



Hybrid Teaching in Data Science Education: Evaluating Its Impact on Learning Outcomes, Student Engagement, and Student Satisfaction at a Chinese University

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Abstract: This study aims to evaluate the effectiveness of hybrid teaching in enhancing learning outcomes, learning engagement, and student satisfaction in university-level data science education. A convergent mixed-methods design was employed to integrate quantitative and qualitative evidence from a Data Preprocessing course at Y University, China. The study involved 242 undergraduate students, comprising 122 students in the hybrid teaching group and 120 students in the conventional lecture-based group. Data were collected using validated five-point Likert-scale questionnaires, academic performance records, and semi-structured interviews. Quantitative data were analyzed using descriptive statistics, reliability and validity analyses, independent-samples *t*-tests, Pearson correlation analysis, and multiple linear regression, while qualitative data were analyzed using thematic analysis. The results showed that students in the hybrid teaching group achieved significantly higher theoretical examination scores ($M = 76.45$ vs. 74.04 , $p = .023$), practical performance scores ($M = 84.91$ vs. 75.97 , $p < .001$), and overall academic achievement scores ($M = 81.53$ vs. 75.20 , $p < .001$) than those in the conventional instruction group. Learning engagement emerged as the strongest predictor of overall satisfaction ($\beta = .455$, $p < .001$), followed by knowledge mastery and skill enhancement ($\beta = .228$, $p < .05$). Qualitative findings further indicated that students valued the flexibility of self-paced learning, collaborative classroom interactions, and authentic programming experiences. Overall, the findings suggest that hybrid teaching is a promising approach for supporting academic achievement, practical competencies, learning engagement, and student satisfaction. The findings support the integration of hybrid learning into data science curricula by combining flexible digital learning resources with face-to-face programming practice, collaborative problem-solving, and authentic data-processing activities.

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Introduction

Data science has become one of the most strategic disciplines in the era of digital transformation, driven by the rapid advancement of artificial intelligence, big data analytics, cloud computing, and intelligent decision-making systems across various industrial sectors. The increasing dependence of governments, businesses, healthcare organizations, financial institutions, and educational sectors on data-driven solutions has substantially expanded the demand for graduates equipped with advanced analytical, computational, and problem-solving competencies. Consequently, higher education institutions are expected to develop learning environments that effectively integrate theoretical knowledge with practical technical skills to prepare students for increasingly complex professional challenges (Abid et al., 2025; Alzoraiki et al., 2023; J. Zhang & Huang, 2022). Data science education therefore requires instructional approaches that enable students to simultaneously master statistical



reasoning, programming, machine learning, data visualization, and real-world data analysis through meaningful learning experiences. However, conventional lecture-based instruction frequently provides limited opportunities for active participation, collaborative problem-solving, authentic project implementation, and continuous practical application, resulting in a persistent gap between conceptual understanding and professional competence (Cahyani, 2025; Lopez et al., 2025; Shqipe, 2023). These pedagogical limitations have become a major concern because inadequate instructional strategies may reduce students' engagement, technological readiness, and confidence in applying data science knowledge to practical contexts. Therefore, improving instructional quality has become an important priority for universities seeking to enhance graduate competitiveness, strengthen learning effectiveness, and support sustainable innovation in higher education through technology-enhanced teaching approaches (Erna, 2026; Fan, 2025; Parveen et al., 2022).

Despite the increasing adoption of hybrid teaching in higher education, defined here as integrating self-paced online resources with face-to-face collaborative programming and problem-solving activities, evidence regarding its effectiveness in data science education remains limited across institutional contexts. Unlike conventional lecture-based instruction, hybrid teaching combines flexible digital learning with structured practical activities. Previous studies have primarily examined hybrid learning in general education or broad STEM disciplines, emphasizing academic achievement and technology acceptance rather than the multidimensional learning processes required in data science (Achi et al., 2025; Muguerza et al., 2025; Windasari, 2024). Data science education requires students to integrate theoretical knowledge with programming, computational thinking, and authentic data manipulation, demanding a balance between conceptual understanding and hands-on practice (Tucaliuc et al., 2023, 2025; C. Zhang et al., 2025). Consequently, findings from other disciplines may not fully represent the specific pedagogical demands of data science. Evidence also remains limited in newly established universities and developing educational systems, where infrastructure, lecturer readiness, and prior learning experiences may influence implementation. Therefore, further investigation is needed to examine learning outcomes, engagement, practical competencies, and satisfaction and inform instructional design for data science education (Kaya, 2023; Yong & Zhang, 2025; Yu & Jang, 2024).

Addressing these research gaps, the present study proposes a comprehensive evaluation of hybrid teaching implementation in a university-level Data Preprocessing course within the context of data science education. Data Preprocessing provides an appropriate pedagogical context for evaluating hybrid teaching because it requires students to integrate conceptual understanding with intensive hands-on activities, including programming, data cleaning and manipulation, debugging, and problem solving. These characteristics allow theoretical concepts to be learned through flexible online resources and subsequently reinforced through collaborative face to face practice. Unlike previous studies that have predominantly focused on academic achievement or technology acceptance, this research integrates learning outcomes, learning engagement, comparative perceptions of hybrid instruction, and student satisfaction into a unified analytical framework to provide a more comprehensive understanding of hybrid teaching effectiveness. Specifically, the study investigates how hybrid teaching contributes to students' conceptual understanding, practical skill development, classroom engagement, and overall learning experiences while considering the influence of demographic characteristics, including gender, academic performance, and previous hybrid learning experience. By combining pedagogical, technological, and learner-centered perspectives, this study offers a broader explanation of



the mechanisms through which hybrid teaching enhances learning quality in technically demanding disciplines. Therefore, this study aims to evaluate the effectiveness of hybrid teaching in strengthening students' competencies, improving learning engagement and satisfaction, and providing evidence-based recommendations for optimizing data science education in higher education.

Research Method

This study employed a mixed-methods research design using a convergent approach (Creswell & Plano Clark, 2018; Feters et al., 2013) to comprehensively evaluate the effectiveness of hybrid teaching in the Data Preprocessing course within the Data Science program at Y University. The mixed-methods design was selected because it enables the integration of quantitative evidence regarding students' learning outcomes, engagement, comparative perceptions, and satisfaction with qualitative insights into their learning experiences, thereby providing a more comprehensive understanding of hybrid teaching implementation than either approach alone (Khafid, 2026; Üztemur et al., 2026). The quantitative component examined differences in academic achievement and students' perceptions of the hybrid learning environment through structured questionnaire data and course performance records, while the qualitative component explored students' experiences, perceived benefits, learning challenges, and recommendations through semi-structured interviews. Both quantitative and qualitative data were collected during the same research period, analyzed independently using appropriate analytical procedures, and subsequently integrated during the interpretation stage (Creswell & Plano Clark, 2018; Feters et al., 2013) to strengthen the validity and comprehensiveness of the findings. This methodological framework allowed the study to investigate measurable educational outcomes of hybrid teaching as well as contextual factors influencing students' engagement, learning autonomy, practical skill development, and overall satisfaction, thereby generating evidence-based recommendations for improving hybrid teaching practices in higher education, particularly within technically demanding data science courses.

The participants in this study consisted of undergraduate students enrolled in the Data Preprocessing course within the Data Science program at Y University during the 2023–2024 academic year. A purposive sampling technique was employed to select participants who had direct experience with the implementation of the hybrid teaching model. The experimental group comprised 122 third-year students who participated in hybrid instruction integrating online learning resources, including recorded lectures, coding exercises, digital handbooks, and self-paced learning materials, with face-to-face sessions emphasizing collaborative programming, debugging, dataset manipulation, and problem-solving activities. For comparative purposes, a control group of 120 students from the previous academic cohort who received conventional lecture-based instruction was included to evaluate differences in learning outcomes between the two instructional approaches. Quantitative data were collected using a structured five-point Likert-scale questionnaire consisting of 14 items across four dimensions: Knowledge Mastery and Skill Enhancement, Learning Engagement and Autonomy, Comparative Perception with Traditional Models, and Overall Satisfaction. Supplementary academic performance data, including examination scores, coding assignments, quizzes, and project-based assessments, were obtained from official course records. To complement the quantitative findings, semi-structured interviews were conducted with [XX] students from the hybrid learning group, who were purposively selected based on [selection criteria] to ensure that participants had direct and relevant experience with the



hybrid teaching model. The interview data were transcribed verbatim and analyzed thematically using [NVivo/ATLAS.ti/manual coding] to identify recurring themes related to learning experiences, perceived benefits, implementation challenges, and recommendations for improving hybrid teaching practices in data science education.

Data analysis was conducted through a sequence of quantitative and qualitative procedures to comprehensively evaluate the effectiveness of hybrid teaching in the Data Preprocessing course. Prior to hypothesis testing, the collected questionnaire data were screened to identify incomplete responses, coding inconsistencies, missing values, and potential outliers to ensure data quality and analytical accuracy. Descriptive statistical analyses, including frequencies, percentages, means, and standard deviations, were performed to summarize participants' demographic characteristics and students' perceptions across the four measured dimensions: Knowledge Mastery and Skill Enhancement, Learning Engagement and Autonomy, Comparative Perception with Traditional Models, and Overall Satisfaction. Instrument reliability was evaluated using Cronbach's alpha coefficient, while construct validity was examined using the Kaiser–Meyer–Olkin (KMO) measure, Bartlett's Test of Sphericity, and exploratory factor analysis. Pearson correlation analysis was subsequently employed to examine relationships among the research variables, followed by multiple linear regression analysis to determine the extent to which Knowledge Mastery and Skill Enhancement, Learning Engagement and Autonomy, and Comparative Perception with Traditional Models predicted students' Overall Satisfaction. Furthermore, qualitative interview data were transcribed verbatim and analyzed thematically to identify recurring patterns related to students' learning experiences, perceived benefits, implementation challenges, and recommendations.

Results and Discussion

The findings demonstrate that the implementation of the hybrid teaching model produced consistently better learning outcomes than the conventional lecture-based approach across all assessed performance indicators. Comparative analysis between the experimental group, which participated in hybrid instruction, and the control group, which received traditional teaching, revealed statistically significant improvements in theoretical achievement, practical performance, and overall academic achievement. Students in the hybrid learning group achieved a higher mean score in theoretical examinations ($M = 76.45$, $SD = 7.72$) than those in the traditional learning group ($M = 74.04$, $SD = 8.60$), with the difference reaching statistical significance ($t = -2.29$, $p = 0.023$). More substantial improvements were observed in practical performance, where the hybrid group obtained a mean score of 84.91 ($SD = 5.15$), exceeding the traditional group ($M = 75.97$, $SD = 6.24$) by 8.94 points ($t = -12.20$, $p < 0.001$). Similarly, students exposed to hybrid teaching demonstrated significantly higher overall academic performance ($M = 81.53$, $SD = 4.19$) than their counterparts receiving conventional instruction ($M = 75.20$, $SD = 4.86$), with a highly significant statistical difference ($t = -10.80$, $p < 0.001$). These findings indicate that integrating online learning resources with face-to-face collaborative activities provides meaningful advantages for improving both conceptual understanding and practical competencies in data science education, particularly in courses requiring intensive programming practice and authentic data preprocessing skills.



Table 1. Demographic Characteristics of Students in the Hybrid Learning Group

Variable	Type	Frequent (people)	Percentage (%)
Gender	Male	57	46.72
	Female	65	53.28
Rank of marks	top 20%	26	21.31
	20% - 50%	33	27.05
	50% - 80%	43	35.25
	lowest 20%	20	16.39
Hybrid learning experience	No	85	69.67
	Yes	37	30.33

Table 1 presents the demographic characteristics of the participants involved in this study. Of the 122 participants, 65 (53.28%) were female and 57 (46.72%) were male, indicating a relatively balanced gender distribution. Based on academic ranking, the largest proportion of participants belonged to the 50%–80% category (35.25%), followed by the 20%–50% category (27.05%), the top 20% (21.31%), and the bottom 20% (16.39%). Regarding previous hybrid learning experience, most participants (69.67%) reported having no prior experience with hybrid learning, while 30.33% had previously participated in hybrid learning activities, reflecting limited exposure to this instructional approach before the study.

Table 2. Descriptive Statistics of the Measurement Items Across Research Dimensions

Dimension	Item	Measurement Item	Mean	SD	Skewness	Kurtosis	Cronbach's α
Knowledge and Skills	Q1	Principle Understanding	3.7	0.93	-0.15	-0.91	[$\alpha = \dots$]
	Q2	Coding Ability	3.65	0.9	-0.21	-0.44	
	Q3	Tool Usage	3.75	0.91	-0.22	-0.54	
	Q4	Project Capability	3.72	0.83	-0.24	-0.49	
Learning Engagement	Q5	Extracurricular Research	3.64	0.93	-0.22	-0.55	[$\alpha = \dots$]
	Q6	Classroom Interaction	3.61	0.88	-0.11	-0.72	
	Q7	Help Seeking Collaboration and	3.62	0.91	-0.3	-0.44	
	Q8	Communication	3.78	0.89	0.02	-1.06	
Comparative Perception	Q9	Personalized Pace Effect	3.71	0.91	-0.31	-0.71	[$\alpha = \dots$]
	Q10	Superiority	3.61	0.91	-0.27	-0.18	
	Q11	Memory Retention	3.59	0.95	-0.09	-0.7	
Satisfaction	Q12	Curriculum Arrangement	3.71	0.92	-0.35	-0.16	[$\alpha = \dots$]
	Q13	Resource Coordination	3.71	0.9	-0.17	-0.79	
	Q14	Overall Effect	3.7	0.88	-0.41	-0.17	



Table 2 presents the descriptive statistics and internal consistency reliability of the 14 measurement items across the four research dimensions: Knowledge and Skills, Learning Engagement, Comparative Perception, and Satisfaction. The mean scores ranged from 3.59 to 3.78, indicating that students generally expressed positive perceptions of the hybrid teaching approach. Collaboration and Communication recorded the highest mean score ($M = 3.78$, $SD = 0.89$), whereas Memory Retention showed the lowest mean score ($M = 3.59$, $SD = 0.95$). The standard deviations ranged from 0.83 to 0.95, indicating moderate variability in students' responses. In addition, the skewness values ranged from -0.41 to 0.02 , while the kurtosis values ranged from -1.06 to -0.16 , indicating acceptable distributional characteristics for subsequent statistical analyses. The Cronbach's alpha coefficients for Knowledge and Skills ($\alpha = [XX]$), Learning Engagement ($\alpha = [XX]$), Comparative Perception ($\alpha = [XX]$), and Satisfaction ($\alpha = [XX]$) demonstrated the internal consistency reliability of each measurement dimension. Overall, these results indicate that the measurement items exhibited appropriate descriptive characteristics and internal consistency for further analysis.

Table 3. Independent-Samples t-Test Results for Academic Performance

Academic Performance	Hybrid Group M (SD)	Conventional Group M (SD)	Mean Difference	t	p
Theoretical Examination	76.45 (7.72)	74.04 (8.60)	2.41	-2.29	0.023
Practical Performance	84.91 (5.15)	75.97 (6.24)	8.94	-12.20	< .001
Overall Academic Achievement	81.53 (4.19)	75.20 (4.86)	6.33	-10.80	< .001

As presented in Table 3, the independent-samples t-test revealed statistically significant differences between the hybrid and conventional groups across all three academic performance indicators. The hybrid group achieved higher theoretical examination scores ($M = 76.45$, $SD = 7.72$) than the conventional group ($M = 74.04$, $SD = 8.60$), $t = -2.29$, $p = .023$. The difference was more pronounced for practical performance, with the hybrid group achieving $M = 84.91$ ($SD = 5.15$) compared with $M = 75.97$ ($SD = 6.24$) for the conventional group, $t = -12.20$, $p < .001$. Overall academic achievement was also significantly higher in the hybrid group ($M = 81.53$, $SD = 4.19$) than in the conventional group ($M = 75.20$, $SD = 4.86$), $t = -10.80$, $p < .001$.

Table 4. Multiple Linear Regression Predicting Overall Satisfaction

Predictor	Standardized β	p	Interpretation
Knowledge Mastery and Skill Enhancement	0.228	< .05	Significant
Learning Engagement and Autonomy	0.455	< .001	Significant
Comparative Perception with Traditional Models	—	> .05	Not significant

As shown in Table 4, multiple linear regression analysis indicated that Learning Engagement and Autonomy was the strongest significant predictor of Overall Satisfaction ($\beta = .455$, $p < .001$), followed by Knowledge Mastery and Skill Enhancement ($\beta = .228$, $p < .05$). Comparative Perception with Traditional Models did not remain a statistically significant predictor after controlling for the other variables. These findings indicate that students' engagement and autonomy contributed most strongly to their overall satisfaction with the hybrid teaching model.

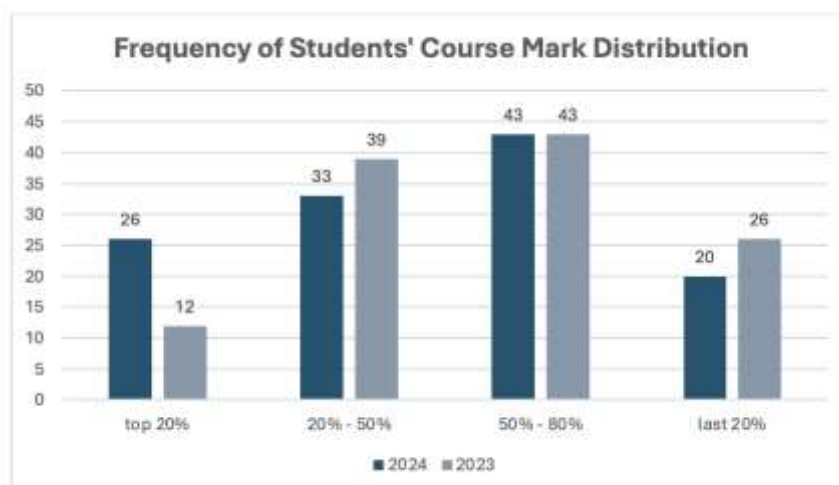


Figure 1. Frequency of Students' Course Mark Distribution

Figure 1 illustrates the distribution of students' final grades in the Data Preprocessing course across four academic performance categories for the 2023 and 2024 cohorts. Unlike the baseline GPA-based academic ranking reported in Table 1, Figure 2 specifically presents students' final course grades after completion of the Data Preprocessing course. The results show that the number of students in the top 20% category increased from 12 in 2023 to 26 in 2024. Meanwhile, the number of students in the 20%–50% category decreased from 39 to 33, whereas the 50%–80% category remained unchanged at 43 students in both cohorts. The number of students in the bottom 20% category also decreased from 26 in 2023 to 20 in 2024. Overall, the distribution indicates a shift toward higher final course performance in the 2024 cohort, characterized by an increase in students within the top 20% category and a decrease in those within the bottom 20% category.

Overall, the quantitative and qualitative findings consistently demonstrate the effectiveness of the hybrid teaching model in improving multiple dimensions of learning within the Data Preprocessing course. Comparative analysis revealed that students exposed to hybrid instruction achieved significantly higher theoretical examination scores, practical performance, and overall academic achievement than those receiving conventional lecture based instruction, with the greatest improvement observed in practical coding and dataset manipulation competencies. Descriptive analysis further indicated that students expressed positive perceptions across all evaluated dimensions, including Knowledge Mastery and Skill Enhancement, Learning Engagement and Autonomy, Comparative Perception with Traditional Models, and Overall Satisfaction, reflecting favorable acceptance of the hybrid learning environment. Instrument evaluation confirmed excellent measurement quality, as reliability and validity analyses demonstrated satisfactory internal consistency and construct validity, ensuring the robustness of subsequent statistical analyses. Pearson correlation analysis showed significant positive relationships among all research variables, indicating that improvements in knowledge mastery, engagement, comparative perceptions, and satisfaction were closely interconnected. Multiple linear regression analysis further revealed that Learning Engagement emerged as the strongest predictor of Overall Satisfaction ($\beta = 0.455$, $p < 0.001$), followed by Knowledge Mastery and Skill Enhancement ($\beta = 0.228$, $p < 0.05$), whereas Comparative Perception did not remain statistically significant after controlling for other variables. In addition, qualitative interview findings reinforced these quantitative results by indicating that students highly appreciated the flexibility of self-paced



online learning, collaborative classroom activities, immediate lecturer feedback, and authentic programming experiences, although several participants suggested further improvements in theoretical content reinforcement and classroom interaction. Collectively, these findings provide robust empirical evidence that hybrid teaching creates a comprehensive learning environment capable of strengthening academic achievement, practical competencies, student engagement, and learning satisfaction in university-level data science education while offering valuable guidance for future instructional improvement.

The findings demonstrate that hybrid teaching constitutes an effective instructional approach for university level data science education because it successfully integrates flexible online learning with collaborative face to face practice. The superior learning outcomes achieved by students in the hybrid group indicate that combining asynchronous learning materials, coding exercises, and classroom-based problem solving enables learners to acquire both conceptual understanding and practical competencies more effectively than conventional lecture-based instruction. These results are consistent with constructivist learning theory and the Community of Inquiry framework, which emphasize that meaningful learning emerges through active knowledge construction, social interaction, and sustained teaching presence within technology-supported environments. The positive perceptions observed across knowledge mastery, learning engagement, comparative evaluation, and overall satisfaction further suggest that hybrid instruction promotes learner autonomy while maintaining sufficient academic support during complex programming and data preprocessing activities.

The findings also imply that repeated access to digital learning resources encourages self-regulated learning, allowing students to revisit difficult concepts before applying them to authentic datasets during classroom sessions (Doğan, 2025; Ma, 2026; States, 2024). Furthermore, the integration of qualitative evidence strengthens the interpretation that students value the flexibility, collaborative experiences, and practical relevance offered by the hybrid model. Nevertheless, the effectiveness of hybrid teaching depends heavily on instructional design, technology integration, lecturer facilitation, and the alignment between online and face to face components. Therefore, universities should prioritize pedagogically structured hybrid environments that foster active participation, continuous feedback, authentic project-based learning, and sustainable development of professional data science competencies.

Conclusion

Based on the findings, this study concludes that hybrid teaching is an effective instructional approach for enhancing learning quality in university-level data science education, particularly in Data Preprocessing courses that require the integration of theoretical understanding and practical technical competencies. Empirical evidence demonstrates that students receiving hybrid instruction achieved significantly higher theoretical examination scores ($M = 76.45$ vs. 74.04 , $p = 0.023$), practical performance ($M = 84.91$ vs. 75.97 , $p < 0.001$), and overall academic achievement ($M = 81.53$ vs. 75.20 , $p < 0.001$) than students receiving conventional instruction, with the most substantial improvement observed in practical performance. Furthermore, multiple linear regression confirmed that Learning Engagement and Autonomy was the strongest predictor of Overall Satisfaction ($\beta = 0.455$, $p < 0.001$), followed by Knowledge Mastery and Skill Enhancement ($\beta = 0.228$, $p < 0.05$), demonstrating the important contribution of active engagement to students' satisfaction with hybrid learning. These findings indicate that combining flexible asynchronous resources with collaborative face to face programming, debugging, dataset



manipulation, and problem-solving activities can support both conceptual understanding and practical competency development. Overall, the study provides empirical support for designing hybrid data science courses that prioritize active engagement, authentic programming practice, learner autonomy, and meaningful interaction to strengthen academic performance and student satisfaction.

Recommendation

Instructors and curriculum designers are encouraged to strengthen hybrid teaching by integrating high-quality online learning resources with interactive face to face activities that promote active engagement, collaborative learning, and practical skill development. Particular emphasis should be placed on coding exercises, dataset manipulation, problem-solving activities, and project-based learning to connect theoretical knowledge with practical data science competencies.

Universities and educational policymakers should support the sustainable implementation of hybrid teaching by providing adequate technological infrastructure, reliable digital learning platforms, continuous technical support, and professional development programs for lecturers. Institutional policies should also establish clear quality standards for integrating online and face to face learning components and ensuring consistent implementation across courses.

Future research should examine additional factors that may influence hybrid teaching effectiveness, including digital literacy, learning motivation, self-regulated learning, instructor competency, and technological readiness. Longitudinal studies should investigate whether improvements in learning outcomes, practical competencies, engagement, and satisfaction are sustained over time. Multi-institutional and cross-disciplinary studies are also recommended to improve the generalizability of findings and determine whether similar effects occur across different educational contexts, student populations, academic disciplines, and institutional settings. Further evidence could guide sustainable hybrid practices.

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