Improvement of Students’ Autonomous Learning Behavior by Optimizing Foreign Language Blended Learning Mode

Xue Wang1 and Wei Zhang1

Abstract
Given the significance of cultivating students’ autonomous learning ability, there is a need to develop an instructional model that can improve students’ awareness and behavior of autonomous learning, as well as to explore the effectiveness and optimization of this model effectively. Taking college English course as a case study, this paper constructs a blended learning mode based on SPOC, which combines advantages of online and offline teaching. 15 types of nonredundant sets resulting from 500 questionnaires has been explored, and the optimal factor combinations have been found out from 15 types with the technology of data mining to optimize the mode constructed previously. Optimized blended learning mode, emphasizing the optimal factors more, has been applied to College English curriculum design and teaching practice in China. Surveys of students’ achievement and autonomous learning behavior have been conducted after experiment. The results of the research indicate that the optimized blended learning mode will stimulate foreign language learners’ learning motivation, cultivate their autonomous learning ability, so as to construct and improve their autonomous learning behavior further.

Keywords
autonomous learning behavior, blended learning mode, foreign language teaching, teaching optimization, data mining

Introduction
With the advancement of informatization, great changes in teaching methods have happened and “transformation of technology-enhanced learning has occurred in recent years” (Zou et al., 2018, p. 427). Web-based learning, which is student-centered and focuses on students’ autonomous participation, has been carried out in full swing in foreign language instruction. This new mode, breaking the barrier of limited space and time, has great effect on linear instruction centered on classroom, textbook and teacher in foreign language teaching and learning. Nevertheless, the online learning will lead to the lack of systematic knowledge, and it is difficult to cultivate students’ ability of autonomous learning in language teaching. Similarly, the face-to-face teaching will lead to students’ passive role in learning; therefore, it is difficult to arouse students’ enthusiasm for learning in the foreign language course. It is shown that the pure online or offline mode will not affect autonomous learning behavior in foreign language instruction positively. Consequently, it is a major issue in the field of foreign language education how to construct and optimize a learning mode with appropriate combination of online and face-to-face teaching in order to develop students’ ability of autonomous learning and improve their autonomous learning behavior.

In 2007, the Department of Higher Education in China put forward that “the new teaching mode should be supported by modern information technology, especially network technology, so that English teaching will not be limited by time and place, and will develop in the direction of personalized learning and autonomous learning” in College English Teaching Requirements. College English is a compulsory course for all non-English majors during the first 2 years in China. This Teaching Requirements provides a detailed description and suggestions on the extensive application of modern information technology to teaching, optimizing the shortage of traditional teaching and constructing a comprehensive teaching mode, so as to create conditions for autonomous learning to meet the needs of students’ personalized learning. Indeed, people pay more attention to the autonomous learning mode

Mudanjiang Normal University, Heilongjiang, China
All authors are equally contributed.

Corresponding Authors:
Xue Wang, Department of Western Language, Mudanjiang Normal University, Mudanjiang, Heilongjiang 157011, China.
Email: susan1982@126.com

Wei Zhang, Department of Computer Science and Information Technology, Mudanjiang Normal University, Mudanjiang, Heilongjiang 157011, China.
Email: zhangwei706@126.com
on the Internet, and it is more popular with the development of network, multimedia and information technology. Especially in colleges and universities, teachers have started to build online learning platforms suitable for their needs. Besides, scholars also study the meanings of autonomous learning in the information environment (Alraimi et al., 2015; Chen et al., 2013), construct some autonomous learning mode in the information environment (Hsieh, 2017; Xu et al., 2004), design autonomous learning courseware (Ji et al., 2021) and online learning system (Cotterall, 2000). Nevertheless, there is a gap between the development of technology and education technology application (Zou, 2017). Most of online learning platforms lack interaction for the student-teacher and student-student, which results in no interpersonal collision and exchange of ideas. Knowledge, thought, and vision are limited, and it is detrimental to the expansion of students’ knowledge and development of their ability. No satisfactory results and changes have been brought by application of information technology in teaching practice. A survey by Seroussi and Yaffe (2020) also proves the limitation of the current network teaching platform. So the challenge and difficulty for teachers in practice is how to stimulate students’ learning motivation and improve students’ autonomous learning behavior through scientific and effective curriculum design combined online and face-to-face instruction.

Therefore, this paper redesigns the whole course completely and tries to construct a kind of blended teaching mode based on SPOC (Small Private Online Course), which is an effective linkage and complementary teaching mode of cooperative learning and autonomous learning supported by classroom teaching and internet technology. The research process shows that the mode will promote the changes of traditional teaching methods and teaching ideas, meet the needs of autonomous learning to the maximum extent, develop students’ autonomous learning ability, improve students’ autonomous learning behavior, and promote the realization of the overall teaching objectives.

**Autonomous Learning Behavior and Blended Learning**

Learning is a spontaneous behavior to meet individual needs. Loyens et al. (2008) believed that learning is an active behavior, which must be carried out by learners themselves. Learners construct their knowledge from the information they have.

Since the middle of the 20th century, the research of autonomous learning has developed rapidly, which further promotes the development of foreign language learning. What really brings autonomous learning into foreign language teaching is Henri Holec’s elaboration of the concept and practice of autonomous learning in his book Autonomy in Foreign Language Learning in 1981 (Holec, 1981). Foreign language autonomous learning is to make what learners learn become a part of themselves (McMillan & Rivers, 2011). Since then, the research and application of autonomous learning in foreign language teaching has been increasing. Some scholars focus on exploring the meanings of autonomous learning (Benson, 2007; Peeters, 2018); some scholars focus on exploring the teaching practice of autonomous learning (Macaskill & Denovan, 2013; Oxford, 2015), and the role of teachers’ play in teaching (Hamed et al., 2021; Lai et al., 2016; Rosell-Aguilar, 2018); some scholars are dedicated to exploring learning strategies related to foreign language autonomous learning (Cockrum, 2014; Oxford, 2015). Besides, some scholars believe that autonomous learning is rooted in western theories and is committed to exploring the cultural adaptability of foreign language autonomous learning in other environments (Schmid, 2018). In 2019, Yong Zhong et al proposed a new teaching approach known as Curriculum 2.0, which fills the missing content in autonomous learning (Zhong et al., 2019).

The development of modern information technology has brought great changes in teaching methods, which is of great significance to the cultivation of students’ foreign language autonomous learning ability. It has also been closely concerned by teachers and scholars, such as Benson (2007), Zhang and Wu (2009), Lai and Gu (2011), Lewis (2013), Rienties et al. (2018), Shadiev and Yang (2020). They have studied the application of modern technology to cultivating students’ autonomous learning ability, improving students’ autonomous learning and promoting students’ learning enthusiasm from different perspectives.

Blended learning is exactly a kind of teaching mode combining modern information technology with traditional teaching. It is not a new concept, but it has been given a completely new meaning, which is closely related to information technology. Resources can be used in an optimal way in order to improve students’ learning outcomes (Garrison & Kanuka, 2004). It combines the advantages of traditional learning methods and E-learning in the cultivation of students’ autonomous learning ability. It will fully reflect students’ initiative, enthusiasm, and creativity as the main body during the learning process (He, 2005). Blended learning can integrate resources effectively to meet the needs of autonomous learning, develop the ability of autonomous learning, and improve the quality of learning. This blended learning mode will bring about changes in teaching effect (Cockrum, 2014; Fox, 2013; Zhang et al., 2006) and learning effect (Vo et al., 2017).

In December 2003, Professor He Kekang officially advocated “blended learning” in China for the first time at the Seventh Global Chinese Computer Education Application Conference, which opened the prelude of “blended teaching” research in China. Blended learning becomes the mainstream mode of teaching. Chinese scholars always focus on the micro-level of blended learning strategies, mainly using empirical research paradigm to verify the impact of some strategies on blended learning, or focus on the development
of blended teaching activities and resource utilization. However, there is rare study of SPOC-based blended teaching mode in College English course in China, and the research on the relationship between autonomous learning behavior. SPOC was first proposed by Professor Fox in 2013, hoping to organically combine high-quality MOOCs resources with face-to-face classroom teaching, so as to flip classroom teaching, change teaching structure and improve teaching quality (Fox, 2013). With more abundant learning form, more professional teaching content and more effective interactive experience, it will provide more resources and learning methods for learners to choose, so that learners will learn autonomously according to their own needs, so as to cultivate the ability of autonomous learning and improve the behavior of autonomous learning gradually. SPOC, with small scale and restrictive conditions, is more suitable for the characteristics of College English teaching in China, and is an effective way of foreign language blended teaching. Thus, the blended learning mode based on SPOC will be beneficial, especially the optimization of module after the construction of curriculum model is creative. So this paper is of significance.

**Construction of Blended Learning Mode**

Self-determination Theory (SDT), which was proposed by American psychologists Deci and Ryan in the 1980s, constructed an autonomous behavior promotion model from the perspective of motivation, and discussed the influence of external environment on autonomous behavior (Wehmeyer & Little, 2007). It emphasizes that when the reward provided by the external environment meets the psychological needs of autonomy, it is most likely to stimulate the internal motivation and promote the individual’s autonomous behavior. In the process of offline and online learning, autonomous learning behavior is closely related to psychological factors, learning environment and learning demand. The learning environment can be directly improved through the analysis of learners’ needs, so as to improve the autonomous learning behavior. Scholars generally believe that learning behavior can be divided into explicit learning behavior and implicit learning behavior. Explicit learning behavior refers to the behavior that can be recorded by online learning platform and smart classroom IOT (Internet of things) devices while explicit learning behavior refers to the behavior related to learners’ learning motivation, reflection, learning satisfaction and other psychological activities. The occurrence of learning behavior is affected by internal factors and external conditions. Constructivism provides theoretical support and guidance for information teaching (He, 2005). As one of the information-based teaching methods, blended learning is a Constructivism Learning Theory which focuses on learner-centered teaching, emphasizes interaction and attaches importance to learning environment. Constructivism Learning Theory holds that learning is a process of meaning construction through interpersonal cooperation in the context of corresponding learning environment. Situational Cognitive Theory emphasizes the importance of real and specific social environment for learning more (Brown et al., 1989). Therefore, it is particularly important to create a model of autonomous learning behavior through appropriate learning environment.

Under the guidance of Constructivism, according to Self-determination Theory and Behavioral Stratification Theory, the application of modern educational means to curriculum reform can improve learners’ interest in learning and promote their autonomous learning behavior (Zhang & Zou, 2020; Zou et al., 2018). It will improve students’ initiative of autonomous learning by completing tasks, solving corresponding problems and promoting interaction (Shadiev & Yang, 2020). By means of educational technology, integrating blended learning model (Chung et al., 2016; Golonka et al., 2014; Hoic-Bozic et al., 2009) and blended learning curriculum framework (Huang et al., 2008), combining with the characteristics of College English curriculum, this paper constructs a SPOC-based blended learning mode for College English course. This mode organically combines high-quality online resources with face-to-face classroom teaching to improve teaching quality and learners’ participation. Meanwhile, learning is also a process of self-construction, and students will enhance their autonomous learning ability and fulfill the self-construction of autonomous learning behavior with the new mode.

According to the management by objectives, teaching process is divided into three stages: teaching preparation, teaching implementation, and teaching evaluation (Taylor et al., 2016). The blended learning based on SPOC consists of three basic parts: autonomous learning before class, face-to-face communication in class, and knowledge expansion after class as shown in Figure 1.

Firstly, autonomous learning before class mainly reflects learners’ explicit learning behavior, which directly affects the teaching effect later. During this period, learners are the main part of learning/teaching activities; their knowledge preparation, ability level, maturity, and motivation directly affect autonomous learning behavior. The technical support and rich resources of E-learning are major external factors. College English teaching includes skills training like listening, speaking, reading, writing and translating, which are practical and full of culture. Therefore, it is necessary to create a friendly and harmonious external environment for SPOC-based blended learning. Through the improvement of vivid multimedia courseware and video teaching, we build an online integrated ecosystem to provide environmental support for learners. Then learners will register and login SPOC platform according to teachers’ requirements and course selection, and begin their online autonomous learning.
Before class. They watch SPOC micro-video, find related resources, conduct preliminary test, and self-evaluation with the principle of time autonomy, place autonomy, and learning process autonomy.

Secondly, face to face communication in class is the embodiment of implicit learning behavior. The design of learning resources includes situational communication and interactive discussion. Activities are mainly organized by teachers, such as scenario simulation, role play, project training, case discussion, debate, problem discussion, and the like. Further, students will solve the questions in the previous stage with teachers’ help.

Thirdly, knowledge extension after class is the test of autonomous learning behavior. Students should continue to study online after class to expand the theme knowledge, explore cultural connotation, and conduct professional practice. It is found that the appropriate implementation of collaborative learning in teaching can significantly improve students’ degree of acceptance about teaching and their sense of social presence (So & Brush, 2008). Besides both face-to-face interaction and the online interaction are of importance. The use of chat rooms, e-mail and other tools can promote timely interaction between students and teachers. Students can communicate with teachers and classmates by BBS in SPOC, and social networking sites. Meanwhile, online test should be carried out to test students’ mastery of knowledge, so as to find out the deficiencies and continue to learn. After-class knowledge development can stimulate students’ motivation, promote students’ reflection, deepen the connection between new and old knowledge, so as to improve their interest and behavior in autonomous learning.

Through the analysis and discussion, we design a basic system model. According to the learning process of self-learning before class, face-to-face communication in class, and knowledge expansion after class, blended learning based on SPOC mainly consists of three parts: computer on network, face to face learning, device for online test. Computer on network mainly links learning server and learning terminal to provide services for online learning. Face to face learning is mainly situation and discussion, which realizes personalized learning by the situation simulation of computer technology. Online examination is realized by network and media technology, which tracks the effect of examination and promotes the improvement of learning scheme. Interactive and collaborative language learning promoted by technology will improve the learning environment.

In fact, the construction of blended learning mode based on SPOC provides an effective interaction and resource platform for teachers and students. Teachers’ online teaching and students’ online learning form a dynamic learning ecosystem with the network. In this ecological environment, teachers are the designers and implementers of teaching while students are beneficiaries. In the big data environment, a large number of teaching resources, learning resources and various intelligent systems are stored in the resource management platform. In the feedback system, students can self-analyze, self-test, and self-reflect. Combining the advantages of online and face-to-face teaching, an autonomous and collaborative learning mode is constructed. It is conducive to mobilizing students’ learning enthusiasm, achieving personalized learning goals and improving their autonomous learning behavior.
Optimization of Blended Learning Model with Data Mining Algorithms

Rough Set theory is proposed by professor Pawlak in 1982, which is a mathematical tool used to deal with imprecise, inconsistent, incomplete knowledge (Pawlak & Skowron, 2007). It is a kind of quantitative analysis whose prototype is derived from the simple information model. It forms concepts and rules through the classification and induction of relational database; it realizes knowledge discovery by the classifying equivalent relations and approximating classification to objectives (Hung, 2015).

Data mining technology based on rough set adopts association rules for statistics, which can find out the key attributes of teaching optimization reform (Ji et al., 2021). Blended learning will adjust the teaching path according to students’ learning interests. The optimization provided by data mining technology can provide reference for optimization of teaching design and teaching methods (Gao, 2020). Therefore, data mining technology provides the guarantee for basic information from the perspective of teaching decision-making so as to support optimization decision for blended teaching and learning (Hamed et al., 2021).

With the relevant theory and the practice of teaching reform (Liu et al., 2019; Zhang & Zou, 2020), the research analyzes the needs of blended autonomous learning mode to optimize the design. According to our model and technical support, learners’ needs and teaching practice, the optimization scheme of the course has been divided into three main parts including six aspects totally: online learning before class, face-to-face classroom learning, and online supplement after class. Online learning before class includes improved courseware and teaching video; face-to-face classroom learning includes situational communication and interactive discussion; online supplement after class includes knowledge development and online test.

Before optimization, this study has analyzed learners’ needs and found factors that can improve learners’ autonomous learning behavior in their mind from six aspects in constructed mode by survey from two different developed regions in Northeast China and East China. Five hundred subjects were selected from two institutions at different levels, including 250 students in grade one and two respectively, and 493 valid questionnaires were collected. According to blended learning mode constructed, there are six options for selection. Learners can choose at least one option or more than one. Then learners carry out experimental learning according to their own choice of optimization options for 2 months. Two months later, the learning effect of the students’ selected combination is evaluated by investigation, so as to analyze the effectiveness of each combination in improving learners’ autonomous learning ability. Sorting out the survey results, it can be found that subjects who have chosen more aspects from six options can better improve their autonomous learning behavior in general. But this is only a quantitative analysis, but not a qualitative analysis, which cannot screen effective external factors in the mode to improve students’ autonomous learning behavior. Therefore, the effective data is filtered from the questionnaire, and the repeated questionnaires with the same selected items are deleted. Finally, 15 kinds of combination of options with completely different content and decision-making are obtained. Through the rough set algorithm, the external factors improving the autonomous learning behavior are effectively screened. Mark decision fully accepted by learners with (A), whereas with (D). The decision-making conclusion of learning effect is expressed by “YES” whereas “NO.” Finally, decision has been made to judge whether it is suitable for curriculum improvement through the overall conclusion. The specific data are shown in Table 1.

Through the calculation of the relative positive area from sampling data, the core attributes are calculated. Define the core of data as CRI.

\[
\text{CRI(H)} = \emptyset; \\
\text{For the } k(i) \in H \\
\text{Relative positive region computation} \\
\text{COL(H-\{k\})(g)} \\
\text{If } (\text{COL(H-\{e\})(g)} \neq \text{COLH(g)}) \\
\text{CRI(M)} = \text{CRI(M)} + \{e\}; \\
\text{Endif} \\
\text{EndFor} \\
\text{PIT} = \text{CRI(M)} \\
\]

Where CRI(H) is the core of attributes, \( k(i) \) is relative component of CRI(H), \( \text{COL(k)} \) is the relative positive domain, \( \text{CRI(M)} \) is reduced value, and \( \text{PIT} \) is the result of reduced value. Firstly, the core of compatible information systems is obtained by using relative positive domain. Then, the importance of attribute is defined by the attribute dependency. According to the importance of attribute as heuristic information, the attributes with higher importance are added to the reduction set until the termination condition is satisfied. The detailed calculation process is shown in the appendix.

For comparison K2 with K3, the value of K2 is 4/15, and K3 is 9/15. Obviously, K3 is higher than K2 in numerical value, and K3 is relatively important. Therefore, K3 is added to the reduction union set \{K1, K3, K6\}. And then cycle calculation has been conducted by comparing the values of two attributes in turn and adding the relatively important attributes to the union set. The calculation will be terminated when the reduction degree is greater than or equal to 0.6. Finally, it is calculated that \{K1, K3, K6\} is the core of the attribute. Therefore, improved courseware, situational communication and online test are the cores of optimization.

According to the results of attribute reduction calculation, the cores were selected from six basic attributes of improving autonomous learning ability, that is, improved courseware, situational communication and online test. The results were consistent with the learners’ choice in which improved courseware (92%), situational communication (88%), and
online test (76%) accounts for a higher proportion. After attribute reduction, improved courseware, situational communication and online testing are considered as the key points of curriculum reform. Through the reform and optimization of core attributes, learners’ autonomous learning behavior will be improved under the new curriculum mode.

In teaching practice, the improved courseware, situational communication and online test are helpful in cultivating the autonomous learning capability. Courseware is the essential part in network teaching. The improved courseware has been combined with multimedia to improve usability, which should be flexible and vivid, and it will attract learners to join the learning activities directly. Situational communication can make scholars better integrate into the language environment. With the appropriate environment, learners can accept language learning more easily. Online test can evaluate the effect of learning at any time. It is helpful for learners to transform learning strategies and change learning progress. Learners can compare with classmates, so as to promote the improvement of autonomous learning behavior.

### Evaluation of Blended Learning Mode Optimized

This paper applies data mining based on rough set to determining the cores of the blended teaching mode. The cores are considered as improved courseware, situational communication and online test, which will improve the students’ autonomous learning behavior in College English learning. Therefore, the improvement of these three aspects has been paid more attention in the optimization of curriculum. Due to the unique advantages of the optimized blended learning model, we selected 600 freshmen and sophomores totally from four Chinese universities for reform and testing. These learners have studied College English for at least 12 months with the improved blended learning mode based on SPOC. After learning, the English abilities such as listening, speaking, reading, writing, and translating have been compared between pre-experiment and post-experiment to find out effect of the mode on autonomous learning. Through the comparative analysis of the data as shown in Figure 2, the learners’ foreign language skills have been greatly improved and learners’ learning effect has been significantly improved with this mode on the whole. By investigating the learners’ satisfaction with the application of the optimized model, it can be found that the learners’ satisfaction of listening, speaking, reading, writing, and translating with the SPOC blended learning model is higher than that of the traditional teaching
model. As shown in Figure 3, this mode can improve the learning effect and learners’ satisfaction with foreign language teaching effectively; in addition, the learners’ initiative of autonomous learning and their autonomous learning behavior have been greatly improved. Conversely, the improvement of autonomous learning behavior has a positive impact on learning interest, learning efficiency and learning effect. The formation of this virtuous circle is of great beneficial to blended teaching in College English course.

This paper has investigated the situation of English autonomous learning through questionnaire and interview, and the subjects are non-English major freshmen and sophomores from six universities in Northeast and East China, including both key ones and local ones. It is available in arts, science, medicine and normal school, which is representative. A total of 1,200 questionnaires were distributed. Among them, 600 questionnaires for students with traditional teaching methods, and valid questionnaire is 569, with an effective rate of 94.8%. The others questionnaires for students who have studied college English with the improved blended learning mode based on SPOC for more than 1 year, and valid questionnaire is 574, with an effective rate of 95.7%. The subjects’ features such as groups, schools, gender ratio and students’ levels in two distributed parts tend to be consistent.

In the light of autonomous learning framework, combined with the characteristics of autonomous learning behavior and scholars’ studies, autonomous learning behavior can be divided into five parts: (1) to understand teachers’ teaching objectives and requirements; (2) to establish learning objectives and make learning plans; (3) to use learning strategies effectively; (4) to monitor the use of learning strategies; (5) to monitor and evaluate English learning process (Oxford, 2015). Referring to Oxford’s language learning strategy scale (Oxford, 2015), this paper adopts Xu Jinfen’s questionnaire on students’ English autonomous learning ability (Xu et al., 2004) as the basic questionnaire content, which includes five aspects and 32 indicators. The self-report questionnaire has been used, which focuses on five aspects of College Students’ Autonomous English learning ability. All the items are graded by Likert’s five subscale (Likert, 1932). The scale consists of a group of statements, each of which includes five kinds of answers: “very agree,” “agree,” “uncertainty,” “disagree,” and “very disagree,” which were recorded as 5, 4, 3, 2, and 1, respectively. The questionnaire involves five variables that constitute English autonomous learning, and the internal unity of each variable meets the statistical requirement. SPSS 22.0 was used to analyze the data. According to the questionnaire, 30 students were selected randomly as the interviewees. The interview also focused on five aspects of autonomous learning ability. In order to improve the reliability of the research results, the results of the questionnaire were compared with those of the interview to describe the situation of students’ autonomous learning behavior in College English course more accurately.

The statistical results of the mean value about self-learning ability questionnaire are shown in Figure 4. It can be seen that the average values of the questionnaire about the students who have studied with the improved mode for more than 1 year are distributed from 3.9 to 4.6, while the average values of the students with traditional teaching method are distributed from 2.4 to 4.0. So it is clear that the former is higher than the latter, especially in establishing learning objectives and learning plans, monitoring the use of learning strategies and evaluating learning process. Traditional teaching methods can not carry out personalized learning according to learners’ characteristics. It is difficult for students to find out their own learning problems, let alone solving the problems, so the initiative of autonomous learning is poor. Blended learning mode based on SPOC can help students better understand teaching objectives and teachers’
requirements, clarify learning objectives and make learning plans to meet their own needs, so as to use learning strategies effectively. In addition, it can also monitor the use of learning strategies and monitor and evaluate the learning process. Therefore, the initiative of learning will be greatly enhanced, and the autonomous learning behavior will be improved in the learning process.

Conclusion and Recommendation

It is significant to emphasize students’ individuality in foreign language teaching. Foreign language learners’ autonomous learning behavior is mainly dominated by learning needs, learning interests, and learning mode. Blend learning mode is an integration of online and offline methods endowed with humanistic characteristics, which is helpful in promoting students’ learning engagement and interaction, providing students personalized learning experience, turning the inefficient passive learning into effective active learning. This paper has constructed a blended learning mode based on SPOC according to the characteristics of College English course and the students’ requirements. The paper has applied the attribute reduction algorithm to data analysis to solve the basic problems on the premise of keeping the attributes unchanged. Through the attribute reduction, the core of the attributes have been found out, the needs of curriculum design have been calculated, the curriculum decision-making and curriculum design have been simplified, and our mode optimization design has been gained. Then, the optimized blended learning mode for College English has been put into practice for 12 months, after which the feedback about learners’ autonomous learning behavior and learning achievement has been collected. The statistics results have shown that the optimized blended learning model based on SPOC focuses on using priority factors of the mode in teaching; besides, it has played an active role in constructing and improving autonomous learning behavior and autonomous learning effect. Naturally, the samples have been chosen from two regions in China for the limited conditions, and it is hoped that more subject will participate in this research, more samples from different regions will be collected to contribute to optimizing the blended learning mode based on SPOC.

Appendix

Calculation of the functions by computer:

\[
PTE_{(k_1)}(g) \neq PTE_{A}(g),\]
\[
PTE_{(k_2)}(g) = PTE_{A}(g),\]
\[
PTE_{(k_3)}(g) \neq PTE_{A}(g),\]
\[
PTE_{(k_4)}(g) = PTE_{A}(g),\]
\[
PTE_{(k_5)}(g) \neq PTE_{A}(g),\]
\[
PTE_{(k_6)}(g) = PTE_{A}(g),\]

Figure 4. Mean value statistics of self-learning ability questionnaire.
M = \{k1, k3, k5\}, \{Improved courseware, Situational communication, Knowledge development\} for the data of core.

R/M = \{\{1, 2\}, \{3\}, \{4, 5, 6, 7\}, \{9, 10\}, \{12, 13, 14, 15\}, \{8\}, \{11\}\}

R/M∪\{a2\} = \{\{1, 2\}, \{3\}, \{4, 5, 6, 7, 8, 9, 10\}, \{12, 13\}, \{11\}, \{14\}, \{15\}\}

R/\{d\} = \{O1, O2\},

O1 = \{3, 8\},

O2 = \{1, 2, 4, 5, 6, 7, 8, 9, 10, 12, 13\}

K_M(g) = 4/15,

K_M∪\{k2\}(g) = 9/15,

PIT(k2, M, g) = 4/15.

R/M∪\{k3\} = \{\{1, 2\}, \{3\}, \{4\}, \{5, 6, 8, 9\}, \{7\}, \{10\}, \{11\}, \{12, 13, 14\}, \{15\}\}

K_M(g) = 9/15,

K_M∪\{k3\}(g) = 6/15,

PIT(k3, M, g) = 9/15.

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ORCID iD

Xue Wang https://orcid.org/0000-0003-4013-8031

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