

PAPER

Using Structural Equation Model Questionnaire Technology for Assessing Blending Teaching in STEAM Courses

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2018090106@zjtu.edu.cn**ABSTRACT**

Questionnaires for blending teaching effect evaluation from the perspective of science, technology, engineering, arts, and mathematics (STEAM) were reviewed in this study, and measurement problems for the questionnaire were designed. Effects of online and offline teaching environments, online teaching resources, and offline teaching processes in blending teaching of *Engineering Surveying* on learning satisfaction of university students were estimated using structural equation model (SEM) questionnaire technology. Results demonstrated that the overall Cronbach's α of the questionnaire is 0.796 and the KMO value is 0.828 (> 0.8), indicating the good reliability and validity of the questionnaire. The online and offline teaching environments and offline teaching processes have a significantly positive promotion effect on learning satisfaction in the blending teaching mode. The online teaching resources have positive promotion effects on learning satisfaction, but such effects are not significant. Research conclusions have important references to disclose and analyze the online and offline interaction in blending teaching, recognize major problems to determine improvement direction, and design blending teaching strategic interventions and practices that promote learning engagement.

KEYWORDS

science, technology, engineering, arts, and mathematics (STEAM), blending teaching, effect evaluation, structural equation model (SEM)

1 INTRODUCTION

In the background of the rapid development of Internet information technology, modern information technologies represented by big data, cloud computing, the Internet of Things, and artificial intelligence are applied to various industries quickly and bring great convenience to people's production and lives. The continuous development of information technology also promotes further combination

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with the education field, thus resulting in continuous development and changes in education modes. To cope with the COVID-19 pandemic, more teaching modes have been developed, and professional course teaching at universities is continuously developing toward the Internet-based mode. Blending teaching that provides unified coordination of online and offline classes has become a new teaching point, and it is an important tool for educators to improve the teaching and management effects under regular COVID-19 control measures. During the pandemic, Chinese universities implemented different teaching modes from the traditional offline teaching modes according to the requirements of the Ministry of Education of the People's Republic of China on "classes suspended but learning continued." Online teaching was popular, and it has become a major channel for teaching different majors in universities. Nevertheless, the teaching objectives of universities are to train the consciousness of innovation and comprehensive quality of students in professional fields rather than teaching theoretical knowledge only. Simple online teaching cannot reach the knowledge-learning degree that students need or assign tasks for students to practice. Limited by spaces, teachers cannot easily observe the learning conditions of students, and students cannot get effective feedback on their learning from teachers.

Blending teaching integrates the characteristics of online and offline teaching. Hence, specifically offsetting defects in offline teaching and online teaching modes is necessary. The traditional conventional teaching mode in universities has exposed many obvious disadvantages in practices over the years, such as failure to motivate students' enthusiasm effectively and the single and unscientific setting of course contents. Internet information technology has brought changes to various industries, including the education industry. At present, with the increasing development of mobile terminal networks, the new university teaching mode has become increasingly popular, and various mobile apps have begun to be appreciated by university student users. To offset the negative influences of the COVID-19 pandemic, accelerating teaching mode reform is more necessary, and a new teaching mode is developed accordingly, in which Internet information plays a crucial role. The traditional simple offline science, technology, engineering, arts, and mathematics (STEAM) course cannot overcome spatial limitations and cannot realize the popularization of STEAM education. Offline resources alone cannot fully develop teaching effectiveness. Blending STEAM teaching can merely offset these disadvantages. However, the development design of existing STEAM courses cannot be copied directly due to the characteristics of the blending teaching mode. To guarantee the practice of higher education quality, university students attract increasing attention as learning and evaluation subjects. Student-centered approaches and concerns about students' employment have become important orientations for talent training and quality assurance. The early higher education quality evaluation should shift attention from resource input to the evaluation of students' learning fruits. More attention has to be paid to blending the teaching effect from the perspective of the STEAM concept.

2 LITERATURE REVIEW

With the continuous development of informatization technology in recent years, online and offline modes have been applied in several fields. Offline and online teaching modes are becoming increasingly popular in the education field.

To overcome the temporal and spatial limitations of learning, the online and offline teaching modes need to fully complement each other. This is a new trend in present teaching reform in education, and it pays attention to knowledge transfer in the teaching process as well as in the internalization process. Nevertheless, the new learning environment of the Internet and teaching practices is forming with the development of age. With respect to teaching scenes of information technology, designing a blending teaching effect evaluation mode with reliability and validity is a research hotspot. With respect to blending teaching effect evaluation, Wagner, N et al. [1] investigated the effects of gender and race of teachers on the teaching evaluation of university students, indicating that teaching evaluation in recruitment and promotion decision-making might put women teachers in a disadvantageous position. Xiaotong, M. et al. [2] reported that the blending teaching mode could improve the learning outcomes of the timely self-understanding stage of students effectively and influence the adjusting (or solving) of specific links (or problems) in the teaching process. Memduhoglu, H.B. et al. [3] believed that blending teaching is closely related to the teaching experiences of teachers, and he suggested that teachers improve the blending teaching effect by improving their teaching ability. Dai, Y. [4] designed four teaching steps of “construction, guidance, tutorship, and reflection” in blending teaching (O2O) and carried out a comparative evaluation of teachers’ teaching ability before and after the implementation of blending teaching by using the classification and regression tree (CART) algorithm of data mining technology. Results demonstrated that this teaching reform was conducive to training the critical thinking and innovation abilities of students. Li, Y [5] believed that the establishment of normal monitoring and feedback mechanisms for basic teaching data based on information technology could successfully promote the evaluation of new teaching modes, such as online-offline blending teaching of courses. Li, G., et al. [6] found from an experiment that students were relatively satisfied with the blending teaching mode and believed that it played a great role in the learning process, bringing a significant improvement in both teaching efficiency and teaching quality. Yue, Y [7] believed that online personalized learning services could provide good services to learners, and the O2O flipped classroom mode might better reflect the characteristics of intelligent learning. Dou, Y [8] carried out a case study of badminton and explored the design and implementation of the mobile teaching platform under the O2O sports teaching mode. Setyawan, H [9] demonstrated that blending teaching was conducive to improving the English reading performances of learners. Yen, S. C., et al. [10] compared the face-to-face, online, and blended teaching modes for the undergraduate course on child development. They found that under all three teaching modes, students achieved the same good results in three types of exams, research papers, and overall academic performances of the course, relieving traditional retaining of online and blending teaching effects. Wu, X [11] believed that with the progress of Internet technology, the current basic educational concept of universities was mainly based on the “online + offline” teaching mode that could improve teaching efficiency and thereby promote progress in the current education system. Veeraiyan, D. N., et al. [12] demonstrated that an interactive teaching method using offline and online platforms could improve the academic performances and critical thinking abilities of learners. Wang, Q., et al. [13] chose 63 juniors majoring in anesthesiology from Wenzhou Medical University and divided them into two groups randomly. Results showed that online-offline interactive teaching modes cannot only improve the theoretical exam scores of students but are

also conducive to increasing their learning engagement and helping them to get good teaching effects. Rachmah, N. [14] investigated the responses of 16 university English majors to online and offline courses. He found that blending teaching could promote teacher-student interaction in class, and students were more interested in the teaching process and enjoyed themselves in class. Bryson, J. R., et al. [15] believed that the transition to complete online teaching involved a process in which the role of teachers was changed to that of planners of students' online and offline experiences. According to existing studies, although blending teaching is the current teaching reform trend in higher education, it involves more complicated influencing factors because it combines the characteristics of online teaching and classroom face-to-face teaching. The effect of blending teaching has attracted increasing attention. Blending teaching proposes higher requirements for learners, teachers, and the environment. On the individual level of students, the cognition, learning interest, and self-efficacy of students in the blending course, as well as the independent learning abilities of learners, including self-planning, self-monitoring, and self-adjustment, are all important factors in the learning outcome. On the level of the teaching environment, the blending of the teaching environment involves online and offline environments. Social learning theory pays attention to individual-environment interaction, software and hardware teaching facilities, and network fluency that may influence the learning experiences of students. Designs such as learning resources and teaching interaction in the teaching process may also influence the learning outcomes of students. On the teacher level, how teachers can coordinate online and offline teaching content, motivate the learning enthusiasm of students, follow up on their learning conditions promptly, and give them support, feedback, and evaluations is crucial. Hence, how to develop the advantages of blending teaching, improve the teaching effect by motivating positive factors in all aspects, keep the advantages of online and offline teaching modes, and avoid their shortages to improve the learning outcome is an important research goal at present.

3 METHODOLOGY

3.1 Model

The structural equation model (SEM), also known as the covariance structure, is a modeling technique to process and test the relations of variables. Compared with other statistical models, SEM is superior for processing the path relations of several independent variables and dependent variables simultaneously. It is also more comprehensive and flexible in terms of data fitting and model tests. SEM is extensively applied to economics, behavioristics, psychology, management science, and education. SEM methods also play an important role in studies on multivariate statistics. SEM is part of empirical analysis, and it tests the reasonability of a structural relation or hypothesis in the model by finding the inherent structural relations among variables. This provides indexes and theoretical support for the modification of the model. SEM includes structural and measurement equations:

$$\begin{aligned} X &= \Lambda x \xi + \delta \\ Y &= \Lambda y \eta + \varepsilon \end{aligned} \quad (1)$$

1. is the measurement equation, and it reflects the relationship among the endogenous latent variable, exogenous latent variable, and observable variable. The relationship between the exogenous latent variable and the exogenous observable variable can be expressed as Λx . The relationship between the endogenous observable variable and the endogenous latent variable can be expressed as Λy .

$$\eta = \beta\eta + \Gamma\xi + \zeta \quad (2)$$

2. is a structural equation, and it reflects the relationship between the exogenous latent variable and the endogenous latent variable. ρ is a path coefficient, and it shows the relationship among endogenous latent variables. Γ is a path coefficient, and it reflects the effects of exogenous latent variables on endogenous latent variables. δ , ζ , and ε are error terms.

3.2 Data source

Based on existing studies, a questionnaire of *Blending Teaching Effect Evaluation under the Perspective of the STEAM Concept* was compiled. The questionnaire chose three aspects of online and offline teaching environments, online teaching resources, and offline teaching processes as independent variables. On the basis of the research results of Schriesheim, C. A., et al. [16] and Fieuws, S., et al. [17], these three aspects were measured by five, four, and four problems, respectively. The learning satisfaction of students was set as the independent variable. Following the research results of Topala, I., et al. [18] and Chen, M. L., et al. [19], four measurement problems were designed. The questionnaire used a five-point Likert scale for investigation. The scale in the present study used “five-level attitudes,” namely, “strongly satisfying, satisfying, moderate, unsatisfying, strongly unsatisfying,” which were valued at “5, 4, 3, 2, 1,” respectively. In the fall semester of the academic year 2021–2022, the questionnaire was sent to six universities in Henan Province, China (Institutes of Technology of Henan, Huanghe Jiaotong University, Huanghuai University, Henan College of Surveying and Mapping, Henan University, and Zhengzhou University). A total of 486 questionnaires were sent, and 425 questionnaires were collected. After preliminary inspection and screening, 320 integrated and effective questionnaires remained. This conforms to the basic requirements of the SEM model.

4 RESULT ANALYSIS

4.1 Reliability and validity test

Reliability mainly means whether the measuring results are reliable, consistent, and stable. It mainly reflects whether the results from the test tools are consistent or stable, rather than being dependent on the test or the scale itself. If reliability is not high, validity is not high. Reliability and validity may not merely be good; validity and reliability must be very high. Cronbach’s α is a common measurement index of reliability, and it mainly measures consistency in the scale. In this study, the collected data were analyzed using SPSS 22.0.

Table 1. Reliability test results

Type of Variables	Name and Number of Variables	Number of Problems	α Coefficient After Term Deleted	Cronbach's α	Cronbach's α
Independent variables	Online and offline teaching environments Factor 1	A1	0.827	0.861	0.796
		A2	0.836		
		A3	0.834		
		A4	0.829		
		A5	0.833		
	Online teaching resources Factor 2	B1	0.755	0.816	
		B2	0.766		
		B3	0.767		
		B4	0.787		
	Offline teaching process Factor 3	C1	0.81	0.839	
		C2	0.794		
		C3	0.77		
		C4	0.808		
Dependent variable	Learning satisfaction Factor 4	Y1	0.669	0.747	
		Y2	0.714		
		Y3	0.689		
		Y4	0.681		

Table 1 shows that the calculation method of Cronbach's α was used to test the whole questionnaire, and the overall Cronbach's α was calculated as 0.796. The dimensions of all influencing factors are higher than 0.747, and the reliability coefficient of the research data was higher than 0.7, indicating that the data generally have high reliability and are applicable for further analysis. Based on the analysis, the chosen scale has good stability and internal consistency, and it has good overall reliability. The scale can be used for further research and analysis.

Validity analysis is an analysis of the validity of the questionnaire. In this study, the validity analysis mainly tests whether the measurement questionnaire can reflect the satisfaction of university students with the blending teaching effect. It mainly includes the KMO test and Barlett's sphericity test of the questionnaire. If the KMO value is higher than 0.8, the research data are very appropriate for information extraction (this proves that the validity is very good indirectly). If the KMO value is between 0.7 and 0.8, the research data are appropriate for information extraction (this proves that the validity is relatively good indirectly). If the KMO value is between 0.6 and 0.7, the research data are relatively appropriate for information extraction (this proves that the validity is moderate indirectly). If the KMO value is lower than 0.6, the data are inappropriate for information extraction.

Table 2. Validity test results

KMO value		0.828
Barlett's sphericity test	Approximate chi-square	1989.891
	df	136
	p-value	0

Validity was verified by KMO and Bartlett's sphericity test. Table 2 shows that the KMO value is 0.828 (> 0.8), indicating that research data are very appropriate for information extraction (this proves that the validity is very good indirectly).

4.2 SEM results

Table 3. Results of model fitting indexes

Common Indexes	P	Chi-Square Degree of Freedom Ratio χ^2/df	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judgment criteria	> 0.05	< 3	> 0.9	< 0.10	< 0.05	> 0.9	> 0.9	> 0.9
Value	0.127	1.153	0.956	0.022	0.029	0.991	0.936	0.989

Table 3 shows that the common fitting index results of SEM show very good fitting results and they can be further analyzed.

Table 4. Summary of model regression coefficients

X	→	Y	Standardized Regression Coefficient	SE	Z (CR Value)	P
Factor1	→	Factor4	0.405	0.062	5.703	0.000
Factor2	→	Factor4	0.048	0.057	0.728	0.467
Factor3	→	Factor4	0.242	0.062	3.545	0.000

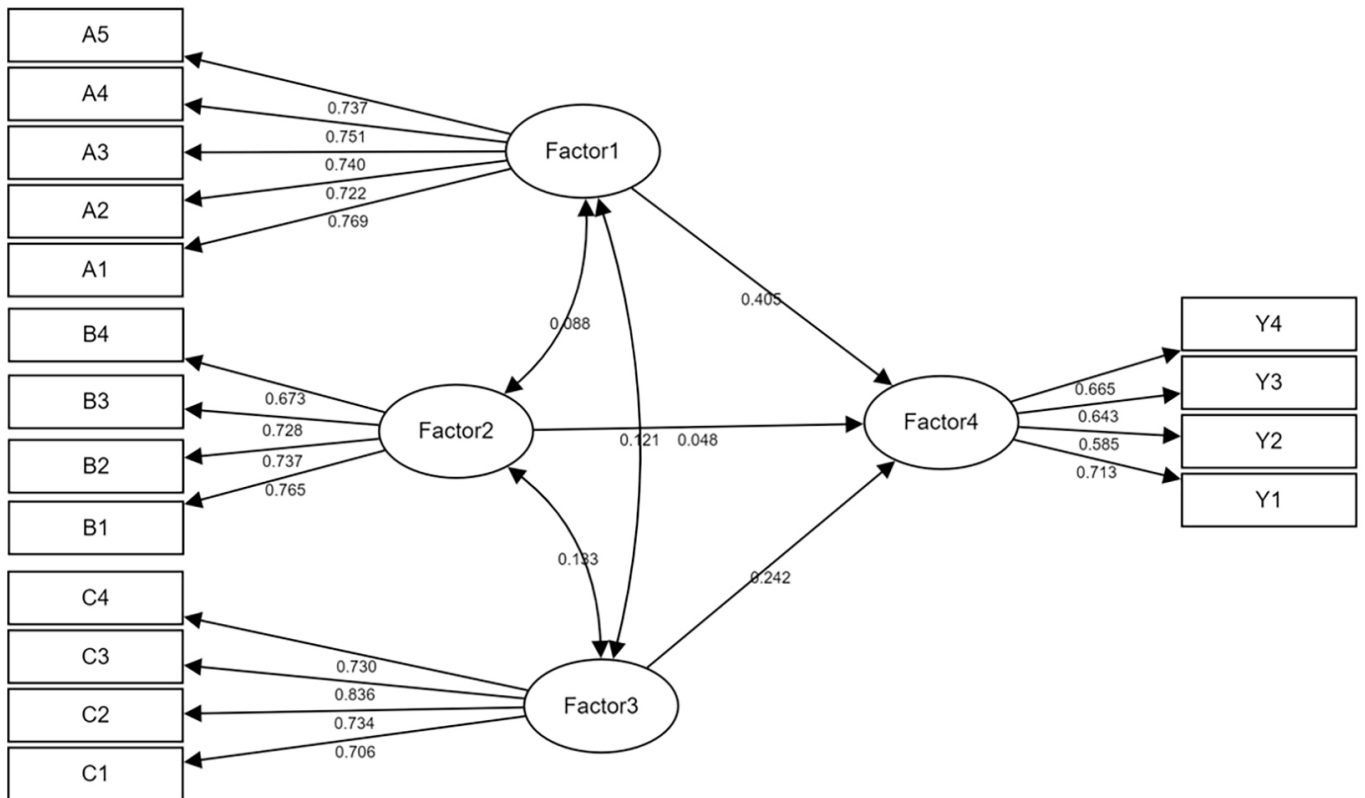


Fig. 1. SEM results

Table 4 and Figure 1 show that:

1. Online and offline teaching environments in the blending teaching mode have a significantly positive effect on learning satisfaction. This is mainly because, on the online teaching platform, teachers from ordinary universities and colleges usually prefer the SPOC platform to provide teaching services to their students. With characteristics of small size and private property, the SPOC platform concerns the complete and profound learning experiences of students and can meet the personalized learning needs of students. Teachers can also adjust and control the teaching progress according to the specific learning conditions of students and adjust the teaching contents specifically. In the offline teaching environment, more university teachers prefer flipped classrooms to assure a good teaching environment and improve the teaching quality of the blending teaching mode. The flipped classroom is equipped with two intelligent screens for the convenience of students in different positions. The classroom has round tables, and each table has a microphone and sockets, so that students can complete classroom interaction and assure the normal use of learning tools. The intelligent teaching tool uses *Rain Classroom*, *Tencent Conference*, and other advanced teaching tools, which can combine classroom teaching and information technology effectively. The tool assures that students enter the learning state before the class by recommending learning tasks and teaching reminders. During class, teacher-student interaction efficiency can be improved by real-time classroom answers and the bullet-screen interaction mode. After class, the tool helps students make deep reviews and consolidations through methods such as PPT pushes and synchronous live broadcasts of the course. Teachers can also monitor the learning conditions of students at any time by logging into various online teaching platforms. Thus, the pre-, in-, and after-class are all covered, bringing good support to the adjustment of teaching strategies and improvement of teaching efficiency.
2. Online teaching resources in blended teaching modes have a positive promotion effect on the learning satisfaction of students, but such an effect is not significant. This conclusion seems to be inconsistent with some existing studies to some extent. However, the potential reasons can be recognized after deep reflection. In the blending teaching mode, there are considerable online teaching resource reversals. (a) Online courses mainly refer to video data issued by teachers on the SPOC platform before classes. Students have to complete pre-class learning requirements independently and master the course content. (b) After-class homework and test: after completing the online course learning requirements, students have to finish the corresponding after-class homework and test exercises according to the teaching arrangement, helping them to check missing and non-comprehended contents and test their learning outcome. (c) Courseware: Teachers make and publish courseware through various online teaching platforms and help students further learn course contents and review the learned knowledge deeply. (d) Resource index: Teachers provide other course-related network linkages or video data as supplements to the learning of students. Students use online teaching resources reasonably according to their learning state and learning outcome. Such mass online resources include various media environments and all available material teaching conditions (including hardware resources and software resources) for the successful completion of teaching activities. Given that university students have to learn such mass learning resources through various means through online learning links, more learners will be trapped in learning fatigue with time, and they will lose interest in

and motivation for the online learning resources. In particular, the mass online learning resources have unequal quality, such as a lack of resource management and information filtering. As a result, students cannot find the needed learning resources quickly, thus resulting in their confusion and helplessness. These research results also inspire our university teachers to devote themselves to research and develop higher-quality online teaching resources rather than pursuing a quantity of online teaching resources blindly. They shall make more efforts toward the development of personalized learning resources that can meet different majors and different grades and improve the application values of online learning resources.

3. The offline teaching process in blended teaching mode has significant positive promotion effects on the learning satisfaction of learners. This is mainly because the offline teaching process covers many scientific and systematic links. Teachers shall set explicit teaching objectives, and teaching activities are carried out around the teaching objective at any time. Before the implementation of teaching activities, teachers have to set a specific teaching objective according to the curriculum objectives and implement a series of teaching activities according to the teaching objective. The learning conditions of students can be understood. The learning conditions of students have significant influences on teachers' overall design of the course. Teachers shall adjust their teaching content with consideration for the specific learning states of students. Teaching keys shall guarantee that students can absorb course contents effectively. A meticulous design of teaching content can be made. Under the guidance of the teaching objective, teachers can design teaching content according to a plan, mainly including teaching video making, PPT making, and chapter division. Teaching activities and teaching methods can be determined. Teachers have to adopt the appropriate teaching methods according to the contents of different chapters, such as using discussion methods for difficult problems. Teachers can guide students to study difficult problems through discussions. Rich and diversified teaching activities have been determined to improve the learning atmosphere and stimulate the learning enthusiasm of students. The feedback-teaching effect is also observed. After finishing the course, teachers can give feedback on the class conditions of students promptly, and students can practice deep learning and solve weak links easily.

5 DISCUSSIONS

The continuous development of higher education informatization technology promotes the development and reform of educational teaching modes. The blending teaching mode combines the advantages of traditional face-to-face and online teaching modes and bridges the border between time and space. Implementing the online and offline teaching modes can be done in many ways. It pays attention to a combination of various emerging teaching forms, such as flipped classrooms and massive open online courses (MOOCs). Specifically, the online teaching mode has a simpler implementation, more explicit online-offline division, more single needs for offline teaching, and stronger practices. The use of the new blending teaching mode provides a new idea and method for diversified and intelligent teaching. It is also indispensable for making teaching evaluations. Many teaching evaluations have been based on the academic performances of students. Some are based on ordinary performances, mid-term exams, and final exam performances. Some are based on the improvement of comprehensive quality performances. Some are based on the implementation

process and formative evaluation. These generally lack student-centered evaluations. Hence, evaluating the blending teaching effect in the new teaching modes is extremely necessary. However, blending teaching can easily be interfered with by teachers and environmental influences. Teachers may lack confidence in their education level and education concepts. From the perspective of the environmental effect, some policy support is in place, and the equipped hardware facilities of schools can meet the daily teaching needs of teachers. Nevertheless, there are few course resources and limited teaching platforms, such that teachers believe the lack of these two resources may influence the application of the blending teaching mode. Hence, with the continuous development of the Internet, the learning emotions of learners in the learning process are tested based on blending teaching, thereby influencing attention, memory, thinking, and other cognitive activities of learners by corresponding teaching strategies. The key contents of future studies will focus on solving the disadvantages of offline teaching and online independent learning that teachers cannot master and analyze the emotional states of students promptly, thereby assisting educational teaching to promote learners to learn with a better emotional state.

6 CONCLUSIONS

With continuous reforms of emerging technologies such as big data, the Internet of Things, cloud computing, and artificial intelligence, they have been included in the education field to some extent and may facilitate education reform significantly. Blending teaching not only assures the full development of the dominant role of teachers but also assures the creativity and subjective initiatives of students as the learning subject and promotes the development and utilization of high-quality education resources. In this study, measurement problems for the questionnaire for blended teaching effect evaluation are designed. Effects of online and offline teaching environments, online teaching resources, and offline teaching processes in blending the teaching of *Engineering Surveying* on the learning satisfaction of university students are estimated using the SEM questionnaire technology. Three major conclusions could be drawn: (1) the overall Cronbach's α of the questionnaire is 0.796, and the KMO value is 0.828. (2) Online and offline teaching environments and offline teaching processes under the blending teaching mode all have positive promotion effects on the learning satisfaction of students, and such effects are significant at the 1% level. (3) Online teaching resources have a positive promotion effect on the learning satisfaction of students, but such an effect is insignificant. Future researchers are suggested to consider the close relationship between different types and different levels of blending teaching modes in different regions with society, universities, teachers, families, and learners.

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