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Influence of blended instruction on students' learning effectiveness: the role of Flow

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Abstract

The rapid development and extensive application of information and communication technologies has facilitated blended instruction, which is regarded as the "new normal" in the field of modern education and has become the focus of academic research. This study thus explored the influencing mechanism of blended instruction on students' learning effectiveness from the perspective of complementarity and conflict with the support of flow. This study collected 349 survey data from universities in Southwest China that adopted a blended instruction mode and analyzed them using the structural equation model. The results demonstrated that complementary advantages and practical conflicts in blended instruction influenced students' flow experience during the learning process. Flow experience plays an important role in blended instruction and influences positively students' cognitive, emotional, and behavioral engagement. Learning engagement impacted positively students' learning effectiveness. In addition, self-efficacy positively moderated the relationship between students' learning engagement and learning effectiveness in blended instruction. These findings contribute to related research on blended instruction. The implications and limitations of this study are discussed.

Keywords Blended instruction · Flow experience · Learning engagement · Learning effectiveness

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1 Introduction

The rapid development and extensive application of information and communication technologies (ICTs) has effectively promoted its deep integration in the field of education. In particular, the COVID-19 pandemic severely disrupted traditional learning patterns worldwide, forcing students to learn in ways that require fundamental changes (Ahmed & Opoku, 2022; Heo et al., 2021). Blended instruction is a new teaching paradigm that combines traditional face-to-face teaching with online learning (Garrison & Kanuka, 2004; Lim & Morris, 2009). As a major revolutionary upgrade of the traditional teaching mode and fully online learning mode, blended instruction provides the best opportunity for students to find the most appropriate learning style based on their own learning needs (Rasheed et al., 2020). Blended instruction has been regarded by many scholars as the "new normal" in the field of modern education due to its unprecedented potential and subversive advantages (Dziuban et al., 2018; Ma & Lee, 2021). As such, blended instruction has become the focus of many studies.

Research has focused on whether blended instruction can effectively improve students' learning effectiveness (López-Pérez et al., 2011); however, the results were contradictory with no consensus on the issue (Kintu et al., 2017; Law et al., 2019; Ma & Lee, 2021; Vo et al., 2020). In addition, most previous studies have focused on the pure network environment, with few of them investigating students' learning effectiveness during blended instruction. Therefore, further studies are required to confirm this hypothesis.

To explore the learning effectiveness of students during blended instruction, this study investigated flow due to its strong absorbing role (Khan et al., 2017). The concept of flow was proposed by the famous psychologist Csikszentmihalyi (1977), who believed that focusing on a certain thing produces flow, which is characterized by a high concentration of attention, a feeling that time flies, and feeling happy. Flow experience is defined as an optimal learning experience for students in the blended learning process, which can intrinsically motivate students to engage in the learning activities more actively and regularly (Csikszentmihalyi, 1977). Flow produces a blended learning experience of enjoyment through stimulation, which absorbs and immerses students in the process of blended learning. This triggers sustained and high-intensity learning engagement, which is considered a key factor in determining students' learning effectiveness in the learning environment (Blasco-Arcas et al., 2013; Panigrahi et al., 2021; Phan et al., 2016). Therefore, the flow in blended learning provides an inexhaustible source of motivation for promoting and maintaining students' learning engagement, as the flow itself has fluidity. However, previous studies have not addressed the role of flow in blended instruction. Specifically, there is a lack of research on which aspects of blended instruction will affect the flow and how the flow, in turn, will affect students' learning effectiveness through learning engagement. In addition, while previous studies examined the role of learning engagement in blended instruction, detailed analyses of learning engagement are lacking. Therefore, this study attempted to divide learning engagement into cognitive, emotional, and behavioral engagement.

Previous studies have shown that the combination of traditional face-to-face teaching and e-learning has created many complementary advantages (Bouilheres et al., 2020; Chiu, 2021; Jnr, 2021; Law et al., 2019; Prasad et al., 2018; Rasheed et al., 2020). However, blended instruction reform in colleges and universities revealed that some practical conflicts emerged (Smith & Hill, 2019). For instance, online and offline information is not fully integrated, and blended learning involves significant information redundancy and repetition, which increases student learning burden and may overwhelm them, thus creating information overload (Chen et al., 2011). Second, while e-learning systems provide a variety of rich features, some features are rarely used by students, as they exceed students' learning needs, causing system feature overload (Karr-Wisniewski & Lu, 2010). Previous studies observed that the complementary advantages and practical conflicts brought by blended instruction exist simultaneously. Nevertheless, the flow may play an important role in how the complementary advantages and practical conflicts of blended instruction impact students' learning effectiveness. However, the impact mechanism of how complementary advantages and practical conflicts of blended instruction influence flow and how flow influences students' learning effectiveness through learning engagement remains to be explored.

In addition, the difference in students' personal traits may influence their behavior, which can be attributed to self-efficacy. Flow may affect students' learning effectiveness through learning engagement. Essentially, learning engagement is the decisive factor in students' learning effectiveness, and this relationship may be moderated by self-efficacy. However, the mechanism of moderation is unclear. Self-efficacy is a belief in personal ability that affects people's choices, ways of doing things, efforts, perseverance, and resilience (Bandura, 1977). Furthermore, self-efficacy affects students' thoughts and emotions (Van Dinther et al., 2011). Therefore, self-efficacy may play an important role in blended instruction.

This study explored the influencing mechanism of blended instruction on students' learning effectiveness from the perspective of complementarity and conflict with the support of flow. The following research questions were posed:

RQ1: How do blended instruction's complementary advantages and practical conflicts affect students' flow experience?

RQ2: How does students' flow experience affect learning effectiveness through learning engagement in blended instruction?

RQ3: How does self-efficacy moderate the relationship between students' learning engagement and learning effectiveness in blended instruction?

The remainder of this paper is organized as follows. Section 2 describes the theoretical model and hypothesis development of this study. Section 3 introduces the research methodology. Section 4 provides the results of the data analysis. Section 5 discusses the research findings, theoretical implications, and practical implications of the study. Finally, Section 6 discusses the study limitations and future research directions.

2 Theoretical model and hypothesis development

2.1 Complementary aspects of blended instruction

Blended instruction organically combines the advantages of traditional face-to-face teaching and e-learning, and subverts the traditional teaching process. It creates many complementary advantages, which are mainly reflected in perceived convenience and complementarity, and can provide the most effective learning experience.

2.1.1 Perceived convenience

Blended instruction fully integrates the advantages of ICTs into the learning process. Rapidly growing online learning platforms provide a series of practical functions and convenient tools for students to carry out learning tasks (Bai et al., 2016), such as answering questions online, arranging electronic curricula, commenting, and downloading course materials. In addition, students can quickly access learning resources using mobile terminals and PCs, making the time and place of learning more flexible (Colin Milligan and Allison Littlejohn, 2014; Law et al., 2019; Owston et al., 2013; Ustun et al., 2021). Moreover, students can independently master the learning progress, effectively monitor their learning, and participate in the learning process more conveniently using online learning platforms (Jnr, 2021; Law et al., 2019; Owston et al., 2013). As such, students tend to like blended instruction courses, leading to higher satisfaction (Hogarth, 2010), which effectively improves their learning experience. Therefore, we propose:

H1: Perceived convenience positively influences flow experience.

2.1.2 Perceived complementarity

The introduction of e-learning technology effectively complemented traditional face-to-face classroom teaching, and blended instruction has become an indispensable part of traditional classroom teaching rather than a replacement (Huang et al., 2012; Kember et al., 2010; López-Pérez et al., 2011; Mitchell & Forer, 2010; Raes et al., 2020). Integrating e-learning technology into the learning process allows students to enjoy massive teaching resources and information and compensate for the deficiency of traditional teaching information (Al-Fraihat et al., 2020; Ustun et al., 2021). In addition, it also increases the methods by which students can capture knowledge and diversify information acquisition methods (Bai et al., 2016). Furthermore, online learning platforms include a variety of interactive features for students (Boelens et al., 2017; Rasheed et al., 2020). For instance, students can post comments or questions online and receive timely feedback from other students or teachers. Recognizing these advantages of blended instruction leads to higher satisfaction and effectively improves students' learning experiences. Therefore, we propose:

H2: Perceived complementarity positively influences flow experience.

2.2 Conflicting aspects of blended instruction

Blended instruction includes some practical conflicts, such as information and system feature overload. These conflicts are the main challenges faced by students in blended learning and have a negative impact on their learning experiences.

2.2.1 Information overload

Information overload is one of the main problems students encounter when using e-learning (Chen et al., 2011). Online learning platforms use internet technology and amass massive learning resources, producing a large amount of learning information after integration. However, this integration is not very effective (Bower et al., 2014), resulting in a significant amount of redundancy and repetition of online learning and traditional classroom learning information. When the amount of information that needs to be handled exceeds students' processing ability, students cannot effectively integrate, absorb, and utilize the information, leading to information overload (Karr-Wisniewski & Lu, 2010). Information overload distracts students from their daily learning activities and leads to burnout and pressure (Eppler & Mengis, 2004). The amount of information in blended instruction may overwhelm students (Karr-Wisniewski & Lu, 2010). A deeper sense of being overwhelmed and burdened by the excessive amount of information leads to higher learning boredom and a negative learning experience (Misra & Stokols, 2012). Therefore, we propose:

H3: Information overload negatively influences flow experience.

2.2.2 System feature overload

If the features of e-learning platforms exceed students' learning needs, system feature overload occurs (Karr-Wisniewski & Lu, 2010). Online learning platforms provide a variety of rich learning features (Al-Fraihat et al., 2020), such as electronic voting, live broadcast, note-taking, focus groups, discussion communities, hot news, and short videos. However, some features are rarely used and exceed the students' basic learning needs. Moreover, irrelevant features interfere with students' normal learning activities. In addition, some online learning platforms have a poor interface design (Prasad et al., 2018; Rasheed et al., 2020), which reduces students' learning efficiency and creates difficulty in performing learning tasks. In blended instruction, stronger feelings related to problems caused by system feature overload cause higher levels of boredom and lead to a negative learning experience. Therefore, we propose:

H4: System feature overload negatively influences flow experience.

2.3 Flow experience and learning engagement

Flow plays a vital role in blended learning, allowing students to fully immerse themselves in it (Khan et al., 2017). Flow releases positive and pleasant psychological elements, allowing students to enjoy blended learning experiences and encourage engagement in learning activities. Previous studies on the association between flow

experience and engagement have been conducted (Algharabat & Rana, 2021; Mesurado et al., 2016; Shin, 2018).

Flow in blended instruction produces a series of psychological activities of perception and thinking, allowing students to mobilize cognitive resources and try to understand and digest the knowledge they have learned. When students encounter incomprehensible concepts, they actively read additional learning materials to adjust the learning process and realize blended learning goals. Therefore, we propose:

H5: Flow experience positively influences cognitive engagement.

When students experience flow in blended instruction, they are more likely to immerse themselves in blended learning and invest all their energy into it, resulting in a high sense of fulfillment and pleasure and a positive emotional experience. Therefore, we propose:

H6: Flow experience positively influences emotional engagement.

Flow in blended instruction encourages purposeful learning behavior and concentration consistently, allowing students to actively solve the problems encountered in learning and participate in discussions between teachers and peers, becoming actively engaged in blended learning activities.

H7: Flow experience positively influences behavioral engagement.

2.4 Learning engagement and effectiveness

Fredricks et al., (2004) conducted an extensive literature review and proposed a theoretical framework of learning engagement that includes three unique and interrelated dimensions: cognitive, behavioral, and emotional engagement. This study thus adopted this framework to investigate students' learning engagement in blended instruction.

Learning engagement is a necessary condition for students to effectively participate in learning activities (de Brito Lima et al., 2021; Hu & Hui, 2012). High engagement can activate students' learning desires and guide them to actively and deeply engage in the learning process (Blasco-Arcas et al., 2013). Previous studies have shown that students' learning engagement is a key determinant of learning effectiveness, which is positively correlated with students' learning effectiveness (Chen, 2017; Phan et al., 2016; Rajabalee & Santally, 2021).

High cognitive engagement in blended courses leads to the reading of extra learning materials to gain more knowledge. When students encounter unknown concepts or fail to understand the material, they actively take action to solve this, such as reviewing the material. This helps students gain learning effectiveness. Therefore, we propose:

H8: Cognitive engagement positively influences learning effectiveness.

High emotional engagement in blended courses produces a series of positive emotional experiences, causing students to like blended courses and feel excited about their performance. Students are increasingly interested in blended courses and feel happy, thus improving their learning effectiveness. Therefore, we propose:

H9: Emotional engagement positively influences learning effectiveness.

High behavioral engagement in blended courses causes students to consciously follow course rules and concentrate their energy and attention consistently, devot-

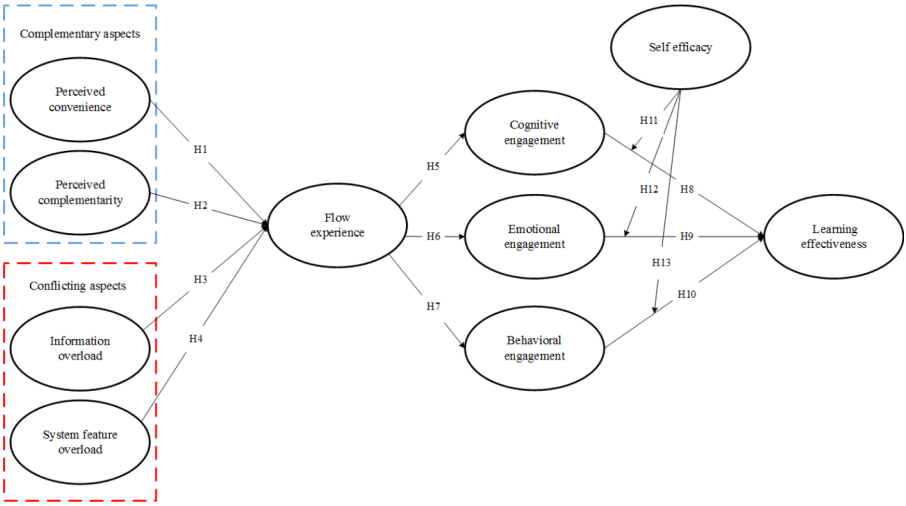

Fig. 1 Research model

ing time to coursework, actively engaging in classroom discussions, and completing homework on time, which improves learning effectiveness. Therefore, we propose:

H10: Behavioral engagement positively influences learning effectiveness.

2.5 The moderating role of self-efficacy

Self-efficacy is characterized by a person's belief in their ability to achieve the expected goals or standards (Bandura, 1977). Self-efficacy is composed of universal psychological demand, which moderates individual cognition, emotion, and behavior (Bandura, 1977). Individuals with high self-efficacy tend to evaluate potential stress situations as challenges rather than threats compared to individuals with low self-efficacy, making them more inclined to use adaptive coping strategies in blended learning environments (Boelens et al., 2017; Owston et al., 2013). Therefore, self-efficacy plays a key role in blended learning environments and helps students moderate their learning (Bandura, 1977). Figure 1 illustrates the research model used in this study. Therefore, we propose:

H11: Self-efficacy positively moderates the relationship between cognitive engagement and learning effectiveness.

H12: Self-efficacy positively moderates the relationship between emotional engagement and learning effectiveness.

H13: Self-efficacy positively moderates the relationship between behavioral engagement and learning effectiveness.

3 Research methodology

3.1 Measures

To ensure the reliability and validity of the variables, a mature scale was adapted from previous studies to measure all variables. All items were measured on a 7-point Likert scale (1 = strongly disagree, 7 = strongly agree). As the participants of the questionnaire were students from the Chinese mainland, to improve the reliability and validity of the questionnaire, we translated the questionnaire into Chinese with the help of three experts in the field of education. According to their comments before the test, we made slight modifications to the wording of the measurement items to fit the blended instruction context and ensure the readability and clarity of the questionnaire. Before the formal distribution of the questionnaire, a small-scale pilot test was conducted with students in blended courses. Finally, we obtained a final research questionnaire. The final measurement items are listed in Table 1.

To be specific, perceived convenience was measured using the items adapted from Chang et al., (2012); perceived complementarity was measured using the items adapted from Lin & Lu (2011); information overload was measured using the items adapted from Zhang et al., (2016); system feature overload was measured using the items adapted from Karr-Wisniewski & Lu (2010); flow experience was measured using the items adapted from Chang & Zhu (2012); cognitive, emotional, and behavioral engagement was measured using the items adapted from Sun & Rueda (2012); learning effectiveness was measured using the items adapted from Jr (2019); and self-efficacy was measured using the items adapted from Lee et al., (2010).

3.2 Data collection

This study surveyed students in colleges and universities in southwest China that adopted the blended instruction mode. Data were collected from October to November 2021 by combining online and offline methods. Online collection was conducted using an online professional survey platform on the Chinese mainland (www.wjx.cn), which has over 33 million registered users and has completed over 2.3 billion questionnaires. Offline collection was conducted during blended instruction classes in colleges and universities to distribute the questionnaires. Blended instructions were briefly described at the beginning of the questionnaire. In addition, to ensure that the subjects answered honestly and the results were valid, screening items were included in the questionnaire, and those who failed were excluded. In total, 349 valid questionnaires were obtained. Demographic data of the respondents are presented in Table 2.

Table 1 Constructs and measures

Constructs	Items	Sources
Perceived convenience	1. The blended instruction platform allows me to carry out learning tasks at any time. 2. The blended instruction platform allows me to carry out learning tasks anywhere. 3. The blended instruction platform makes it convenient for me to participate in learning. 4. The blended instruction platform makes my learning feel convenient.	Chang et al., (2012)
Perceived complementarity	1. The teaching resources and information on the blended instruction platform are updated in time. 2. A large number of open resources provided by the blended instruction platform compensates for the shortage of traditional teaching information. 3. The blended instruction platform solves the problem of the single interactive form of traditional teaching.	Lin & Lu (2011)
Information overload	1. There is a lot of information to check and deal with in blended instruction, and I feel overwhelmed. 2. There is a lot of redundant information in blended instruction, which makes me feel that it is a burden. 3. The amount of information in blended instruction often makes me feel upset. 4. There is a lot of information in blended instruction, but not all of it is what I need.	Zhang et al., (2016)
System feature overload	1. The features of the learning platform in blended instruction often distract my attention and are not necessary for my learning. 2. The learning platform in blended instruction has a poor interface design, which reduces the efficiency of my learning. 3. The redundant feature settings of the learning platform in blended instruction complicate the implementation of my learning plan. 4. The feature settings of the learning platform in blended instruction are more complicated than those necessary for me to complete the learning tasks.	Karr-Wisniewski & Lu (2010)
Flow experience	1. I have a clear learning goal in blended instruction. 2. I feel that I am integrated into what I have learned in blended instruction. 3. I feel happy and time flies during blended instruction. 4. Blended instruction makes me form attachment and retention to learning.	Chang & Zhu (2012)
Self-efficacy	1. Compared with others in my class, I think I am a good student. 2. My study skills are excellent compared with others in my class. 3. I am certain that I can understand the ideas taught in my classes. 4. I am sure I can do an excellent job on class assignments and homework.	Lee et al., (2010)
Cognitive engagement	1. I read extra materials to learn more about things we do in the blended instruction courses. 2. If I do not know a concept when I am learning in the blended instruction courses, I do something to figure it out. 3. If I do not understand what I learned in the blended instruction course, I review the online course.	Sun & Rueda (2012)

Table 1 (continued)

Constructs	Items	Sources
Emotional engagement	1. I like taking blended instruction courses. 2. I feel excited by my work in blended instruction courses. 3. I am interested in the work in blended instruction courses. 4. I feel happy when taking blended instruction courses.	Sun & Rueda (2012)
Behavioral engagement	1. I follow the rules of blended instruction. 2. I can consistently pay attention during blended instruction. 3. I complete my homework in blended instruction on time.	Sun & Rueda (2012)
Learning effectiveness	1. My learning efficiency is higher in the blended instruction course. 2. My academic performance is better in the blended instruction course. 3. Blended instruction courses have broadened my knowledge. 4. The quality of my homework is higher in the blended instruction course.	Jr (2019)

Table 2 Demographics of the research sample (n = 349)

Measures	Item	Frequency	Percentage (%)
Gender	Male	146	41.83%
	Female	203	58.17%
Age	< 18	5	1.43%
	18–22	296	84.82%
	23–26	43	12.32%
	> 27	5	1.43%
Education	Specialist	5	1.43%
	Undergraduate	295	84.53%
	Master degree or above	49	14.04%

4 Data analysis and results

4.1 Assessment of the measurement model

The SPSS 23.0 and Amos 21.0 were used to analyze the data. Cronbach's alpha was calculated using SPSS 23.0. The Cronbach's alpha values were all > 0.7, indicating good data reliability. AMOS 21.0 was used to carry out confirmatory factor analysis. The results demonstrated that the chi-square value ($\chi^{2)}$ was 1256.012, the degree of freedom (df) was 584, and the ratio of χ^2/df was 2.151, which was lower than the recommended value of 5 (Bagozzi & Yi, 1988).

In addition, the comparative fit index (CFI = 0.929), tucker-lewis index (TLI = 0.919), incremental fit index (IFI = 0.929), and root mean square error approximation (RMSEA = 0.058) all met the recommended standards, indicating a good model fit. In addition, convergence validity was analyzed. As shown in Table 3, the standard factor loading of all measurement items exceeded 0.7, the composite reliability (CR) value exceeded 0.7, and the average variance extraction (AVE) value exceeded 0.5, which indicated that the data had good convergent validity (Fornell & Larcker, 1981). The results are shown in Table 3.

Table 3 Construct reliability and validity

Construct	Items	loadings	CR	AVE	Cronbach's α	VIF
Perceived convenience (PCON)	PCON1	0.81	0.89	0.66	0.89	1.91
	PCON2	0.71				
	PCON3	0.84				
	PCON4	0.88				
Perceived complementarity (PCOM)	PCOM1	0.81	0.82	0.60	0.81	1.89
	PCOM2	0.78				
	PCOM3	0.74				
Information overload (IO)	IO1	0.83	0.89	0.68	0.89	1.96
	IO2	0.86				
	IO3	0.84				
	IO4	0.75				
System feature overload (SYO)	SYO1	0.73	0.88	0.66	0.88	2.00
	SYO2	0.74				
	SYO3	0.89				
	SYO4	0.87				
Flow experience (FE)	FE1	0.81	0.90	0.68	0.89	2.57
	FE2	0.86				
	FE3	0.80				
	FE4	0.84				
Self efficacy (SEEF)	SEEF1	0.74	0.88	0.66	0.88	1.52
	SEEF2	0.81				
	SEEF3	0.83				
	SEEF4	0.86				
Cognitive engagement (CE)	CE1	0.81	0.82	0.60	0.82	1.68
	CE2	0.81				
	CE3	0.69				
Emotional engagement (EE)	EE1	0.89	0.94	0.80	0.94	2.35
	EE2	0.92				
	EE3	0.89				
	EE4	0.88				
Behavioural engagement (BE)	BE1	0.72	0.79	0.55	0.79	1.91
	BE2	0.81				
	BE3	0.70				
Learning effectiveness (LE)	LE1	0.89	0.90	0.70	0.90	/
	LE2	0.85				
	LE3	0.78				
	LE4	0.84				

Furthermore, the correlation coefficients of all structures were compared with the square root of the AVE value. The results demonstrated that the correlation coefficients of each structure were less than the square root of the AVE value, indicating that these structures had good discrimination validity (Tenko Raykov, 2010). Table 4 presents the results of this study

Finally, as the data collected were based on the subjective perception of students' self-reports, common method bias may affect the reliability of the data analysis results. Therefore, multiple collinearity tests were conducted, and the results showed

Table 4 Discriminant validity

	AVE	PCON	PCOM	FE	IO	SEEF	SYO	CE	EE	BE	LE
PCON	0.66	0.81									
PCOM	0.60	0.62	0.78								
FE	0.68	0.52	0.51	0.83							
IO	0.68	-0.05	-0.01	-0.19	0.82						
SEEF	0.66	0.31	0.32	0.47	0.02	0.81					
SYO	0.66	-0.04	-0.02	-0.12	0.68	0.15	0.81				
CE	0.60	0.37	0.45	0.47	0.07	0.44	0.16	0.78			
EE	0.80	0.51	0.47	0.72	-0.15	0.46	-0.08	0.46	0.89		
BE	0.55	0.47	0.40	0.59	-0.11	0.47	-0.03	0.52	0.57	0.74	
LE	0.70	0.55	0.56	0.66	-0.06	0.50	0.02	0.54	0.69	0.69	0.84

that all VIF values were less than the recommended index of 3.3 (Diamantopoulos & Siguaw, 2006). Therefore, common method bias was not a problem in this study.

4.2 Assessment of the structural model

Hypotheses were tested using Amos 21.0. In the structural model, the χ^2/df ratio was 2.34. The structural model fit indicators were as follows: RMSEA=0.062, CFI=0.924, TLI=0.916, and IFI=0.924. These indicators met the recommended standards, indicating that the structural model was acceptable (Hair et al., 2009).

The results demonstrated that perceived convenience ($\beta=0.38$, $p<0.001$) and perceived complementarity ($\beta=0.34$, $p<0.001$) positively and significantly influenced the flow experience, supporting H1 and H2. Information overload ($\beta=-0.23$, $p<0.01$) negatively and significantly impacted the flow experience, supporting H3. System feature overload ($\beta=0.09$, $p=0.25$) did not significantly influence the flow experience, and H4 was not supported. Flow experience positively and significantly affected cognitive engagement ($\beta=0.60$, $p<0.001$), emotional engagement ($\beta=0.80$, $p<0.001$), and behavioral engagement ($\beta=0.77$, $p<0.001$), thus supporting H5, H6, and H7. Cognitive engagement ($\beta=0.14$, $p<0.01$), emotional engagement ($\beta=0.34$, $p<0.001$), and behavioral engagement ($\beta=0.54$, $p<0.001$) positively and significantly affected learning effectiveness, thus supporting H8, H9, and H10. Figure 2 presents the results of the structural equation model analysis.

4.3 Moderation effect test

Using SPSS 23.0, this study tested the moderating effects of self-efficacy using a hierarchical regression method. To reduce the high correlation between independent and moderator variables and their interaction terms, variables were decentralized to reduce multicollinearity in the regression equation.

The results revealed that the interaction coefficient between self-efficacy and cognitive engagement was positive, but not significant ($\beta=0.078$, $p=0.072$). The interaction coefficient between self-efficacy and emotional engagement was positive and significant ($\beta=0.156$, $p<0.001$). The interaction coefficient between self-efficacy and behavioral engagement was positive and significant ($\beta=0.08$, $p<0.05$). Therefore, H12 and H13 were supported, whereas H11 was not.

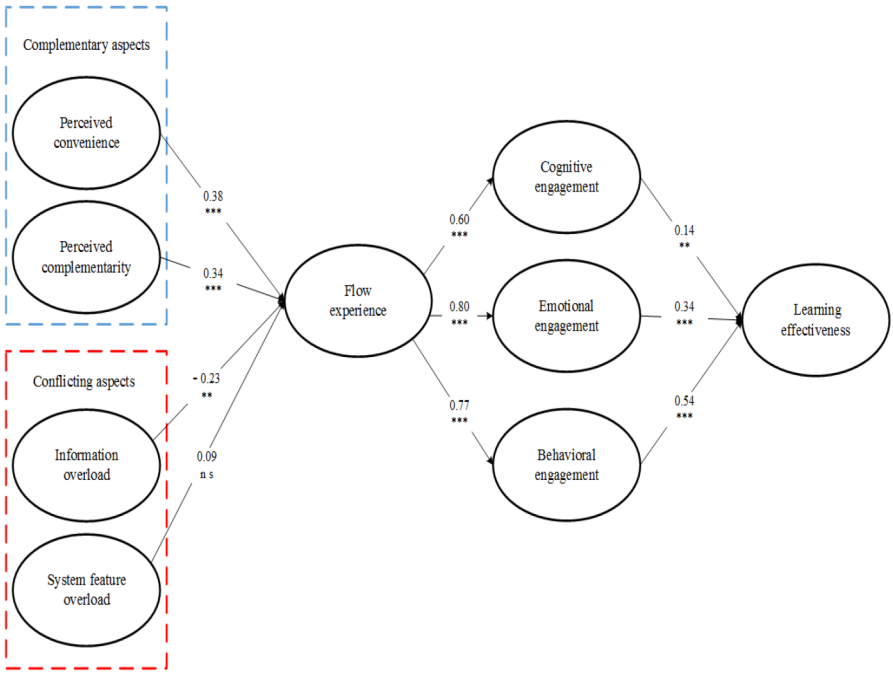

Fig. 2 Structural model results

5 Discussion and implications

5.1 Discussion

This study empirically analyzed the influence of blended instruction on students' learning effectiveness.

The results revealed the complementary advantages of blended instruction, such as perceived convenience and complementarity, which positively influenced students' flow experience and supported H1 and H2. In addition, the results demonstrated practical conflicts caused by the introduction of technology, such as information overload, which negatively influenced students' flow experience and supported H3. However, modern students are considered "technological born" (Akçayir et al., 2016), because they possess certain technical literacy allowing them to balance the technical challenges and personal abilities when using technology. Furthermore, teachers provide students with the necessary technical training and guidance during blended learning to ensure that students can effectively use technologies. The results show that the complementary advantages of blended instruction are helpful in enhancing students' learning perception and experience, strengthening and supporting the learning process, and making students deeply benefit from the blended learning. Meanwhile, we should notice that in the development process of blended instruction, practical conflicts have arisen, and these challenges may bring unease to some students, which will negatively affect students' learning experience.

In a word, with the blended instruction mode being adopted by a growing number of universities, the previous teaching mode and practice have changed. In the changing learning environment, blended instruction provides new opportunities for students, while bringing new challenges. Therefore, it is necessary that it be a thoughtful fusion of the face-to-face approach and ICTs to facilitate the students' learning process and enhance their learning experience.

Moreover, the flow experience had a positive impact on students' cognitive, emotional, and behavioral engagement, supporting H5, H6, and H7. The results show that flow can help students actively mobilize their cognitive resources, critically consider learning materials, adopt active learning strategies, adjust their learning process, strive to understand what they have learned, and achieve a deep digestion of knowledge. Additionally, flow can release positive and pleasant psychological elements, arouse students' positive emotional state in deep heart, and create a series of pleasant learning experiences. Moreover, the flow can help students adjust their learning behavior, help them maintain their concentration consistently, actively engage in the discussion between teachers and peers, bravely face the difficulties encountered in learning, and actively find solutions.

In a word, it is crucial to establish a strong students' learning engagement to achieve effective learning, as learning engagement is a prerequisite for effective learning. However, it is challenging to cultivate students' learning engagement in the blended learning environment. This study found that flow can play a highly positive role. Flow is similar to a kind of "fuel" or energy, which can intrinsically motivate students to continuously engage in blended learning activities regarding cognition, emotion, and behavior. This addresses the key question of how to continuously promote and maintain students' learning engagement during blended instruction, suggesting that flow provides students with an inexhaustible source of motivation.

Learning engagement is a key factor in determining students' learning effectiveness. Students' cognitive, emotional, and behavioral engagement positively influenced learning effectiveness from different aspects, supporting H8, H9, and H10. The results show the importance of learning engagement, which is an important explanatory variable for students in achieving effective learning. A high degree of learning engagement is a reliable predictor index of students' learning achievement. However, learning engagement includes three unique and interrelated dimensions: cognitive, emotional, and behavioral engagement. Therefore, we must consider the different dimensions of learning engagement and cultivate students' learning engagement from comprehensive, to ensure the highest learning effectiveness. In a word, in the blended learning environment, it is crucial to cultivate student's learning engagement, which is not only related to students' commitment to achieving learning goals, but also to their satisfaction and persistence in blended learning.

Self-efficacy was important in blended instruction and positively moderated the relationship between students' learning engagement and effectiveness. In the blended learning environment, self-efficacy, as a valuable psychological resource owned by students, can help students moderate their psychological functional structure and affect their own learning situation. Students with a strong sense of self-efficacy may persist in learning for a longer time, enhance their self-confidence, and be more self-disciplined and actively respond to the pressures and challenges encountered in the

learning process. Therefore, it is necessary to consider the cultivation of students' self-efficacy in the process of blended learning.

5.2 Theoretical implications

This study considered the complementary and conflicting aspects of blended instruction. This study revealed the influencing mechanism of students' learning effectiveness during blended instruction, filled the existing research gap in this field, and further enriched research on blended instruction.

In addition, this study enriches research on flow theory in the field of education, integrates the concept of flow into blended instruction, and emphasizes the unique role of flow in blended learning. Flow can fully absorb students into blended learning, provide an immersive learning experience, and continuously promote and maintain students' learning engagement. These results provide meaningful insights.

Furthermore, the results emphasized the importance of cognitive, emotional, and behavioral engagement, further enriching research on this issue in blended instruction. These results confirmed that learning engagement is a key factor that determines students' learning effectiveness in a blended learning environment.

5.3 Practical implications

This study provided important insights for educators using blended instruction.

University administrators should consider the complementary and conflicting aspects of blended instruction. E-learning has become an indispensable part of modern classroom teaching. Educators should make full use of the advantages of e-learning, combine it with traditional face-to-face classroom teaching, and utilize the unique role of technical tools. However, administrators should also be aware of the practical conflicts of technology to optimize the design and control of blended instruction systems.

Teachers should utilize their guiding roles. Teaching remains important in the blended instruction. Teachers should focus on the creation of flow experiences in the process of blended instruction and adopt various learning forms to enhance students' learning experience and effectiveness. In addition, teachers can provide students with training and assistance in the use of technology, reduce the obstacles encountered by students in the process of blended learning, and keep students on the correct learning track to help them achieve their learning goals more effectively.

6 Limitations and future research directions

This exploratory study had some limitations.

First, this study explored students' learning effectiveness during blended instruction through empirical methods and adopted only a questionnaire survey method following the completion of blended instruction courses to understand students' subjective feelings. Therefore, future research should consider using experimental techniques to further confirm these results.

Second, students' learning effectiveness during blended instruction may be influenced by many subjective and objective factors. However, this study considered a limited number of factors. In addition, students' learning states are always in a process of dynamic change and development, which is difficult to grasp in a short time and requires long-term follow-up research. Therefore, future research should consider a wider range of influencing factors and conduct dynamic follow-up research.

Third, the influence of system feature overload on flow experience was not significant in this study; however, the explanation is somewhat limited. Future studies should further consider the indirect influencing factors of this relationship.

Fourth, this study explored the influence of complementary and conflicting aspects of blended instruction on flow experience. However, other aspects of blended instruction may also affect the flow, such as pedagogical aspects. Therefore, future research should investigate the influence of other aspects of blended instruction on flow.

Finally, this study examined the moderating effect of self-efficacy on the relationship between students' learning engagement and learning effectiveness. However, self-efficacy may also moderate other relationship paths in the model. As such, future studies should investigate the moderating effect of self-efficacy.

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Statements and Declarations

Competing interests The authors have no conflicts of interest to declare that are relevant to the content of this article.

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