Eng Int Syst (2026) 1: 119–127

Engineering
Intelligent Systems

Optimization of Course Sequence in Private Universities Based on Random Forest and Association Rules

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The learning process of college students is a gradual one. The study of prerequisite courses helps students build a knowledge foundation, enabling them to more easily achieve flow experience in subsequent courses, which has a significant impact on their course satisfaction. This study took 372 upgraded students majoring in Tourism Management at Guangzhou Vocational and Technical University of Science and Technology as samples. The study investigated their satisfaction with 15 professional courses and overall course satisfaction, conducted decision tree model and random forest model analyses to identify the important professional courses affecting overall course satisfaction, and then used the association rules model to mine the prerequisite courses of these important professional courses. The results show that Tourism Psychology, Ecotourism, Tourism English, Tourism Hospitality, and Tourism Consumer Behavior are important professional courses affecting overall course satisfaction, and there are valuable associations between important professional courses and other professional courses. The conclusion indicates that by scientifically formulating the teaching sequence of professional courses in private universities, this can significantly improve overall course satisfaction.

Keywords: flow theory, random forest, association rules, course sequence

1. RESEARCH BACKGROUND

Private universities, due to their self-financing operational model, face challenges such as inadequate facilities and equipment and higher tuition fees compared to public universities that receive substantial government subsidies. This puts them at a disadvantage in terms of enrollment numbers, often having to admit students with relatively weaker learning abilities. After entering university, these students generally show poor self-discipline: more than half do not listen attentively in class, and some even focus solely on their mobile phones, leading to them having poor post-graduate capabilities. Additionally, China's friendly political relations with Russia have led to political confrontations with the United States and the European Union, exerting significant negative impacts on the domestic economy. Official data shows that the post-graduate employment rate in 2024 was only 55.5%, with the actual situation likely being far more severe than official figures indicate. This dire employment situation and students' inadequate skills have resulted in private university students having difficulty finding employment, posing great challenges to school enrollment numbers.

To improve students' employment rate and enrollment competitiveness, private universities frequently add or replace teaching courses to increase curriculum attractiveness and align course offerings with economic and social development trends. However, due to insufficient research on the sequence of courses, the arbitrary insertion of courses has a negative impact on students' cognitive process, with serious implications for teaching effectiveness. How to follow objective laws,

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scientifically determine the priority of courses, and improve teaching satisfaction has become an urgent issue that private universities need to address.

2. LITERATURE REVIEW

Students' state of attentive listening in class is a type of flow experience. Flow theory posits that flow experience is a psychological state people enter when fully immersed in an activity. When students' knowledge foundation matches the challenge of new knowledge in class, they are more likely to enter this subjective state of flow, where they can concentrate strongly on the current activity, feel that time flies by, and truly enjoy the process. When students have a strong knowledge foundation but are not challenged enough by new course material, they may become bored. Conversely, when their knowledge foundation is weak but the challenge of new knowledge is strong they may become anxious.

Given the teaching practices in private universities, it is uncommon for students to feel bored because university courses are numerous and some are quite difficult. Due to their poor self-efficacy, when students lack a sufficient knowledge foundation and face strong challenges from having to acquire new knowledge, they rarely experience anxiety. Instead, they generally adopt an evasive mindset.

To better apply flow theory to guide students' learning, many scholars have proposed various solutions. First, teachers need to construct a virtual environment (including game environments), especially those built with advanced educational technologies, to help students generate flow experiences more easily. Lin and Wang developed a technology-enhanced mathematical board game and found that students' flow experiences were significantly improved compared to those using traditional mathematical board games, indicating that advanced educational technologies can create better virtual environments to enhance students' flow experiences [1]. Hu et al. constructed a virtual environment for the metaverse education system and verified that enhancing the interactivity, narrative quality, and sense of presence in the virtual environment can significantly strengthen students' flow experiences [2]. Dogan et al. confirmed that immersive VR with advanced educational technologies can significantly enhance students' flow experiences compared to desktop VR [3]. Husain et al. integrated gamification elements into flipped classrooms at the university level through modern educational technologies. The study found that the flow experience of the gamified flipped classroom group was better than that of the non-gamified group, suggesting that integrating gamification elements based on modern educational technologies into flipped classrooms can significantly improve students' flow experiences [4].

Second, some previous scholars have noted that virtual environments alone do not naturally generate flow experiences for students. Silva et al. created a quiz game environment based on classroom knowledge for accounting students but found no significant difference in their flow experiences compared to traditional teaching methods [5]. Chapman et al. verified that students performed better in gamified courses than in non-gamified ones, but observed no significant difference in flow experiences between the two types of courses [6].

Third, some scholars have pointed out that students must play or immerse themselves in roles within virtual environments, allowing their personal characteristics to play a role, in order to generate flow experiences. Qi created a virtual scenic environment and tour guide identity for tourism students, enabling them to generate flow experiences during the design of video demonstrations and online live broadcasts. Further verification revealed that learning attitudes, educational technologies, students' knowledge levels, and social skills significantly influence the generation of flow [7]. Marinho et al. constructed a technology-enhanced gamified educational environment and confirmed that ordinary competition and cooperation alone do not bring flow experiences. However, in a gamified educational environment, competition and cooperation can enable students to focus deeply, significantly increasing their flow experiences [8]. This means that students' spontaneous social behaviors change in virtual environments, and these changes play an important role in generating flow experiences. Su et al. explored the interactions between flow experience, self-efficacy, learning motivation, and academic performance in music education and verified that flow experience not only directly affects academic performance but also indirectly influences it through self-efficacy and learning motivation [9]. Rachmatullah et al. created a gamified environment for middle school students and noted that such environments can generate both positive flow experiences and frustration. Self-efficacy and pre-test scores are important factors influencing students' frustration [10]. Wang et al. conducted a group experiment on fifth-grade primary school students using a digital game teaching method based on a two-tier test. The results showed that compared with the traditional digital game learning model, the two-tier test-based model helps improve students' academic performance, especially for low-level students who can make greater progress. This indicates that students with a weak knowledge foundation often have many misconceptions, making it difficult for them to generate flow experiences through traditional digital games. However, if they start from hands-on operations, their cognitive level is not low, and they are more likely to generate flow experiences [11].

The studies above show that virtual or gamified environments are only external factors for students' flow experiences, while students' own characteristics are internal factors. External factors work through internal factors, and students' own personalities play a very important role in generating flow experiences [12, 13].

Previous research has been very in-depth and meaningful. However, most studies on flow theory have focused on classroom education and have not deeply analyzed the role of flow experience in optimizing course sequences. According to flow theory, undertaking prerequisite courses builds students' knowledge foundation. After acquiring the necessary knowledge foundation, students can form flow experiences when facing the challenge of new knowledge in class; otherwise, they can only develop an evasive mindset. Especially in private universities where students have a weak knowledge foundation, scientifically arranging the course sequence to consolidate students' knowledge foundation can

Table 1 Results of reliability and validity analysis.

Reliability Analysis	Cronbach's Alpha	0.969
Validity Analysis	Number of Items	16
	Sample Size	372
	KMO Value	0.960
	Bartlett's Sphericity Test	0.000***

(*** indicates highly significant at the 0.01 significance level)

enable them to more calmly face the challenge of encountering new knowledge in class, making it easier for them to generate flow experiences and changing the current situation where most students do not listen attentively in class.

In view of this, this study starts by examining students' course satisfaction, explores the mutual promotion relationships between courses, and proposes a scientific optimization plan for course sequences, aiming to provide useful references for improving the quality of classroom teaching in private universities.

3. RESEARCH DATA AND METHODS

This study took the students majoring in Tourism Management (Top-up Program) at Guangzhou Vocational and Technical University of Science and Technology as the sample, and conducted a survey to determine their satisfaction with 15 existing professional courses and their overall satisfaction with all professional courses. The questionnaire data passed the reliability and validity tests. Through R language programming, this study first adopted a decision tree model to prove that the satisfaction with important courses has a decisive impact on the satisfaction with all courses. Secondly, a random forest model was used to analyze the professional courses affecting students' overall satisfaction with all courses, and the important courses were obtained. Thirdly, to determine the important courses and improve students' satisfaction with them, association rule mining was used to analyze the preceding courses. Fourthly, since the academic system of the top-up program is two years, including three semesters of on-campus study and one semester of enterprise internship, a scientific course sequence was derived by combining the academic system of one and a half years with the results obtained by association rules.

4. ANALYSIS AND RESULTS

4.1 Reliability and Validity Testing

First, SPSS 27 was used to conduct reliability and validity tests on the questionnaire data. A total of 372 students filled out the questionnaire, with a questionnaire recovery rate of 100% and a questionnaire validity rate of 100%. The questionnaire included 16 items in total, covering the satisfaction with 15 professional courses and the overall satisfaction with all courses. The Cronbach's Alpha value of the questionnaire was 0.969, indicating that the data quality was highly reliable. The KMO value of the questionnaire was 0.960, and the Bartlett's Test of Sphericity was significant at the 0.01 level, suggesting that the questionnaire could effectively measure the satisfaction with professional courses and all courses, as shown in Table 1.

4.2 Decision Tree Model

To understand the relationship between students' overall satisfaction with all professional courses and their satisfaction with 15 specific professional courses, this study constructed a decision tree model to explore the decision-making mechanism behind overall course satisfaction. Among the 372 samples, 300 samples were randomly selected without replacement to form the training dataset for training the decision tree model, while the remaining 72 samples served as the testing dataset. A confusion matrix was constructed to verify the accuracy of the decision tree model, and the results are shown in Figure 1.

As can be seen from the decision tree model in Figure 1, students' overall satisfaction with all courses is mainly determined by three courses: Ecotourism, Tourism English, and Tourism Consumer Behavior. In the Figure 1 corresponds to "very dissatisfied", 2 corresponds to "somewhat dissatisfied", 3 corresponds to "average", 4 corresponds to "somewhat satisfied", and 5 corresponds to "very satisfied". The main interpretations are as follows: if students are somewhat or very satisfied with the Ecotourism course, the probability that they are satisfied with all courses is 83%, and this group of students accounts for 77% of the total. If students are very dissatisfied, somewhat dissatisfied, or average with the Ecotourism course, and further very dissatisfied, somewhat dissatisfied, or average with the Tourism English course, then the probability that these students are dissatisfied with all courses is 89%, accounting for 15% of the total students. The above decision tree model was used to predict the overall course satisfaction using the testing dataset, and the predicted values were combined with the actual values of the overall course satisfaction from the testing dataset to construct a confusion matrix. In the confusion matrix, the rows represent the predicted values and the columns represent the actual values, as shown in Table 2.

As shown in Table 2, the decision tree model achieved 86.1% accuracy, indicating good predictive performance. The overall course satisfaction is primarily determined by the satisfaction with Ecotourism, Tourism English, and Tourism Consumer Behavior courses, suggesting that overall course satisfaction can be influenced by the satisfaction with a few key courses. Since different datasets are randomly selected without replacement, the decision tree models trained

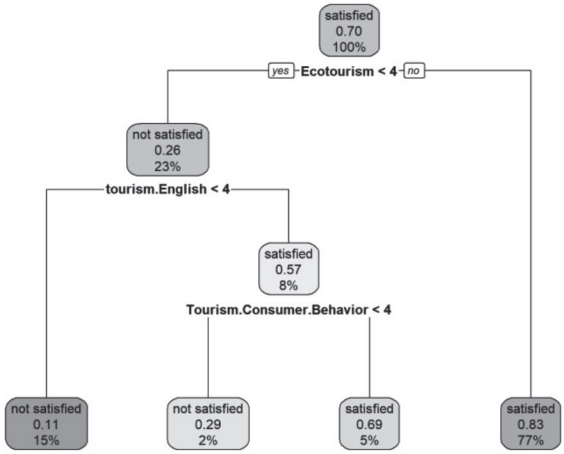

Figure 1 Decision tree model for overall course satisfaction.

Table 2 Confusion matrix of the decision tree.

	not satisfied	satisfied
not satisfied	9	1
satisfied	9	53

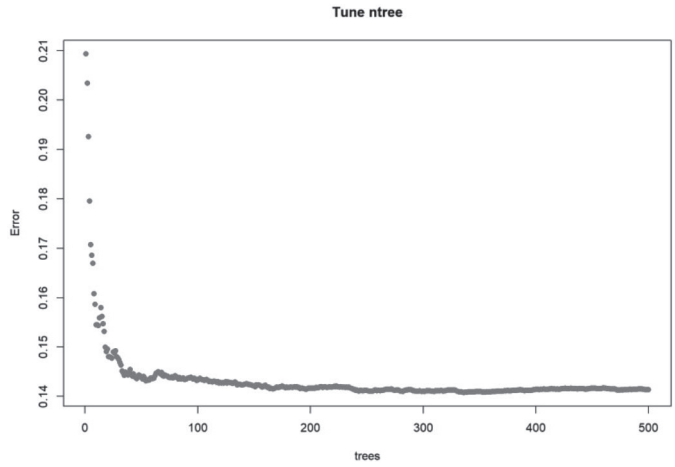

Figure 2 Optimal number of decision trees for random forest model.

will vary. Nodes on a specific decision tree should be regarded only as important references rather than absolute correct choices. The random forest model can decorrelate decision trees through random variable selection and stabilize prediction results by training multiple decision trees via random sampling with replacement. Therefore, this study further employed the random forest model for analysis.

4.3 Analysis of Random Forest Model

First, this study aimed to determine the optimal number of decision trees. A random forest model was established with 10 random variables, and the variation in model error under different numbers of decision trees was observed. The number of decision trees corresponding to the minimum error was defined as the optimal value. The error of the random forest model is shown in Figure 2.

Figure 2 shows that when the number of random variables is 10, the error of the random forest model is minimized when the number of decision trees reaches 300. An error less than 14% indicates that the model accuracy exceeds 86%, suggesting good predictive performance of the random forest model. Therefore, the optimal number of decision trees is 300.

The next step is to determine the optimal number of random variables for the random forest model. By using a loop statement, the out-of-bag (OOB) data error was measured for the number of random variables ranging from 1 to 15, as shown in Figure 3.

Figure 3 indicates that when the number of random variables is 2, the out-of-bag (OOB) data error of the random forest model is minimized, with an error of less than 13.8%. Therefore, the optimal number of random variables for the random forest model is 2. Synthesizing the above analyses, the optimal random forest model has 2 random variables and 300 decision trees, as shown in Figure 4.

Figure 4 shows that the error of the optimal random forest model is less than 14%, indicating high accuracy. However, since the number of random variables is 2, it does not clearly specify which important courses have a greater impact on

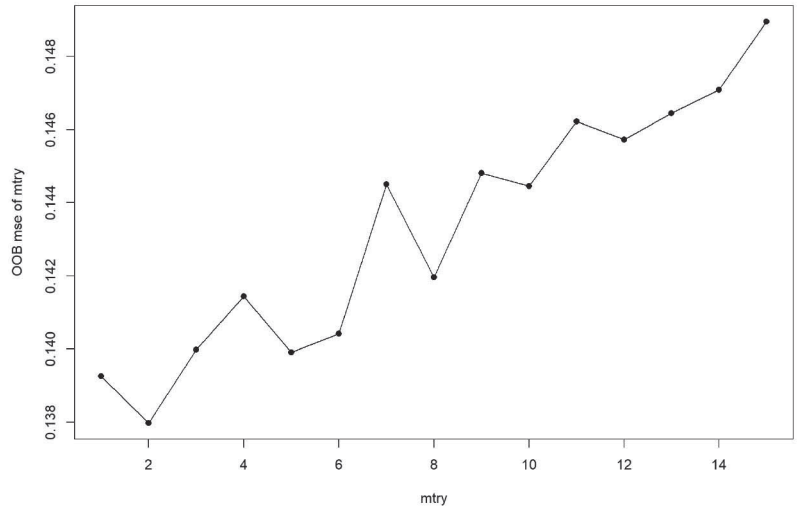

Figure 3 Optimal number of random variables for random forest model.

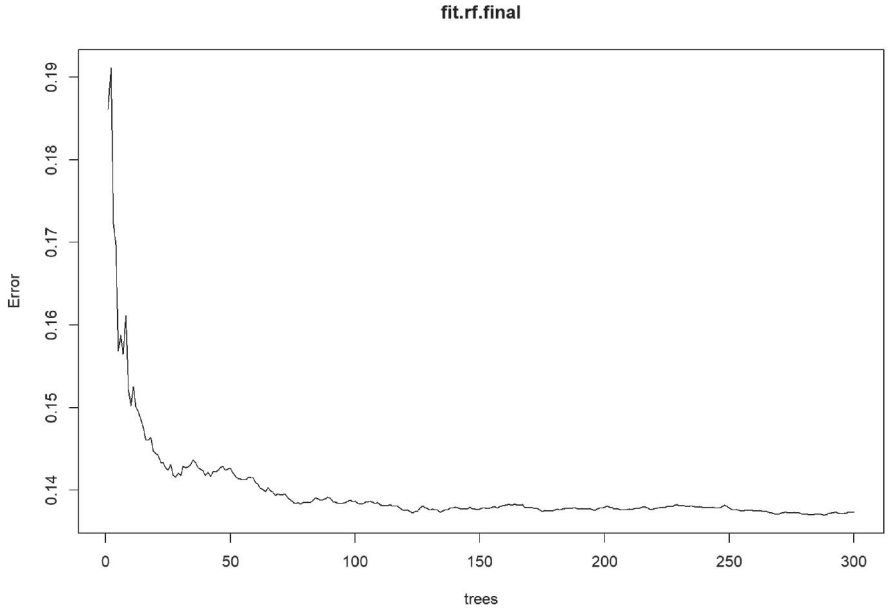

Figure 4 Optimal random forest model.

overall course satisfaction. Therefore, an importance analysis of influencing factors is required, as shown in Figure 5.

Figure 5 shows that the satisfaction with Tourism Psychology, Ecotourism, Tourism English, Tourism Hospitality, and Tourism Consumer Behavior courses has a significant impact on overall course satisfaction. Therefore, improving the satisfaction with these five key courses should be the primary approach so as to enhance overall course satisfaction. In terms of improving satisfaction with important courses, flow theory suggests that students' inattentiveness in class is likely due to insufficient knowledge foundations, which makes them unable to cope with the challenges of new classroom knowledge and thus fail to enter a state of flow experience. If the contextual relationship between other courses and the five key courses can be optimized, enabling students to have a more solid knowledge foundation when learning key courses, they will more easily achieve a flow state, thereby improving satisfaction with the five key courses and ultimately enhancing overall course satisfaction. Based on this, this study takes other courses as antecedent (condition) courses and key courses as consequent (result) courses, conducting association rule mining centered on key courses to derive objective laws for curricular relationships.

4.4 Association Rule Mining

Through association rule mining between other courses and key courses, this study aimed to identify other courses that can enhance satisfaction with key courses. Taking these courses as antecedent courses can solidify students' foundational knowledge and promote flow experience in key courses. To ensure the general applicability of association rules, the support degree was set at 20%; to guarantee their reliability, the confidence degree was set at 80%; and to ensure their value, the lift degree was set at 2.5. The association rules were calculated according to the importance ranking of professional courses.

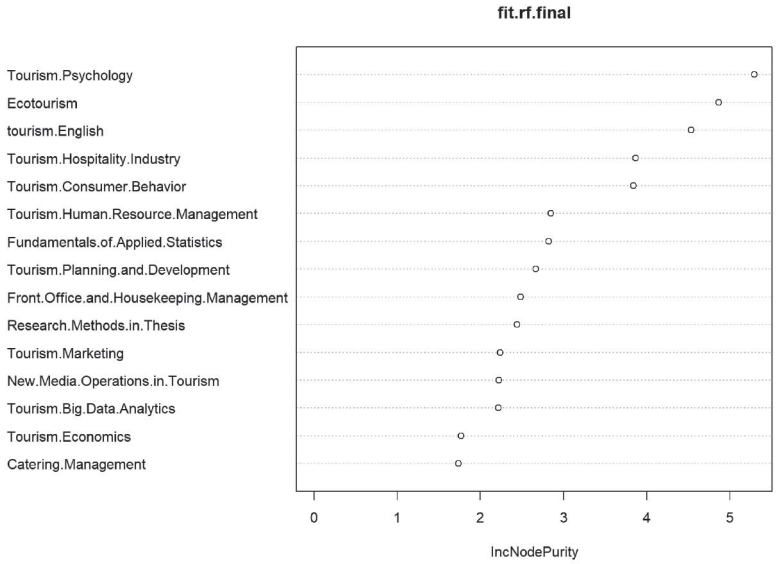

Figure 5 Importance ranking of random variables.

Table 3 Association rules of Tourism Psychology course.

Antecedent Courses	Consequent Courses	Support	Confidence	Lift
CateringManagement=5	Tourism Psychology = 5	0.24	0.94	3.05
Tourism Planning and Development = 5	Tourism Psychology = 5	0.24	0.81	2.64
Front office and Housekeeping Management = 5	Tourism Psychology = 5	0.25	0.81	2.63
Tourism Human Resource Management= 5	Tourism Psychology = 5	0.26	0.85	2.78
Tourism Big Data Analytics = 5	Tourism Psychology = 5	0.26	0.82	2.67
Tourism Marketing = 5	Tourism Psychology = 5	0.26	0.81	2.63
Ecotourism = 5	Tourism Psychology = 5	0.26	0.81	2.64
Tourism Hospitality Industry = 5	Tourism Psychology = 5	0.27	0.80	2.63

Table 4 Association rules of Ecotourism course.

Antecedent Courses	Consequent Courses	Support	Confidence	Lift
CateringManagement = 5	Ecotourism = 5	0.22	0.88	2.74
Tourism Planning and Development = 5	Ecotourism = 5	0.26	0.88	2.73
Tourism Human Resource Management = 5	Ecotourism = 5	0.26	0.84	2.61
Tourism Psychology = 5	Ecotourism = 5	0.26	0.85	2.64
Tourism Big Data Analytics = 5	Ecotourism = 5	0.26	0.83	2.57
Tourism Economics = 5	Ecotourism = 5	0.26	0.84	2.59
Tourism Marketing = 5	Ecotourism = 5	0.27	0.83	2.58
Tourism Hospitality Industry = 5	Ecotourism = 5	0.27	0.82	2.55
New Media Operations in Tourism = 5	Ecotourism = 5	0.28	0.82	2.54

4.4.1 Analysis of Tourism Psychology Course

The results of association rule mining between Tourism Psychology course and other courses are shown in Table 3.

Table 3 shows that when students are highly satisfied with courses such as Catering Management, Tourism Planning and Development, Front Office and Housekeeping Management, Tourism Human Resource Management, Tourism Big Data Analysis, Tourism Marketing, Ecotourism, and Tourism Hospitality, their satisfaction with the Tourism Psychology course will be significantly improved. If the above courses are taught as antecedent courses, and the Tourism Psychology course is taught after students have mastered the foundational knowledge of these courses, it will be easier to generate flow experience in the teaching process of the Tourism Psychology course, which can improve students' satisfaction with this course and further enhance their overall course satisfaction.

4.4.2 Ecotourism Course

The results of association rule mining for the Ecotourism course and other courses are shown in Table 4.

Table 4 shows that taking Catering Management, Tourism Planning and Development, Tourism Human Resource Management, Tourism Psychology, Tourism Big Data Analysis, Tourism Economics, Tourism Marketing, Tourism Hospitality, and Tourism New Media Operation courses as antecedent courses, when students are highly satisfied with these

Table 5 Association rules of Tourism English course.

Antecedent Courses	Consequent Courses	Support	Confidence	Lift
Catering Management = 5	Tourism English = 5	0.23	0.89	2.68
Tourism Human Resource Management =5	Tourism English = 5	0.26	0.84	2.53
Tourism Psychology = 5	Tourism English = 5	0.26	0.85	2.55
Tourism Big Data Analytics = 5	Tourism English = 5	0.26	0.84	2.53
Tourism Marketing = 5	Tourism English = 5	0.27	0.84	2.52

Table 6 Association rules of tourism hospitality course.

Antecedent Courses	Consequent Courses	Support	Confidence	Lift
Catering Management = 5	Tourism Hospitality Industry = 5	0.24	0.95	2.86
Tourism Planning and Development = 5	Tourism Hospitality Industry = 5	0.26	0.88	2.67
Tourism Human Resource Management = 5	Tourism Hospitality Industry = 5	0.26	0.85	2.57
Tourism Psychology = 5	Tourism Hospitality Industry = 5	0.27	0.87	2.63
Tourism Economics = 5	Tourism Hospitality Industry = 5	0.26	0.84	2.56
Tourism Marketing = 5	Tourism Hospitality Industry = 5	0.28	0.88	2.67
Ecotourism = 5	Tourism Hospitality Industry = 5	0.27	0.84	2.55

Table 7 Association rules of tourism consumer behavior course.

Antecedent Courses	Consequent Courses	Support	Confidence	Lift
Catering Management = 5	Tourism Consumer Behavior = 5	0.22	0.88	2.55
Front office and Housekeeping Management = 5	Tourism Consumer Behavior = 5	0.28	0.90	2.61
Tourism Human Resource Management = 5	Tourism Consumer Behavior = 5	0.27	0.89	2.55
Tourism Psychology = 5	Tourism Consumer Behavior = 5	0.27	0.89	2.55

antecedent courses, they are more likely to experience flow in the Ecotourism course, which will significantly improve their satisfaction with the Ecotourism course and further enhance their overall satisfaction with the course.

4.4.3 Analysis of Tourism English Course

The association rules for the Tourism English course and other courses are shown in Table 5.

Table 5 shows that when the antecedent courses are Catering Management, Tourism Human Resource Management, Tourism Psychology, Tourism Big Data Analysis, and Tourism Marketing, and students demonstrate high satisfaction with these antecedent courses, flow experience is more likely to occur during the teaching process of the Tourism English course. This will significantly improve students' satisfaction with the Tourism English course, thereby enhancing overall course satisfaction.

4.4.4 Analysis of Tourism Hospitality Course

The association rules for the Tourism Hospitality course are shown in Table 6:

Table 6 shows that when the antecedent courses are Catering Management, Tourism Planning and Development, Tourism Human Resource Management, Tourism Psychology, Tourism Economics, Tourism Marketing, and Ecological Economics, and students are highly satisfied with these antecedent courses, flow experience is more likely to occur in the teaching of the Tourism Hospitality course. This significantly improves satisfaction with the Tourism Hospitality course, thereby enhancing overall course satisfaction.

4.4.5 Analysis of Tourism Consumer Behavior Course

The association rules between the Tourism Consumer Behavior course and other courses are shown in Table 7:

Table 7 shows that when the preceding courses are Catering Management, Front Office and Housekeeping Management, Tourism Human Resource Management, and Tourism Psychology, students who are very satisfied with these preceding courses are more likely to experience flow in the teaching of Tourism Consumer Behavior. This can significantly improve their satisfaction with the Tourism Consumer Psychology course, thereby enhancing their satisfaction with all courses.

Based on the above analysis, Catering Management and Tourism Human Resource Management are the courses that should precede all important courses. Therefore, they should be offered in the first semester during the three-semester teaching process for (junior college to undergraduate) students. Additionally, Tourism Marketing is a preceding course for Tourism Psychology, Ecotourism, Tourism English, and Tourism Hospitality; Tourism Planning and Development is a preceding course for Tourism Psychology, Ecotourism, and Tourism Hospitality; and Tourism Big Data Analysis is a preceding course for Tourism Psychology, Ecotourism, and Tourism English. These three courses also have a significant impact on important courses and should be presented in the first semester. Thus, the professional courses for the first semester should be: Catering Management, Tourism Human Resource Management, Tourism Marketing, Tourism Big Data Analysis, and Tourism Planning and Development.

Tourism Psychology plays an important role in the other four key courses. As a key course, it should leverage other courses as preceding courses to enhance students' satisfaction

Table 8 Course sequence for junior college-to-undergraduate students.

First Semester	Second Semester	Third Semester
Catering Management	Tourism Psychology	Ecotourism
Tourism Human Resource Management	Front office and Housekeeping Management	Tourism English
Tourism Marketing	Tourism Economics	Tourism Hospitality Industry
Tourism Planning and Development	New Media Operations in Tourism	Tourism Consumer Behavior
Tourism Big Data Analytics	Fundamentals of Applied Statistics	Research Methods in Thesis

with it, so it should be presented in the second semester. Considering the preceding courses of other key courses, the second semester's courses should include Tourism Psychology, Front Office and Housekeeping Management, Tourism Economics, and Tourism New Media Operations.

The third semester focuses on the remaining four key courses: Ecotourism, Tourism English, Tourism Hospitality, and Tourism Consumer Behavior. The only courses yet to be determined are Basic Applied Statistics and Thesis Research Methods and Writing Training. Logically, mastering basic statistical knowledge is essential for understanding the graduation thesis writing course. Therefore, placing Basic Applied Statistics in the second semester and Thesis Research Methods and Writing Training in the third semester aligns with students' cognitive processes. Based on the above analysis, the scientific course sequence for junior college-to-undergraduate students is shown in Table 8.

5. CONCLUSION

First, based on the course satisfaction data of 372 junior college-to-undergraduate students from Guangzhou Vocational and Technical University of Science and Technology, this study used a decision tree model to analyze key courses influencing overall course satisfaction. The analysis revealed that overall course satisfaction is determined by the satisfaction with a few key courses. In the second step, a random forest model analysis identified that the satisfaction with Tourism Psychology, Ecotourism, Tourism English, Tourism Hospitality, and Tourism Consumer Behavior are significant influencing factors of overall course satisfaction, thus suggesting that these five courses are key courses. The third step employed association rule mining centered on key courses to determine the causal relationships between key courses and other courses. In the fourth step, based on the association rules of key courses and combined with the academic system for junior college-to-undergraduate students, a course sequence was constructed. The results show that the scientific formulation of the course sequence aligns with students' cognitive processes, enabling them to more easily enter a flow experience state during key course learning, thereby improving overall course satisfaction.

STATEMENTS AND DECLARATIONS

None

CONFLICTING INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING

This study was supported by Research on the Integrated Education Model of "Post-Course-Competition-Certificate" in Higher Vocational Business Administration Majors Based on the "Flow Theory"; "2023 Guangdong Higher Vocational Education Teaching Quality and Teaching Reform Project" of Guangdong Provincial Department of Education:Project number: 2023JG258. These projects have been concluded. Please remove them. Thank you. Please add the following items: Guangdong Provincial Department of Education Research Platform and Project in 2025, Specialized Innovation Project (Philosophy and Social Sciences) ≪Research on the Logic and Path of High-Quality Development of Homestay Leisure Tourism Agglomeration Areas≫ Project Number: 2025WTSCX185.

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