PAPER

Evaluation of Blended Teaching in STEAM Education Using Structural Equation Model Questionnaire Technology

Jiayao Cai(✉)

Hainan College of Economics and Business, Haikou, China

202008000010@
hceb.edu.cn

ABSTRACT

Science-technology-engineering-arts-mathematics (STEAM) education is an interdisciplinary education model that breaks the barriers between disciplines and comprehensively cultivates the problem-solving ability of students. Online education has been increasingly recognized by learners by virtue of its unlimited time and space, repeatability, and rich teaching resources. Based on the concept of STEAM education, the blended teaching model integrates the advantages of traditional teaching and online education, sustainably innovating classroom teaching and exerting a far-reaching effect on the current education and teaching reform. In this study, the related questionnaires regarding the evaluation of blended teaching effect under the perspective of the STEAM concept were combed, and questionnaire measurement questions with regard to the evaluation of blended teaching effect were then designed. The effects of online-offline teaching environment, online teaching resource, and offline teaching process in blended teaching on the learning satisfaction of college students were measured via the Structural Equation Model (SEM) questionnaire technology. Results show that the overall Cronbach's α coefficient of this questionnaire is 0.796, and the KMO value is 0.828, which is greater than 0.8, indicating the excellent reliability and validity of the questionnaire. Under the blended teaching model, the online-offline teaching environment and offline teaching process generate significantly positive effects on learning satisfaction. Online teaching resources exhibit a positive, yet insignificant, promoting effect on learning satisfaction. The study results are of important reference values for understanding and analyzing the online-offline interactions in blended teaching and identifying the main problems therein. Ultimately, the goal is to clarify the direction for improving blended teaching and designing blended teaching strategies that promote students' learning engagement, leading to practical interventions.

KEYWORDS

science-technology-engineering-arts-mathematics, blended teaching, effect evaluation, structural equation model

1 INTRODUCTION

With the rapid development of Internet information technology, modern information technologies represented by big data, cloud computing, Internet of Things, and artificial intelligence have been rapidly applied to all walks of life, bringing great convenience to people's productivity and life. At the same time, the continuous development of information technologies has promoted their further integration with the education field, contributing to the continuous development and transformation of the education model. At present, China is strengthening the application of information technologies, updating the concept of information-based teaching, and constantly improving teaching methods. In the process of improving the teaching effect, students are encouraged to engage in active and independent studying by utilizing information resources to strengthen their ability in analyzing and solving problems with the help of information technologies. Under the background of COVID-19, more teaching models are emerging, and specialized courses in colleges and universities are developing in an Internet-based way. Unified and coordinated mixed teaching in online and offline classrooms has become a new teaching focus, making it an important tool for educators to improve teaching and management effects under normal prevention and control. During the pandemic, colleges and universities in China carried out teaching in a manner that was different from the traditional offline teaching model according to the requirements of the Ministry of Education. Online teaching was once popular, and online teaching became the main teaching method for various majors in colleges and universities. However, the teaching goal of colleges and universities is not only to instill theoretical knowledge but also to cultivate students' innovative consciousness and comprehensive quality in professional fields. Simple online teaching cannot provide the level of knowledge learning required by students, and students must be assigned tasks to practice. Space constraints make it difficult for teachers to observe students' learning, and students, in turn, fail to acquire effective feedback from teachers.

Blended teaching combines the key characteristics of online and offline teaching models, making it necessary to compensate for the common shortcomings in each teaching model. In years of practice, many obvious disadvantages of the traditional conventional teaching model in universities have been exposed, such as its failure to effectively mobilize students' enthusiasm and the monotonous and unscientific course content settings. Internet information technology has brought changes to all industries, and the education industry is no exception. With the development of mobile terminal network technology, new university teaching methods are becoming increasingly popular, and students are beginning to favor all types of mobile application software. Given the negative impact of COVID-19, it becomes even more imperative to accelerate the pace of teaching model reform. In fact, the pandemic has spurred the emergence of a new teaching model that extensively incorporates Internet information technology. The traditional simple offline science-technology-engineering-arts-mathematics (STEAM) course cannot overcome the space limitation, realize the popularization of STEAM education, or give full play to the effectiveness of teaching by simply using offline resources. Blended STEAM teaching can make up for these shortcomings, but the characteristics of the blended teaching model make it impossible to directly copy the development and design of the existing STEAM course. In the practice of ensuring the quality of higher education, the status of college students as subjects of learning and evaluation has been paid increasing attention. Taking students as the center and paying attention to their schoolwork have become an important orientation for talent training and quality assurance. It is necessary to shift the focus of the early quality evaluation of higher education from the resource

input to the learning achievements of students, and higher importance should be attached to the evaluation of blended teaching effect under the STEAM concept.

2 LITERATURE REVIEW

With the continuous development of information technology in recent years, online and offline models have been applied in many fields and have gradually become popular in the field of education. This development can overcome the limitations of learning in time and space and promote online and offline teaching models to learn from each other's strengths. This is a new trend in the current education and teaching reform, which focuses on the transfer of knowledge in the teaching process and the internalization process. With the development of the times, however, a new learning environment—Internet+ teaching practice—is taking shape. Aiming at the teaching scenario of information technology, designing a reliable and valid method for evaluating blended teaching effect is a research hotspot. As for the evaluation of blended teaching effect, Wagner et al. [1] studied the influence of teacher gender and race on the teaching evaluation of college students and pointed out that female lecturers may be disadvantaged in case teaching evaluation is adopted in recruitment and promotion decisions. Meng et al. [2] deemed that the blended teaching model can effectively promote students to understand their staged learning effect in a timely manner and influence teachers to adjust (or solve) the specific links (problems) in teaching. Memduhoglu et al. [3] thought that blended teaching is closely related to teachers' teaching experience and suggested that they should strengthen the blended teaching effect by improving their teaching ability. Dai (2021) [4] designed four teaching steps in blended teaching (O2O), namely, construction, guidance, tutoring, and reflection, and compared and evaluated the teaching ability of teachers before and after the implementation of this teaching model by using the categorical regression tree (CART) algorithm of data mining technology. The results show that this teaching reform is conducive to cultivating the critical thinking and innovative ability of students. Li [5] thought that information technology should be used to establish a normal monitoring and feedback mechanism for basic teaching data so as to promote the smooth evaluation of courses under new teaching models, such as online and offline mixed teaching. Hendra Divayana et al. [6] established an evaluation model that is mobile phone based CIPP (Context-Input-Process-Product); they thought that it played a great role in their learning process and that the teaching efficiency and quality were significantly improved. Yue [7] believed that online personalized learning services may provide good services for learners and that the O2O flipped classroom model may better reflect more characteristics of intelligent learning time. Gao et al. [8] integrated the four-element and problem-based instructional design models into the overall task instructional design. The results show that in blended teaching, teachers should pay more attention to the students' learning experience and make full use of various online and offline teaching resources. Taking badminton as an example, Dou [9] studied the design and implementation of a mobile teaching platform under the O2O PE teaching model. Setyawan [10] revealed that blended teaching is conducive to improving the English reading performance of learners. Yen et al. [11] compared face-to-face, online, and blended teaching models in the undergraduate course Child Development. The results showed that under the three teaching models, students perform equally well in all three exams, research papers, and overall course scores, which lightened the traditional reservations regarding online and blended teaching effects. Wu [12] thought that with the progress of Internet technology, the basic education concept

of colleges and universities would be based mainly on the "online+ offline" teaching model, which can improve teaching efficiency and thus promote the progress of the current education system. Veeraiyan et al. [13] held that interactive teaching methods on offline and online platforms can improve the academic performance and critical thinking ability of learners. Wang et al. [14] selected 63 junior students majoring in Anesthesiology in Wenzhou Medical University as the research object and randomly divided them into two groups. The results show that the online and offline interactive teaching method can improve not only the theoretical test scores of students but also their learning participation and that good teaching results are achieved. Rachmah [15] investigated the responses of 16 college English students to online and offline classes. The results show that blended teaching can promote classroom interaction between teachers and students, with students becoming more interested in the teaching process and enjoying it in class. Bryson et al. [16] believed that the transition to complete online teaching involves a process, in which the role of teachers is transformed into the planner of online and offline student experiences.

From the existing research literature, it can be seen that although blended teaching is the trend of higher education teaching reform at present, because it combines the characteristics of online teaching and classroom face-to-face teaching, the influencing factors involved are more complicated. Accordingly, the evaluation of blended teaching effect has attracted research attention. Blended teaching puts forward higher requirements for learners, the environment, and teachers. At the individual level, students' cognition, interest in learning, self-efficacy, and autonomous learning abilities, such as self-planning, self-monitoring, and self-adjustment, are important factors that affect the learning effect. As for the teaching environment, the blended teaching approach involves both online and offline environments, in which social learning theory attaches importance to the interaction between individuals and the environment. Moreover, factors such as teaching software and hardware facilities, network fluency, and the design of learning resources and teaching interactions within the teaching process greatly influence students' learning experiences and outcomes. From the level of teachers, it is very important for teachers to coordinate online and offline teaching content, mobilize students' learning enthusiasm, track students' learning status in time, and provide them support, feedback, and evaluation. Therefore, how to give full play to the advantages of blended teaching, mobilize all positive factors to improve the teaching effect, learn from the advantages of online and face-to-face teaching, and avoid the disadvantages of both to improve the learning effect is an important goal in current research.

3   METHODOLOGY

3.1   Model introduction

Structural equation model (SEM), also known as covariance structure, is a modeling method to deal with and test the relationship between variables. Compared with other statistical models, SEM can handle the path relationships of multiple independent variables and multiple dependent variables simultaneously, and it is more comprehensive and flexible in data fitting and model checking. SEM has been widely used in the fields of economics, behavior, psychology, management, and education, and it plays an important role in multivariate statistical research. SEM belongs to empirical analysis, which mainly tests the rationality of a structural relationship or assumptions in a model by discovering the inherent structural relationship between variables and provides indexes and theoretical support for model modification. It includes a structural equation and a measurement equation, as follows:

$$X = \Lambda x \xi + \delta$$
$$Y = \Lambda y \eta + \varepsilon \tag{1}$$

Equation (1) is a measurement equation reflecting the relationship among endogenous latent variables, exogenous latent variables, and observable variables, where the relationship between exogenous latent variables and exogenous observable variables is expressed as Λx, and the relationship between endogenous observable variables and endogenous latent variables is expressed as Λy.

$$\eta = \beta \eta + \Gamma \xi + \zeta \tag{2}$$

Equation (2) is a structural equation reflecting the relationship between exogenous latent variables and endogenous latent variables, where β denotes a path coefficient characterizing the relationship between endogenous latent variables, Γ is a path coefficient reflecting the effect of exogenous latent variables on endogenous latent variables, and δ, ζ and ε are error terms.

3.2 Data source

Based on the existing research literature, the questionnaire titled "Evaluation of Blended Teaching Effect from the Perspective of STEAM" was compiled in this study. The questionnaire included independent variables in three aspects: online and offline teaching environment, online teaching resources, and offline teaching process. According to Schriesheim et al. [17] and Fieuws et al. [18], five, four, and four measurement questions for each aspect were designed. With students' learning satisfaction as a dependent variable, four measurement questions were designed based on the research results of Topala et al. [19] and Chen et al. [20]. The questionnaire was investigated using the Likert five-point attitude scale (5 = quite satisfied, 4 = satisfied, 3 = ordinary, 2 = dissatisfied, and 1 = very dissatisfied). Undergraduate students from Hainan University, Hainan Normal University, Hainan Tropical Ocean College, Qiongtai Normal University, Sanya College, and Hainan Medical College were selected as the respondents. In the autumn semester of the academic year 2022–2023, a total of 486 questionnaires were distributed in these six universities. Eventually, 425 questionnaires were recovered, and 320 complete and valid ones were acquired through preliminary checking and screening. Since at least 100 samples were required in SEM research, 200 samples were deemed better as a small sample size could easily lead to large errors in model parameter estimation. Hence, the 320 samples collected in this study conformed to the basic requirements of the SEM model.

4 RESULTS

4.1 Reliability and validity test

Reliability, which mainly refers to whether the measurement results are reliable, consistent, and stable, does not lie in the test or the scale itself but mainly depends on whether the results obtained by the test tools are consistent or stable. The validity cannot be high when reliability is low, when neither reliability nor validity is certainly good, or when both validity and reliability will be certainly very high. Cronbach's α coefficient is commonly used to measure reliability, mainly by measuring the internal consistency of the scale. In this study, the collected data were analyzed via SPSS22.0.

Table 1. Reliability test results

Variable Type	Variable Name and Number	Question Number	α Coefficient of Term Deleted	Cronbach α Coefficient	Cronbach α Coefficient
Independent variable	Online and offline teaching environment (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 whole questionnaire was tested using the calculation method of Cronbach's α coefficient, the value of which turned out to be 0.796. The dimensions of all influencing factors were also greater than 0.747, and the reliability coefficient of the research data was higher than 0.7, manifesting that the data were of high reliability quality and applicable to further analysis. The above analysis reveals that the scale used in this study exhibits both good stability and internal consistency, along with favorable overall reliability, thus enabling further research and analysis.

Validity analysis aims to analyze the effectiveness of questionnaires. In this study, validity analysis was performed mainly to test whether the measurement question-naire could reflect the satisfaction of college students with the blended teaching effect, including KMO and Bartlett's sphericity tests. KMO > 0.8 indicated that the research data were very suitable for information extraction (reflecting very excellent validity). If the KMO value was between 0.7 and 0.8, then the research data were suitable for information extraction (reflecting good validity); but if the KMO value was between 0.6 and 0.7, then the research data were relatively suitable for information extraction (reflecting ordinary validity). KMO < 0.6 indicated that the data were not suitable for information extraction.

Table 2. Validity test results

KMO value		0.828
Bartlett sphericity test	Approximate chi-square	1989.891
	Df	136
	p value	0

KMO and Bartlett tests were applied to verify the validity. From Table 2, it can be seen that the KMO value was 0.828, which was greater than 0.8. Thus, the research data were very suitable for information extraction (reflecting very good validity).

4.2 SEM results

Table 3. Results of model fitting indicators

Common Index	p	χ^2/df	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judging standard	>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 illustrates that the common SEM indexes were fitted favorably, which facilitated the further analysis.

Table 4. Summary of model regression coefficients

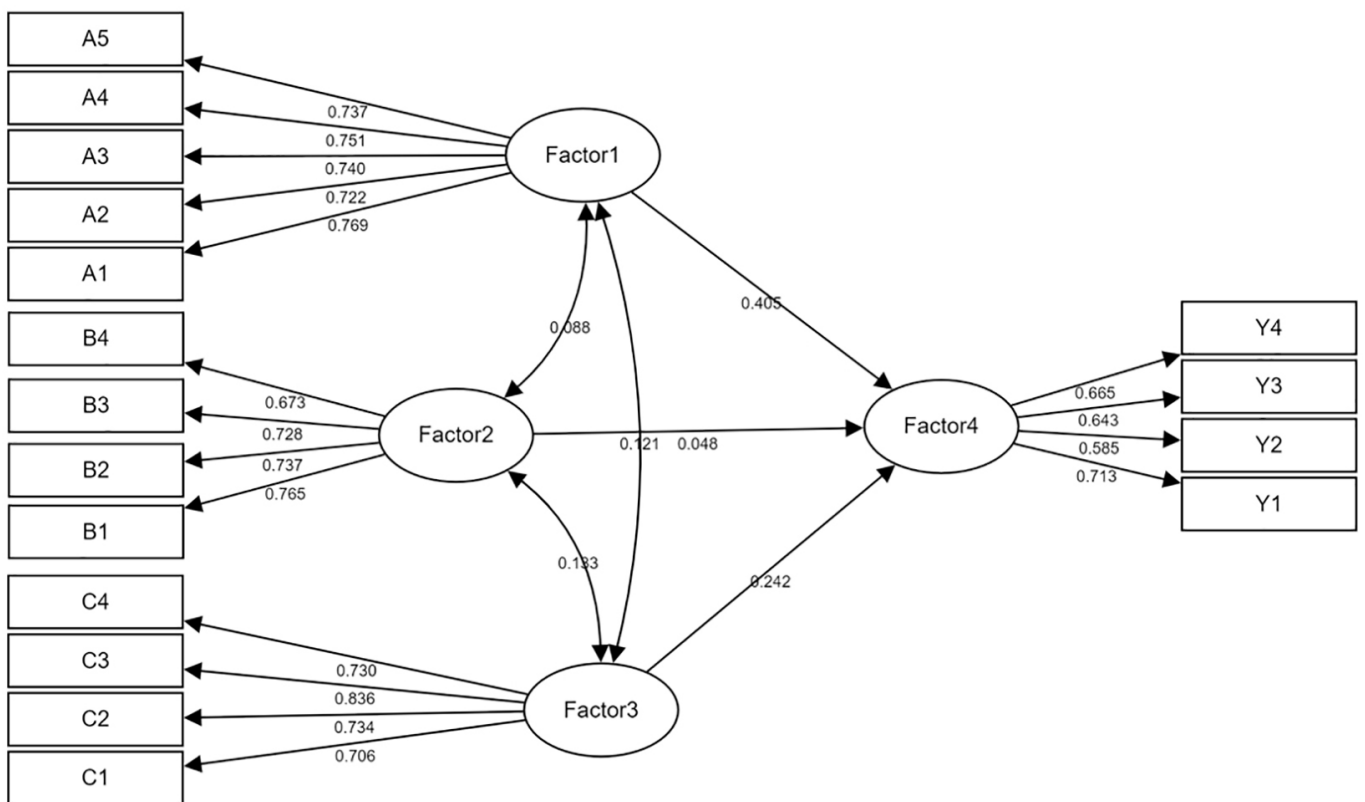| X	→	Y	Normalized Regression Coefficient	SE	z (CR Value)	p
Factor 1	→	Factor 4	0.405	0.062	5.703	0.000
Factor 2	→	Factor 4	0.048	0.057	0.728	0.467
Factor 3	→	Factor 4	0.242	0.062	3.545	0.000

Fig. 1. SEM results

Table 4 and Figure 1 show the following:

1. The online and offline teaching environment under the blended teaching model has a significantly positive effect on learning satisfaction. The main reason is that ordinary college teachers generally use the SPOC platform to teach on online teaching platforms. The SPOC platform, which is small scale and privatized, provides services for students. It focuses on students acquiring a complete and profound learning experience and meeting the individualized learning needs of students. Teachers can adjust and control the teaching progress according to the specific learning situation of the students and perform pertinent adjustments of teaching content. In the offline teaching environment, more university teachers have adopted the flipped classroom to ensure a good teaching environment under the blended teaching model and improve teaching quality. The flipped classroom is equipped with two smart screens to enable students in different positions to view content. It also has round tables, each of which is equipped with a microphone and a socket, making it convenient for students to interact with one another and ensure the normal use of learning tools. Advanced smart teaching tools such as Rain Classroom and Tencent Conference are adopted, which can effectively combine classroom teaching with information technology, and ensure students enter the learning state before class by pushing learning tasks and teaching reminders before class. The flipped classroom likewise uses real-time Q&A and danmu interaction to improve the efficiency of teacher–student interaction during class as well as help students review and consolidate after class through PPT push and synchronous live recording and broadcasting of courses. Meanwhile, teachers can enter various online teaching platforms at any time to watch students' learning situation synchronously and truly achieve full coverage before, during, and after class, which will help them adjust teaching strategies and improve teaching efficiency.

2. Online teaching resources under the blended teaching model have a positive effect on learning satisfaction but not significantly. This conclusion seems to be inconsistent with some existing research literature, but the potential reasons can be revealed through deep reflection. In the blended teaching model, there is a huge stock of online teaching resources, including online courses, which mainly refer to the video materials released by teachers on the SPOC platform before class. Students are required to complete pre-class learning needs and master course content through self-study, after-class assignments, and tests. After completing online course learning needs, they need to finish the corresponding after-class assignments, tests, and exercises according to the teaching arrangement, helping them learn the course content in depth and review the learned knowledge. Through resource indexing, teachers provide other course-related web links or video materials to complete students' learning materials, and students reasonably utilize online teaching resources according to their own learning status and learning effect. These massive online teaching resources include all kinds of media environments that are used to ensure the smooth implementation of teaching activities and all material conditions for teaching, including hardware and software resources. As college students are required to engage with such extensive learning resources during online learning, prolonged exposure may lead to learning fatigue for many of them. This can result in a decline in interest and motivation towards obtaining and using more online learning resources. Especially, many network learning materials are of varying quality and lack resource management and information filtering; consequently, students fail to

find the learning resources they need quickly, which hastens their confused and helpless state. This finding also informs us that college students should prioritize developing higher-quality online teaching resources instead of excessively pursuing the quantity of online teaching resources as well as developing individualized learning resources that meet the needs of different majors and grades to improve the application value of online learning resources.

3. The offline teaching process under the blended teaching model has a significantly positive effect on learning satisfaction. The main reason is that this process includes many scientific and systematic links. Before implementing teaching activities, teachers need to set specific teaching objectives according to the curriculum objectives and implement a series of teaching activities according to these teaching objectives. Students' academic situation should be understood because it has a considerable influence on the overall curriculum design of teachers. Teachers should adjust the teaching content according to the specific learning state of students and focus on teaching to ensure that students can absorb the course content efficiently. Under the guidance of teaching objectives, teachers must design teaching content in a planned way, mainly including video production, PPT production, and chapter division; clarify teaching activities and teaching methods; adopt appropriate teaching methods for different chapters, such as discussion for difficult problems; and guide students to conduct research through discussion. Meanwhile, a variety of teaching activities are determined to improve students' learning environment and stimulate their learning enthusiasm. The teaching effect should be fed back. After the course is taught, teachers should give timely feedback on the students' learning situation in class, making it convenient for the students to study more diligently and overcome weak links.

5 DISCUSSIONS

The continuous development of higher education informatization promotes the development and innovation of education and teaching models. The blended teaching model combines the advantages of the traditional face-to-face teaching and online education models and bridges the time–space boundaries [21]. Online and offline teaching models are implemented by many means, focusing on the combination of various emerging teaching forms (e.g., flipped classroom and MOOC). Therein, the online teaching model is implemented more simply, accompanied by a clearer online–offline division, more single requirements for the offline part, and stronger practicability. The application of the new blended teaching model provides a novel idea and method for diversified and intelligent teaching and, at the same time, makes teaching evaluation indispensable. Among past teaching evaluations, several were based on student performance, some on regular performance, and some on process and formative evaluation, but all lacked a student-oriented and learner-centered evaluation on the whole. Therefore, it is especially necessary to evaluate the blended teaching effect under the novel teaching model. However, blended teaching can be easily disrupted by two aspects: teachers and environmental influence. Teachers may lack self-confidence because of their own educational level and educational concept. From the aspect of environmental impact, policy support is weak and the hardware facilities that schools are already equipped with can barely meet the daily teaching needs of teachers. Owing to the scarcity of curriculum resources and limited teaching platforms, teachers believe that this shortage of resources will affect the application of the blended teaching model. Accordingly, with the continuous

development of the Internet, the learning emotion of learners during the learning process is tested based on blended teaching, affecting the learners' cognitive activities like attention, memory, and thinking through the corresponding teaching strategies. An important research content in the future lies in solving the failure of teachers to acquire and analyze in a timely manner students' emotional state and the difficulties encountered during offline teaching and online autonomous learning as well as facilitating learners to study under a more optimized emotional state.

6 CONCLUSIONS

The continuous innovation of emerging technologies such as big data, Internet of Things, cloud computing, and artificial intelligence has been brought into the field of education to some extent, exerting a considerable effect on promoting education reform. The leading role of teachers should be fully exerted in blended teaching, and efforts should be made to promote the creativity and subjective initiative of students as active learners by effectively facilitating the development and utilization of high-quality educational resources. In this study, questionnaire measurement questions for the evaluation of blended teaching effect were designed, and the effects of three aspects—online and offline teaching environment, online teaching resources, and offline teaching process—in blended teaching on the learning satisfaction of college students were estimated through SEM questionnaire technology. Finally, the following conclusions were drawn: (1) the overall Cronbach's α coefficient of the questionnaire is 0.796 and the KMO value is 0.828. (2) Learning satisfaction is positively promoted by the online and offline teaching environment and offline teaching process under the blended teaching model at a significance level of 1%. (3) Online teaching resources exert a positive, yet insignificant, promoting effect on learning satisfaction. In the future, the blended teaching models of different types and levels of colleges and universities in different regions and the close relationships of learners with colleges and universities, teachers, and their families can be further investigated.

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8 AUTHOR

Jiayao Cai is a lecturer at Ural College, Hainan College of Economics and Business, No.162 Qiongzhou Avenue, Qiongshan District, Haikou, China. He got Master's Degree of tourism management from Hainan University. His research interests focus on Hainan local culture as well as innovation and entrepreneurship (E-mail: 202008000010@hceb.edu.cn).