science landscape.

2.3. Insufficient integration of real-world big data applications

Students majoring in Data Science and Big Data Technology often face insufficient integration of real-world big data applications in their academic curriculum, which limits their ability to apply theoretical concepts to practical industry problems. Many programs emphasize fundamental theories in statistics, machine learning, and database management but fail to provide opportunities for working with large, unstructured, and dynamic datasets commonly encountered in real-world scenarios. This lack of exposure prevents students from understanding the complexities of data collection, pre-processing, and real-time analytics in domains such as finance, healthcare, e-commerce, and cyber-security. Moreover, many courses rely on simplified or pre-processed datasets, which do not reflect the challenges of handling noisy, imbalanced, or high-dimensional data. As a result, students often graduate without the necessary experience in scalable data processing, cloud computing platforms, or distributed computing frameworks like Hadoop and Spark. Additionally, limited industry collaboration and case studies reduce students' ability to engage with real-time data streams, business intelligence, and decision-making processes. To address these gaps, curriculum enhancements should incorporate hands-on projects, internships, industry partnerships, and capstone projects that simulate real-world data challenges, which will better prepare students for careers in data-driven industries, fostering innovation, critical thinking, and technical proficiency.

3. Strategies for optimizing the curriculum of the Data Science and Big Data Technology major through improving the course of Mathematical Modeling

In this section, we discuss strategies for enhancing the curriculum of the Data Science and Big Data Technology major by leveraging improving the course of Mathematical Modeling. As the fields of data science and big data evolve rapidly, keeping the curriculum relevant and aligned with industry demands is essential to preparing students for real-world challenges. Improving the course of Mathematical Modeling involves collaboration between academic institutions and industry partners, enabling students to gain practical insights, hands-on experience, and skills that are directly applicable to the workforce. This section will explore various strategies for curriculum optimization, including reducing lecture time for theoretical courses, increasing focus on practical ones, reorganizing course sequences, establishing collaborative courses with industry partners, and enhancing evaluation methods by integrating industry perspectives, all aimed at equipping students with the knowledge and competencies necessary to thrive in the data-driven job market.

3.1. Enhancing core theoretical content

Optimizing the curriculum of the Data Science and Big Data Technology major involves refining core theoretical content to ensure students develop the essential skills needed to excel in the field. A key aspect of this optimization is enhancing courses like Mathematical Modeling, which plays a crucial role in shaping students' understanding of data analysis and problem-solving techniques. Mathematical Modeling serves as a foundation for data science, offering students the tools to translate real-world problems into mathematical representations. By improving this course, students can be better equipped with the theoretical knowledge to develop algorithms, perform statistical analysis, and predict trends in complex data sets. One approach to enhancing Mathematical Modeling is to incorporate more advanced topics, such as optimization techniques, machine learning, and computational statistics, which are vital for analyzing large data. Additionally, integrating hands-on projects or case studies can help students apply theoretical concepts to real-world challenges, deepening their understanding and improving problem-solving skills. Collaboration with industry professionals and exposure to cutting-edge technologies can further enhance the curriculum, ensuring it remains relevant to the rapidly evolving data science field. Ultimately, strengthening core courses like Mathematical Modeling will not only provide students with a solid theoretical foundation but also enable them to adapt to new developments in Data Science and Big Data Technology, making them more competitive and successful in their careers.

3.2. Incorporating practical and project-based learning

Optimizing the Data Science and Big Data Technology curriculum can be achieved by incorporating practical and project-based learning, particularly in courses like Mathematical Modeling. While theoretical knowledge is important, hands-on experience is crucial for preparing students for real-world challenges. By integrating practical projects, students can apply mathematical concepts to solve actual problems, making the learning process more engaging and relevant.For instance, students could work on data modeling projects involving real datasets from domains such as healthcare, finance, marketing, or environmental science. These projects would provide experience in building predictive models, performing statistical analysis, data preprocessing, and visualizing insights using tools like Python, R, or Tableau. Incorporating cross-disciplinary problems also encourages creativity and systems thinking.

This approach not only reinforces theoretical understanding but also hones problem-solving, analytical reasoning, and critical-thinking skills. Furthermore, collaboration on group projects fosters teamwork, leadership, and communication skills, all of which are essential in today's data-driven industry. Moreover, students exposed to such practical experiences are more likely to develop a strong portfolio of work, which enhances their competitiveness in job markets and graduate programs. Ultimately, integrating project-based learning into Mathematical Modeling not only aligns the curriculum with industry expectations but also empowers students with the confidence and competence needed for success in their professional careers.

3.3. Interdisciplinary integration

Optimizing the curriculum of the Data Science and Big Data Technology major can be achieved through interdisciplinary integration, particularly in courses like Mathematical Modeling. Data science is inherently interdisciplinary, requiring expertise from fields such as mathematics, computer science, statistics, and domain-specific knowledge. To better prepare students for the challenges of the industry, it's essential to integrate diverse disciplines into core courses like Mathematical Modeling. Mathematical Modeling, which traditionally focuses on creating mathematical representations of real-world problems, can be optimized by incorporating interdisciplinary elements. Collaboration with fields like economics, engineering, biology, or social sciences can provide students with a broader perspective on how mathematical models are applied in different industries. This integration can be achieved through case studies, projects, and examples from various sectors, which would help students understand how mathematical techniques solve practical problems in fields such as healthcare, finance, or environmental science. Additionally, blending knowledge from computer science and statistics with mathematical modeling techniques can help students better understand algorithmic development, machine learning, and big data analysis. Exposure to programming languages like Python, R, or MATLAB, commonly used in data science, can be woven into the curriculum alongside traditional mathematical content, providing students with a comprehensive skill set. Moreover, fostering collaborations between different departments or inviting guest lecturers from diverse fields can enrich the curriculum. This approach not only enhances students' theoretical knowledge but also equips them with the interdisciplinary skills necessary to tackle complex, real-world problems in data science. Incorporating interdisciplinary integration in Mathematical Modeling, and other core courses, ensures students are not only proficient in mathematical theory but also capable of applying their skills across a wide range of domains, preparing them for diverse career paths in data science and big data technology.

3.4. Teaching methodology improvements

Optimizing the curriculum of the Data Science and Big Data Technology major can be greatly enhanced through improvements in teaching methodologies, especially in courses like Mathematical Modeling. Traditional teaching methods often focus heavily on lectures and theory, but adopting more interactive, student-centered approaches can better engage learners and improve retention. For example, incorporating active learning strategies into Mathematical Modeling can help students apply theoretical concepts in real-world contexts. Techniques like problem-based learning (PBL) or flipped classrooms, where students learn foundational concepts before class and use class time for practical problem-solving, can make learning more dynamic and relevant. This allows students to work on complex mathematical models in groups, fostering collaboration and critical thinking. Additionally, integrating technology into teaching can significantly enhance the learning experience. Using data visualization tools, simulations, or software like MATLAB or Python can give students hands-on experience with the tools used in the industry.

Incorporating peer reviews or project-based assessments, where students create and present models, can also improve communication skills and build confidence. These activities encourage students to articulate their ideas clearly, defend their modeling choices, and provide constructive feedback to peers—skills that are highly valuable in collaborative work environments. By engaging in such interactive practices, students also develop a deeper understanding of core concepts through discussion and reflection. Additionally, presenting their work to an audience simulates real-world scenarios, helping them become more comfortable with professional communication. By diversifying teaching methods, such as through active learning, flipped classrooms, and the use of interactive technologies like simulation software and collaborative coding platforms, the Mathematical Modeling course can better equip students with both theoretical knowledge and practical skills. Integrating digital tools not only modernizes the learning environment but also exposes students to technologies commonly used in industry. Altogether, these strategies enhance students' preparedness for diverse roles in data science and big data technology, bridging the gap between academia and industry expectations.

3.5. Enhancing evaluation methods

Optimizing the curriculum of the Data Science and Big Data Technology major can be significantly improved by enhancing evaluation methods, particularly in courses like Mathematical Modeling. Traditional assessment methods, such as exams and quizzes, may not fully capture a student's ability to apply concepts in real-world contexts. To better assess student learning and skill development, more diverse and dynamic evaluation techniques should be implemented. One approach is to incorporate project-based assessments, where students create mathematical models to solve practical problems. This type of evaluation allows instructors to assess not only theoretical understanding but also the ability to apply concepts in real-life scenarios, a critical skill in data science. For example, students could work on a team project involving large datasets to model real-world phenomena, such as predicting consumer behavior or optimizing supply chain logistics. This would test their ability to build models, analyze data, and present findings. Additionally, peer assessments and self-assessments can provide valuable feedback on collaborative work and individual progress. These methods encourage reflection on learning, fostering deeper engagement with the material. Continuous assessment through smaller, incremental assignments, such as coding tasks or short reports, can also help track student progress over time and ensure that learning objectives are being met consistently. By moving beyond traditional exams and incorporating project-based, peer, and continuous assessments, the Mathematical Modeling course can better evaluate a student's practical skills, critical thinking, and collaborative abilities, all of which are crucial for success in the data science field.

4. An empirical study based on Factor Analysis (FA)

In recent years, our teaching team has systematically collected a substantial amount of instructional data related to the Data Science and Big Data Technology major. Building on the practical experience of our teaching team, we sought to identify effective approaches for enhancing the curriculum within our affiliated university. To achieve this, we applied factor analysis to explore how enhancements in the Mathematical Modeling course may impact the development of professional capability among students majoring in Data Science and Big Data Technology.

We first conducted the KMO (Kaiser-Meyer-Olkin) test and Bartlett's test of sphericity on the collected data to assess its suitability for factor analysis, to obtain Table 1.

Table 1: The KMO test and Bartlett's test.

KMO statistic	0.9573	
Bartlett's statistic	χ^2	317
	df	27
	p-value	0.0035

By computation, we find that $\text{KMO} = 0.9573 > 0.9$ and $\text{p-value} = 0.0035 < 0.05$. This reveals that our collected teaching data is sufficiently comprehensive and statistically suitable for factor analysis. We conducted a factor analysis, to specify the factors F_i, $i=1,2,3,4,5$, and applied rotation to the factor loadings to clearly identify the underlying factors, to obtain the scree plot (Figure 1) and the rotated factor loadings (Table 2).

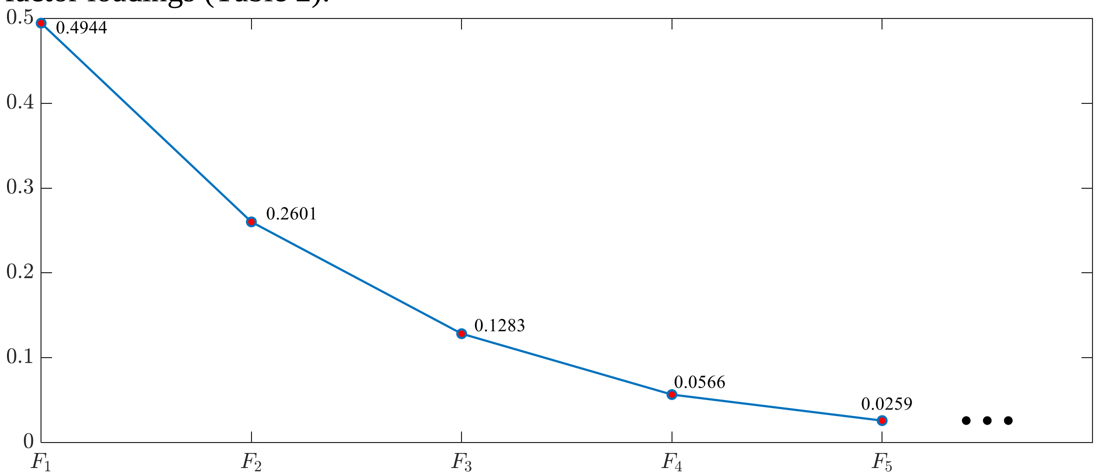

Figure 1: Scree plot during factor analysis.

Table 2: Factors and the rotated factor loadings.

Variables	The rotated factor loadings				
	Factor F_1	Factor F_2	Factor F_3	Factor F_5	Factor F_5
Design collaborative projects across disciplines	0.2312	0.1629	0.0499	0.7321	−0.0048
Align assessments with real-world competency frameworks	−0.1247	0.7992	−0.1251	0.0779	−0.0332
Improve teaching methods	0.1317	0.1348	0.7912	−0.0326	0.1111
Practical learning	0.7892	−0.1356	0.0541	0.0034	−0.0174
Incorporate real-world applications and case studies	0.0741	0.1334	0.1111	0.1782	0.8137
Adopt reflective and self-assessment techniques	−0.1349	0.8473	−0.1464	0.1021	0.1958
Project-based learning	0.8963	−0.0935	0.2012	0.1294	0.0198
Implement active learning strategies	0.1049	−0.1704	0.9012	0.2024	−0.0089
Teaching problem solving	−0.0949	0.0318	0.1069	−0.1844	0.7936
Create interdisciplinary courses or modules	0.1294	0.1510	0.0480	0.8143	−0.0974

By reviewing Figure 1, we observe that the cumulative variance contribution of the first three extracted Factors F_i, $i=1,2,3$, reaches approximately 88.29%, indicating that these three factors together explain a substantial proportion of the total variance in the dataset. When five factors are considered, i.e., F_i, $i=1,2,3,4,5$, the cumulative variance contribution increases to approximately 96.53%, capturing nearly all the information in the original variables. While including more factors may slightly increase explanatory power, it also introduces complexity and the risk of overfitting. Therefore, based on the principles of parsimony, interpretability, and statistical adequacy, we select the first three factors F_1, F_2, F_3 for further analysis. This decision strikes a balance between model simplicity and explanatory power, ensuring that the retained factors capture the most significant underlying structure of the data while maintaining robustness and generalizability. Consequently, subsequent factor rotation and interpretation will be based on this three-factor solution.

In Factor F_1, the factor loadings for practical learning and project-based learning are 0.7892 and 0.8963, respectively. These high loading values indicate a strong association between the factor and these two variables. Therefore, this factor can be interpreted as representing the theme of incorporating practical and project-based learning, highlighting the emphasis on hands-on, experiential learning approaches within the educational context. Within Factor F_2, the variables aligning assessments with real-world competency frameworks and adopting reflective and self-assessment techniques show factor loadings of 0.7992 and 0.8473, respectively. These substantial loading values suggest a strong linkage between the factor and these evaluation-related strategies. As such, this factor can be interpreted as reflecting the underlying theme of improving assessment practices, with a focus on promoting authentic, reflective, and learner-centered evaluation methods. In Factor F_3, the items improve teaching methods and implement active learning strategies have high factor loadings of 0.7912 and 0.9012, respectively. These strong loadings indicate a close relationship between this factor and the enhancement of instructional practices. Therefore, this factor can be interpreted as representing the theme of advancing teaching methodologies, particularly through the adoption of more interactive and student-centered approaches. And similarly, the factors F_4 and F_5 can be interpreted as representing the theme of interdisciplinary integration and enhancing core theoretical content, respectively.

Based on the case study, we conclude that enhancing core theoretical content, incorporating practical and project-based learning, interdisciplinary integration, teaching methodology improvements, and enhancing evaluation methods are all effective strategies for improving the curriculum of the Data Science and Big Data Technology major. Collectively, these components account for approximately 96.53% of the total contribution. Among these strategies, incorporating practical and project-based learning, enhancing evaluation methods, and improving teaching methodologies emerge as the most prominent and impactful approaches for enhancing the curriculum of the Data Science and Big Data Technology major. Together, these three components account for approximately 88.29% of the total contribution. Building on the findings presented above, we have initiated specific curriculum optimization efforts for the Data Science and Big Data Technology major at Suqian University, our affiliated institution.

5. Conclusions

This study explores and evaluates effective strategies for enhancing the Data Science and Big Data Technology curriculum by focusing on the optimization of the Mathematical Modeling course, with the goal of strengthening students' professional competencies. We highlighted the critical role that curriculum design plays in cultivating essential skills for students in this major. Several targeted strategies were proposed to refine the curriculum through improvements in Mathematical Modeling instruction. To support our approach, we carried out, with factor analysis as the main tool, an empirical investigation based on practical teaching experiences from our instructional team. The findings offer meaningful guidance for higher education institutions seeking to implement similar improvements in Mathematical Modeling courses, not only within Data Science and Big Data Technology programs but also in related academic disciplines.

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