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The perspective of teaching systems: The effectiveness of two online teaching approaches in K-12 and school stages differences

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Abstract

This study explores the relationship between teacher teaching support, student involvement, technical environment support, and online teaching effectiveness among K-12 students from the perspective of teaching systems (teacher teaching support, student involvement, and technical environment support) and the differences between online teaching methods and school levels, to provide guidance for teachers to teach using different online teaching methods and at different school levels. The data came from 13,225 primary and secondary school students who participated in online teaching in a district of Beijing. This study used the quantitative research method, we established a model of factors influencing the effectiveness of online teaching through Structural Equation Modelling, and analysed the survey data to explore the factors influencing the effectiveness of online teaching, the paths and their mediating effects. It is worth noting that this study found that student involvement and teacher teaching support significantly and negatively affected the perceived learning effect; teacher teaching support significantly and negatively affected continuance intention; and that the effects of teacher teaching support, student involvement, and technical environment support on satisfaction and the effects of student involvement on continuance intention showed significant differences. These differences affect related mediated pathways, resulting in significant differences in them. In addition, we found that "teacher teaching support → student involvement → perceived learning effect" was different from "teacher teaching support → technical environment support → perceived learning effect." We also found a masking effect for the "teacher teaching support → student involvement → perceived learning effect" and "teacher teaching support → technical environment support → continuance intention" pathways. These findings provide suggestions for teachers at different levels to design appropriate online teaching strategies to improve student learning.

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Keywords Online teaching · K-12 · Teaching systems · School periods · Learning effect

1 Introduction

Since the outbreak of the new coronavirus in 2020, schools around the world have shifted from offline teaching to online; most schools have closed classes and conducted online teaching via the Internet, setting off a massive experiment in online education worldwide (Guo et al., 2021b). The China Academy of Education Sciences (CASE) team surveyed nearly 180,000 teachers and over 1.8 million parents in primary and secondary schools across China. In terms of the main methods of online teaching, 69.55% of the teachers used the Internet to assign self-study tasks, followed by live classrooms (52.18%), interactive online learning using online platforms (45.29%), online flipped classrooms (6.7%), and interdisciplinary thematic inquiry learning (4.65%). Online synchronous teaching is a common approach to this large-scale online education, and although the classroom has moved from the classroom to the Internet, it is more of a "replication" of traditional lectures on the Internet. Thus, further research is needed on how to innovate online teaching and improve its learning effects of online teaching.

Previous studies have mainly focused on the factors and causes of the impact of a single online teaching mode—either online synchronous or asynchronous—and there is thus a lack of research on the differences between the effects of synchronous and asynchronous online teaching modes. With the rapid development of online education, the use of various teaching modes in universities has become increasingly common (Ma & Bu, 2022). Studying the differences in the effectiveness of different online teaching methods can enable teachers to organize teaching, optimize teaching design, enable students to learn effectively, and provide more empirical research material for teacher teaching support, student involvement, and technical environment support.

Most existing studies on online teaching and learning have focused on colleges and universities, and there is a lack of relevant studies on K-12 students. For example, Qin et al. (2021) conducted a study on the differences in online teaching continuance intention among college teachers and students, and Jing et al. (2021) analyzed the factors influencing online learning behavioral intention among college students as the research subjects. Thus, this study was conducted with K-12 students to analyze the differences between school levels, enrich empirical research on online teaching, and provide relevant suggestions for online teaching and learning at the K-12 level.

Jiang et al. (2017) examined the differences between live and recorded contexts in terms of factors influencing satisfaction from the perspectives of learners, educators, platforms, and technical support services. Wang et al. (2021) categorized factors influencing college students' acceptance of online teaching and learning as teacher teaching, student self-management, and online teaching platforms. Arbaugh and Duray (2002) found that technological flexibility and student learning were associated with satisfaction. Hogan and McKnight (2007) suggested

that factors such as the teaching environment and technical support are the main factors affecting satisfaction. Factors influencing student learning effects can be grouped into three dimensions: teacher teaching, students, and the technological environment. Therefore, this study considers the teaching system (teacher teaching support, student involvement, and technical environment support) the main perspective and places a number of variables under the teacher teaching, student, and technological environment dimensions that have been grouped in many studies into related domains, making the framework more systematic and comprehensive and providing a more accurate response to the relationship between teacher teaching, students, and the technological environment.

Therefore, this study analyzes the effects of two online teaching methods, online synchronous and asynchronous, and their differences between school stages from the perspective of teaching systems (teacher teaching support, student involvement, and technical environment support) and K-12 students.

2 Theoretical basis and research hypothesis

2.1 Online synchronous and online asynchronous teaching methods

Distance education models can use synchronous, asynchronous, and blended learning methods (Kumar Basak et al., 2018; Shachar & Neumann, 2003). Synchronous online learning occurs when students participate in classroom instruction in real time. Students and educators can communicate with each other in real time as the course progresses (Zhang et al., 2022a). Asynchronous online learning refers to any form of online learning in which the exchange between learning and teaching does not occur simultaneously. This can include, but is not limited to: watching a prerecorded lesson, viewing a slide presentation, or working on a discussion at a different time (Zhang et al., 2022a). There are no consistent findings regarding which form of online teaching is more effective. Most studies have focused on comparing asynchronous recorded versus face-to-face education, whereas relatively few have focused on the effectiveness of different forms of online education and their mechanisms (Ma & Bu, 2022). In the current study, most research has been conducted separately for online synchronous and asynchronous online formats, revealing the factors influencing the effectiveness of the two online teaching formats and the differences in their school stages from an empirical perspective within the context of the teaching system.

2.2 Teacher teaching support

Knowledge transfer in an online learning environment is also a process of information interaction between teachers and students; teachers play an important role in this process of information interaction (Wu et al., 2020). The learner is the center and subject of online learning. However, the key to educational delivery remains the teacher (Jiang et al., 2017). Teachers can better support online teaching and learning

by verbally communicating with students in a timely manner to ensure course quality. Teaching presence includes three dimensions: designing and organizing instruction, facilitating dialogue, and direct instruction, from instructional design and teacher-student interaction to timely online instruction for students to ensure smooth teaching and learning and better support online teaching and learning. Therefore, the two main variables selected in this study were teacher communication immediacy and teaching presence, which constitute teacher teaching support.

2.2.1 Verbal teacher immediacy behaviors

Communication immediacy refers to the physical and verbal behaviors that reduce the mental and physical distance between individuals (Mehrabian, 1971). Nayernia et al. (2020) emphasize that communication skills have a positive impact on school success, stressing that having the best communication skills is more important than dealing with specific knowledge of the subject. Numerous studies have shown that teacher immediacy behaviors are positively correlated with student cognition (Arbaugh, 2001; Hu et al., 2015; Pan, 2017). Gorham (1988) measured students' immediate perceptions of teachers through statements such as "teachers use personal examples or refer to their experiences outside the classroom," "teachers use humor in lessons," and "teachers address students by name" to measure students' perceptions of teacher immediacy. Thus, teacher immediacy in this study refers to the immediacy of teacher-student communication in online learning contexts, that is, the verbal immediacy of the teacher's behavior.

2.2.2 Teaching presence

Teaching presence is multi-dimensional and comprises three areas of responsibility: design, facilitation, and direct instruction. Each is associated with the integration of social and cognitive processes in terms of the purposeful nature of the learning experience (Arbaugh et al, 2008). In the field of online teaching and learning, teaching presence is one of the most commonly used theoretical frameworks for studying teaching behaviors. Teaching presence is an important component of the community of inquiry theory proposed by Randy Garriso, an internationally influential Canadian academic researcher on blended learning and teaching. Through a meta-analysis, Martin et al. (2022) examined the three basic presences described by the Community of Inquiry frameworks in relation to academic achievement, perceived learning, and satisfaction. They examined the correlation between the three basic presences described by the community of inquiry framework and academic achievement, perceived learning, satisfaction through a meta-analysis, finding a moderate positive correlation between teaching presence and students' academic achievement.

2.3 Student involvement

Constructivist learning theory suggests that students who take control of and direct their own learning will perceive their own competence, autonomy, and personal meaning

with stimulated intrinsic interest, enhanced self-efficacy and learning independence, and increased learning effectiveness and efficiency (Cai, 2021). Currently, the learning effect of online classrooms is receiving increasing attention, and self-regulatory learning and learning engagement are key factors in ensuring that learners experience a good learning effect in computer-based learning environments (Yuan et al., 2013). Therefore, this study focused on self-regulatory learning and learning engagement as dimensions of student involvement.

2.3.1 Self-regulatory learning

Self-regulated learning has been referred to as the desired outcome of the process of "students' self-generated thoughts and behaviors that are systematically oriented toward the attainment of their learning goals" (Zimmerman & Schunk, 2001, p. 125). The importance of self-regulatory learning in improving learning outcomes in online and face-to-face formats cannot be overstated (Barnard et al., 2008). Learning behaviors are important for courses delivered via the Internet and are associated with positive academic outcomes, including student retention and satisfaction (Howland & Moore, 2002).

2.3.2 Learning engagement

Learning engagement is a complex, multidimensional, and multicomponent concept that first emerged in the field of psychological research as an important learning characteristic variable that influences students' learning achievement and persistence. It refers to the level of engagement in learning activities and the sustained positive state that students display (Fredricks et al., 2004; Ma et al., 2023; Lei et al., 2018). Fredricks et al. (2004) described three dimensions of learning engagement: affective, cognitive, and behavioral, and Fredricks et al. (2004) found that learning engagement was significantly related to satisfaction. Research has shown that learning engagement positively affects learning performance (Anderson, 1975; Birch & Ladd, 1997).

2.4 Technical environment support

Technology is widely used as a design and support tool (Wang, 2008) for online learning. Technology is essential in building resources and activities for online teaching and learning, and it must support the online learning environment at all times and make access easy and fast (Tomlinson, 2002). Whether it is teacher-facilitated conversations, teacher-student and student–student interactions, the building of interpersonal relationships in student online learning environments, or immersive experiences in student online teaching and learning, there is a need to create a relevant technological environment that is achieved on the basis of technology, and immersion is a major indicator of the technological environment, with more emphasis on the immersive atmosphere created in the metaverse as well as in VR. Thus, combining technology presence, social presence, and learning immersion are therefore subsumed within the technological environment.

2.4.1 Technology presence

Perceived usefulness is defined here as "the degree to which a person believes that using a particular system would enhance his or her job performance". Perceived ease of use refers to "the degree to which a person believes that using a particular system would be free of effort". Perceived usefulness and perceived ease of use are considered fundamental determinants of user acceptance of computers (Davis, 1989), and both are facilitated by computer technology. Therefore, in this study, perceived usefulness and perceived ease of use constitute the technology presence variables. Rashid and Asghar (2016) explored the relationships among technology use, self-directed learning, student engagement, and academic achievement. The results showed that technology use directly predicts students' cognitive engagement and self-directed learning.

2.4.2 Social presence

Social presence refers to the extent to which learners build personal but purposeful relationships and develop social bonds in an online learning environment (Garrison, 2007). A meta-analysis conducted by Richardson et al. (2017) revealed a significant positive correlation between social presence and satisfaction, and between social presence and perceived learning. Rourke et al. (1999) elaborated on one element of the community of inquiry model, suggesting that social presence can mobilize and sustain critical thinking among learners in learning communities.

2.4.3 Learning immersion

Spatial presence can be defined simply as the subjective sense of a user's "presence" in the space displayed by the media (International Society for Presence Research, 2001; Riva et al., 2003). This concept stems from the observation that users of virtual reality systems sense physical locations in a mediated space (Slater & Steed, 2000; Steuer, 1992), and that spatial presence is considered a conscious experience or sensation (Biocca, 1997). Measures of spatial presence often reflect the degree of "presence" in the student's environment and thus indicate the degree of learning immersion in online learning. Based on immersion theory, Song et al. (2020a) suggested that the immersion experience is an important feature of deep learning and constructed a deep learning measurement model that includes the immersion experience. This study found that the immersion experience directly and positively influenced higher-level thinking in online teaching.

2.5 Learning effect

Current research has explored learning effects or learning outcomes including, satisfaction and perceived progress (Akyol & Garrison, 2008; Rockinson-Szapkiw et al., 2016); using students' self-reported improvement in competencies as a result of online learning compared to offline to measure the online learning effect of graduate

students. Previous research has shown that K-12 online students' satisfaction, perceived progress, and final grades are three important, mutually distinguishing indicators of learning outcomes (Lin et al., 2017; Zhang & Lin, 2020). The user's intention to use the system is the main factor that determines whether the user actually uses or rejects the system (Li et al., 2022b), therefore, this study uses the perceived learning effect (compared to offline classroom instruction), satisfaction, and continuance intention as learning effect variables and measures them separately.

2.5.1 Perceived learning effect

Perceived learning is an objective measure of learning effects that identifies changes in knowledge through rigorous assessment methods and reflects students' self-reported knowledge acquisition (Chen & Yu, 2015). In previous research related to online classrooms, students' perceived learning effects and student satisfaction were two indicators that have been widely used to measure the effectiveness of online education (Alavi et al., 1995).

2.5.2 Satisfaction

Learner satisfaction is a concretization of satisfaction in the learning domain and can be seen as the subjective psychological state of the learner comparing the desired effect of the whole experience provided by the learning "provider" (including learning objectives, learning content, learning style and learning environment) with the actual perceived effect (both cognitive and emotional). Wei and Chou (2020) argued that student course satisfaction is another important measure of online courses.

2.5.3 Continuance intention

Continuance intention refers to the willingness or behavior of users to continue using an information system for a longer period after initial adoption (Bhattacherjee et al., 2008). Bhattacherjee (2001) argues that in information system continuance theory, continuance intention is mainly determined by the satisfaction of using the information system. Cheng (2014) found that teacher quality significantly influenced perceived usefulness, expectation confirmation, and mind-flow experience, which in turn influenced users' continuance intention.

2.6 Research model and research hypothesis

In this study, online teaching methods and school stages were used as moderators, and on the basis of exploring the relationship between teacher teaching support, student involvement, and technical environment support, their effects on perceived learning effect, satisfaction, and continuance intention were analyzed separately, as well as on student involvement, and of technical environment support on perceived learning effect, satisfaction, and continuance intention. We also study online teaching and learning approaches based on them and the differences between school

stages to construct a model of the effectiveness of online teaching and learning approaches and their differences between school stages from the perspective of teaching and learning systems (see Fig. 1). The following research questions are thus proposed:

Uka and Uka (2020) found that teachers can develop students' self-regulatory learning skills by implementing effective teaching methods and guiding them to use self-regulatory learning augmentation techniques. Caskurlu et al. (2020) found in a meta-analysis of undergraduate, graduate, and both graduate and undergraduate students a positive and moderately strong relationship between teaching presence and student satisfaction in online courses. Jiang et al. (2017) found that the quality of an online learning platform in a recorded context has no direct effect on learner satisfaction, while learners' perceived teacher expertise indirectly influenced their satisfaction, and teacher expertise and support were the main influencing factors on their satisfaction; teacher expertise and support in the live mode had a significant impact on satisfaction, and social competence and cognitive motivation factors also social competence and cognitive motivation factors also had an impact on learners' satisfaction. Tan et al. (2012) found that teacher behavior did not have a direct effect on students' intention to use the behavior; that is, there was no direct causal relationship between teacher behavior and students' intention to use. Song et al. (2020b) concluded that there was no significant relationship between pedagogical innovation and learners' intention to use the MOOC. It has also been shown that teaching engagement is not simply positively correlated with student learning performance; it is not the case that more teacher engagement in teaching will lead to improved student learning performance (Li and Zhong, 2020). Sun et al. (2008) found that the timeliness of

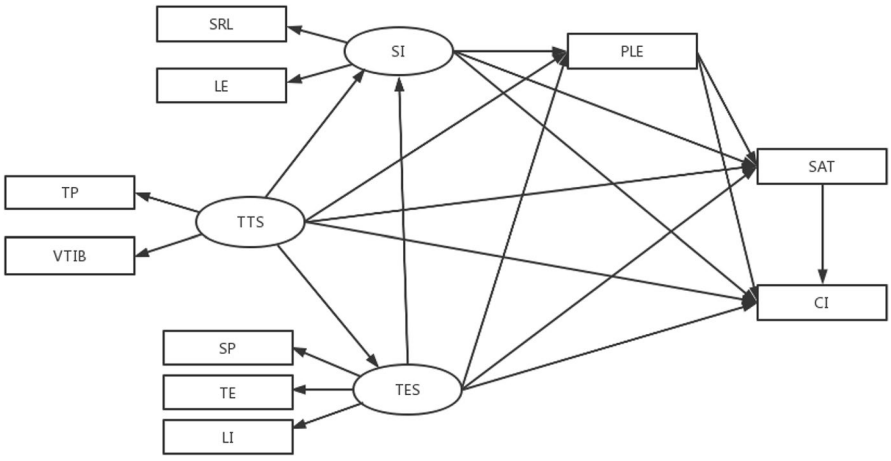

Fig. 1 The hypothesized model (Notes: TTS: teacher-teaching support; SI: student involvement; TES: technical environment support; SRL: self-regulatory learning; LE, Learning engagement; TP: teaching presence; VTIB, Verbal teacher immediacy behaviors; SP, Social presence; TE, Technology presence; EP, Emotional presence; LI, Learning immersion; PLE, Perceived learning effect; SAT, Satisfaction; CI, Continuance intention. Arrows represent the relationships hypothesized to be statistically significant.)

online teacher feedback was not significantly related to student learning satisfaction. Zhang and Lin (2021) found that teaching presence negatively and significantly predicts perceived progress. In summary, teacher teaching support, student involvement, and technical environment support can have an impact on the learning effect; therefore, this study poses the following research questions:

Q1: In an online teaching environment at the primary and secondary levels, do teacher-teaching support, student involvement, and technical environment support influence each other?
Q2: In an online teaching environment at the primary and secondary levels, do teacher-teaching support, student involvement, and technical environment support impact the perceived learning effect, and are there differences between online teaching methods and school stages?
Q3: In an online teaching environment at the primary and secondary levels, do teacher-teaching support, student involvement, and technical environment support impact satisfaction, and are there differences between online teaching methods and school stages?
Q4: In an online teaching environment at the primary and secondary levels, do teacher teaching support, student involvement, and technical environment support impact continuance-intention, and are there differences between online teaching methods and school stages?

It has been shown that perceived usefulness directly and positively predicts continuance intention (Li et al., 2022b). Learning satisfaction can positively influence the intention to continue learning online courses (Zhang et al., 2016; Tan & Shao, 2015). Yang (2016) constructed a research model of the factors influencing users' continuance intention and found empirically that satisfaction has a significant direct impact on MOOC users' continuance intention. Based on the aforementioned studies, which showed that factors such as perceived learning effect and satisfaction can have an impact on continuance intention, the following research questions were proposed in this study:

Q5: In an online teaching environment at the primary and secondary levels, does the perceived learning effect impact satisfaction and continuance-intention, and are there differences between online teaching methods and school stages?
Q6: In an online teaching environment at the primary and secondary levels, does satisfaction have an impact on continuance intention, and are there differences between online teaching methods and school stages?
Q7: In online teaching environments at the primary and secondary levels, can the perceived learning effect be mediated by teacher-teaching support, student involvement, technical environment support, and continuance intention? Are there differences between online teaching methods and school stages?
Q8: In online teaching environments at the primary and secondary school levels, does satisfaction mediate the relationship between teacher teaching support, student involvement, technical environment support, and continuance-intention? Does satisfaction mediate the relationship between teacher-teaching support, stu-

dent involvement, technical environment support, and continuance intentions? Are there differences between online teaching methods and school stages?
Q9: In online teaching environments at the primary and secondary levels, can the perceived learning effect and satisfaction play a role in mediating the relationship between teacher teaching support, student involvement, and technical environment support, and do the perceived learning effect and satisfaction act as a chain mediator between the relationships of teacher teaching support, student involvement, technical environment support, and continuance intention? Are there differences between online teaching methods and school stages?

Jiang et al. (2018) found a moderating effect of self-regulatory learning ability in the pathway of teacher support behavior on learner satisfaction. Specifically, the moderating effect of self-regulatory learning ability in teachers' emotional and social support was influenced by self-regulatory learning ability. Zhu et al. (2020) suggest that online learning experiences, course attitudes, and experience of using IT for learning purposes are indirect predictors of continued online learning intentions through the mediating effect of online learning attitudes. Rui and Liu (2022) found that online self-regulatory learning learning competencies play a mediating role in the relationship between affective factors and catechism continuance intention. Liu, (2019) argued that a well-experienced teaching and learning platform can reduce learners' cognitive load when using the platform, thus enhancing students' factors that influence the learning experience of online courses, focusing on the course environment, course design, instructor or facilitator, learner characteristics, and social interactions (Liu et al., 2016). Meta-analysis studies point to inconsistent findings regarding the relationship between teaching presence and perceptual learning (Caskurlu et al., 2020), with some studies finding a strong association between them (Choi & Tsang, 2015) and others a weak association (Rockinson-Szapkiw et al., 2016), so it is likely that the relationship between teaching presence and perceived learning is moderated by other factors (Caskurlu et al., 2020). Zhang et al. (2022b) found that individual factors moderate the relationship between teaching presence and perceived learning. It is evident that student involvement and technical environment support have an influence on students' continuance intention, and that student involvement and technical environment support mediates the relationship between teacher teaching support and learning effect. Therefore, the following research questions are posed in this study:

Q10: In online teaching environments at primary and secondary school levels, does technical environment support mediate the relationship between teacher teaching support and student involvement? Are there differences between online teaching methods and school stages?
Q11: In online teaching environments at the primary and secondary school levels, does student involvement mediate the relationship between teacher teaching support and satisfaction, perceived learning effect, and continuance intention? Are there differences between online teaching methods and school stages?
Q12: In an online teaching environment at the primary and secondary levels, technical environment support plays a mediating role between teacher teaching

support and satisfaction, perceived learning effect, and continuance intention. Are there differences between online teaching methods and school stages?
Q13: In an online teaching environment at the primary and secondary levels, do student involvement and technical environment support act as chain mediators in the relationship between teacher teaching support and continuance intention? Are there differences between online teaching methods and school stages?

3 Research design

3.1 Research subjects

The participants in this study were primary and secondary school students from Fangshan District, Beijing, China, who completed an online questionnaire distributed through an online survey platform provided by https://www.wjx.cn, during the first half of the 2022 New Coronary Pneumonia outbreak. A pre-survey questionnaire was distributed to primary- and secondary-school students. Based on the results of the pre-survey analysis and questionnaire revision, a formal questionnaire was used to collect information from a large number of primary school (grades 4 and 5 only), junior high school (grades 1 and 2), and senior high school (grades 1 and 2) students. A total of 13,225 valid questionnaires were finally collected, including 8,473 primary school students, 6,025 of them using online synchronous teaching and 1,061 using online asynchronous teaching (see Table 1); 3,697 middle school students, 2,857 of them using online synchronous teaching and 321 using online asynchronous teaching (see Table 2); and 1,055 high school students, 884 of

Table 1 Elementary school students' information

Variable	Frequency	Percentage	Variable	Frequency	Percentage
Sex			Online teaching method		
Males	4289	50.60%	Online synchronization	6025	71.10%
Female	4184	49.40%	Online asynchronous	1061	12.50%
Total	8473	100%	Others	1387	16.40%
			Total	8473	100%

Table 2 Junior high school students' information

Variable	Frequency	Percentage	Variable	Frequency	Percentage
Sex			Online teaching method		
Males	1770	47.90%	Online synchronization	2857	77.30%
Female	1927	52.10%	Online asynchronous	321	8.70%
Total	3697	100%	Others	519	14%
			Total	3697	100%

Table 3 Senior high school students' information

Variable	Frequency	Percentage	Variable	Frequency	Percentage
Sex			Online teaching method		
Males	418	39.60%	Online synchronization	884	83.80%
Female	637	60.40%	Online asynchronous	65	6.20%
Total	1055	100%	Others	106	10%
			Total	1055	100%

them using online synchronous teaching and 65 using online asynchronous teaching (see Table 3; due to the small sample size of the high school section using online recorded teaching, the research on online asynchronous teaching was mainly focused on the primary section and the middle school section).

3.2 Research tools

All questionnaires in this study were rated on a 5-point Likert scale, with 1 indicating *very noncompliant* and 5 indicating *very compliant*.

3.2.1 Teaching presence

The teaching presence scale in this study was based on the COI scale developed by Arbaugh et al. (CoI; Arbaugh et al., 2008), and all selected question items were modified according to age characteristics.

3.2.2 Verbal teacher immediacy behaviors

The Verbal Teacher Immediacy Behavior Scale for this study was adapted from a scale developed by Gorham (1988). An exploratory factor analysis of the scale was conducted post-hoc based on data from each school section, and the items were censored according to the results, resulting in one remaining dimension consistent with the initial preconceptions, four questions for the elementary section, one remaining dimension consistent with the initial preconceptions, five questions for the middle school section, one remaining dimension consistent with the initial preconceptions, and six questions for the high school section.

3.2.3 Self-regulatory learning

The self-regulatory learning scale used in this study was adapted from the web-based Self-Regulatory Learning Scale proposed by Barnard et al. (2008). An exploratory factor analysis of the scale was conducted post-hoc in elementary and secondary schools based on data from each school level, which were censored according to the results, resulting in three dimensions with nine questions consistent with the original setting: goal setting, progress control, and self-evaluation.

3.2.4 Learning engagement

The learning engagement scale for this study was based on the learning engagement scale designed by Wang et al. (2014) for students in grades 4 to 12. It used three Likert-scale questions to measure students' affective engagement, four to measure students' cognitive engagement, and three to measure students' behavioral engagement.

3.2.5 Technology presence

The technology presence scale in this study was adapted from the TAM scale developed by Davis (1989) and used three Likert-scale questions to measure students' perceptions of technology presence.

3.2.6 Social presence

The social presence scale in this study was based on the COI scale (CoI) developed by Arbaugh et al. (2008). Three items are extracted to measure social presence.

3.2.7 Learning immersion

The learning immersion scale used in this study was adapted from the SPES by Hartmann et al. (2016). An exploratory factor analysis of the scale was conducted post hoc based on the data from each school section separately, which were censored according to the results. All were eventually left with one dimension and three questions that were consistent with the initial expectation.

3.2.8 Perceived learning effect

The perceived learning effect in this study was developed by the researcher based on new standards for student development. An exploratory factor analysis of the scale was conducted based on the data from each school period, and the items were deleted according to the results; one dimension with five items remained consistent with the initial setting.

3.2.9 Satisfaction

The satisfaction scale for this study was based on the online course satisfaction scale used by Wei and Chou (2020), which measures student satisfaction through five Likert-scale questions.

3.2.10 Continuance intention

The continuance intention scale for this study was based on the continuance intention scale used by Venkatesh et al. (2003), and the continuance intention of the students was measured using two Likert scale questions.

3.3 Data analysis

In this study, first, descriptive statistics, reliability tests, and correlation analysis were conducted on the research data using SPSS 26.0 software. Then, Amos 26.0 software was used to conduct validation factor analysis, construct structural equation models, and perform model revisions and explanations to test the interrelationships among the variables to explain the research questions, and draw conclusions.

4 Results

4.1 Reliability and validity analysis

4.1.1 Reliability analysis

Considering the differences among student groups, the variables were analyzed for reliability using SPSS26.0 software for the three school levels: elementary, middle, and high school. Normally, a Cronbach's alpha coefficient of 0.8 or more indicates that the data results of this questionnaire have good consistency. As shown in Table 4, the alpha coefficient of each dimension in the data of each school band was greater than 0.8, and the combined reliability CR was greater than 0.8, which indicates that the questionnaire data corresponding to each school band had good reliability.

4.1.2 Validity analysis

To ensure the validity and accuracy of the findings of this study, a validated factor analysis was conducted using Amos 26.0 software for the measurement models of the variables of three school levels: elementary school, middle school, and high school. As shown in Table 5, the RMSEA of each variable measurement model was less than 0.08; the GFI, NFI, TLI, IFI, and CFI were all less than 0.9; and the SRMR was less than 0.08, indicating a good structural fit. The factor loadings of each variable corresponding to each question were greater than 0.7, and the Average of Variance Extracted (AVE) of each variable measurement model was greater than 0.5, indicating that the questionnaire had good structural validity.

As can be seen from Table 6, all variables are significantly correlated with each other ($p < 0.01$), and the correlation coefficients are all less than the square

Table 4 Reliability analysis

Variable	Cronbach's alpha	CR
Elementary school		
Teaching presence	0.954	0.952
Social presence	0.886	0.887
Technology presence	0.895	0.901
Verbal teacher immediacy behaviors	0.909	0.916
Learning immersion	0.932	0.933
Perceived learning effect	0.965	0.962
Satisfaction	0.934	0.933
Self-regulatory learning	0.941	0.936
Learning engagement	0.968	0.966
Junior high school		
Teaching presence	0.941	0.938
Social presence	0.871	0.872
Technology presence	0.893	0.898
Verbal teacher immediacy behaviors	0.904	0.903
Learning immersion	0.922	0.924
Perceived learning effect	0.957	0.956
Satisfaction	0.931	0.933
Self-regulatory learning	0.924	0.91
Learning engagement	0.953	0.951
Senior high school		
Teaching presence	0.937	0.938
Social presence	0.878	0.878
Technology presence	0.892	0.893
Verbal teacher immediacy behaviors	0.85	0.896
Learning immersion	0.938	0.927
Perceived learning effect	0.962	0.962
Satisfaction	0.932	0.928
Self-regulatory learning	0.929	0.922
Learning engagement	0.951	0.949

root of the corresponding AVE. This means that the variables are distinct from each other, which means that the scale has good discriminant validity.

4.2 Structural equation modeling

4.2.1 Model construction and fitting

In order to investigate the effect of two online teaching methods of K-12 and their school section differences from the perspective of teaching system, this study used Amos 26.0 software to construct structural equation models based on hypotheses, and used Maximum Likelihood (ML) to estimate the constructed structural equation

Table 5 Structural validity

Variable	Estimate	AVE	X2/DF	RMSEA	GFI	NFI	TLI	IFI	CFI	SRMR	KMO	Bartlett's P-value
Elementary school												
TP	0.785–0.906	0.743	53.334	0.079	0.976	0.988	0.981	0.988	0.988	0.0144	0.941	***
SP	0.820–0.877	0.724	—	—	—	—	—	—	—	—	0.745	***
TE	0.815–0.926	0.754	—	—	—	—	—	—	—	—	0.74	***
VTIB	0.815–0.896	0.732	19.396	0.047	0.999	0.999	0.995	0.999	0.999	0.0046	0.843	***
LI	0.855–0.940	0.822	—	—	—	—	—	—	—	—	0.755	***
PLE	0.852–0.950	0.834	31.958	0.06	0.994	0.998	0.994	0.998	0.998	0.0051	0.904	***
SAT	0.755–0.926	0.735	34.296	0.063	0.995	0.997	0.991	0.997	0.997	0.0066	0.891	***
SRL	0.636–0.897	0.622	44.119	0.071	0.976	0.985	0.975	0.985	0.985	0.0202	0.936	***
LE	0.836–0.892	0.741	48.922	0.075	0.966	0.985	0.977	0.985	0.985	0.0167	0.963	***
Junior high school												
TP	0.793–0.890	0.715	14.086	0.06	0.991	0.995	0.99	0.995	0.995	0.01	0.914	***
SP	0.800–0.853	0.694	—	—	—	—	—	—	—	—	0.739	***
TE	0.826–0.908	0.746	—	—	—	—	—	—	—	—	0.745	***
VTIB	0.704–0.887	0.653	15.776	0.063	0.995	0.996	0.988	0.996	0.996	0.0103	0.88	***
LE	0.830–0.936	0.803	—	—	—	—	—	—	—	—	0.747	***
PLE	0.832–0.944	0.811	24.062	0.079	0.99	0.995	0.989	0.996	0.996	0.0073	0.899	***
SAT	0786–0.911	0.735	1.803	0.015	1	1	0.999	1	1	0.0017	0.887	***
SRL	0.726–0.883	0.63	16.25	0.064	0.986	0.989	0.982	0.99	0.99	0.0152	0.912	***
LE	0.805–0.891	0.707	18.672	0.069	0.977	0.988	0.982	0.988	0.988	0.0175	0.944	***
Senior high school												
TP	0.803–0.946	0.752	1.093	0.009	0.999	0.999	1	1	1	0.0033	0.893	***
SP	0.820–0.853	0.706	—	—	—	—	—	—	—	—	0.743	***
TE	0.824–0.898	0.737	—	—	—	—	—	—	—	—	0.745	***
VTIB	0.630–0.880	0.594	6.734	0.072	0.988	0.99	0.98	0.992	0.992	0.017	0.802	***

Table 5 (continued)

Variable	Estimate	AVE	X2/DF	RMSEA	GFI	NFI	TLI	IFI	CFI	SRMR	KMO	Bartlett's P-value
LE	0.880–0.940	0.81	—	—	—	—	—	—	—	—	0.764	***
PLE	0.872–0.938	0.836	5.99	0.069	0.989	0.995	0.992	0.996	0.996	0.0077	0.918	***
SAT	0.779–0.930	0.723	3.919	0.053	0.995	0.997	0.993	0.998	0.998	0.0075	0.891	***
SRL	0.606–0.896	0.601	3.181	0.045	0.988	0.992	0.99	0.995	0.995	0.014	0.915	***
LE	0.779–0.889	0.701	7.68	0.08	0.968	0.982	0.976	0.985	0.985	0.01	0.936	***

[a]The goodness-of-fit indicator is 0 when the number of question items of the measurement model is less than or equal to three. Continuance intention measures a question item less than or equal to three; the cardinality value (χ^2) is easily affected by the sample size, and the sample size of this study is large, so the cardinality value and the ratio of the cardinality value to the degree of freedom have not been explored for the time being (the same below)

Table 6 Distinct validity

	SRL	TP	SP	TE	LI	PLE	SAT	LE	VTIB
Elementary school									
SRL	0.789								
TP	0.651**	0.862							
SP	0.765**	0.757**	0.851						
TE	0.690**	0.653**	0.763**	0.868					
LI	0.700**	0.669**	0.777**	0.854**	0.907				
PLE	0.623**	0.477**	0.640**	0.731**	0.714**	0.913			
SAT	0.635**	0.610**	0.682**	0.721**	0.734**	0.707**	0.857		
LE	0.788**	0.702**	0.815**	0.833**	0.867**	0.746**	0.758**	0.861	
VTIB	0.557**	0.807**	0.678**	0.658**	0.663**	0.454**	0.577**	0.689**	0.856
Junior high school									
SRL	0.794								
TP	0.584**	0.846							
SP	0.701**	0.722**	0.833						
TE	0.617**	0.595**	0.731**	0.864					
LI	0.642**	0.626**	0.758**	0.841**	0.896				
PLE	0.563**	0.418**	0.600**	0.697**	0.690**	0.901			
SAT	0.538**	0.551**	0.624**	0.650**	0.677**	0.635**	0.857		
LE	0.752**	0.651**	0.769**	0.792**	0.830**	0.729**	0.689**	0.841	
VTIB	0.518**	0.794**	0.671**	0.643**	0.651**	0.434**	0.547**	0.666**	0.808
Senior high school									
SRL	0.775								
TP	0.541**	0.867							
SP	0.668**	0.773**	0.840						
TE	0.560**	0.614**	0.709**	0.858					
LI	0.592**	0.602**	0.720**	0.804**	0.900				
PLE	0.590**	0.458**	0.618**	0.740**	0.748**	0.914			
SAT	0.489**	0.516**	0.577**	0.648**	0.685**	0.658**	0.850		
LE	0.710**	0.623**	0.744**	0.770**	0.829**	0.778**	0.690**	0.837	
VTIB	0.602**	0.730**	0.735**	0.690**	0.700**	0.562**	0.551**	0.723**	0.771

** At the 0.01 level, the correlation is significant, the diagonal is the square root of AVE, and the lower triangle is the Pearson correlation coefficient

models, taking the online synchronous model of elementary school as an example, the initial model fitting showed that The correction index MI values of residual paths such as "e2 → e3," "e3 → e6," and "e3 → e6" are large, indicating that "self-regulatory learning and teaching presence," "teaching presence and social presence," "self- regulatory learning and social presence," "self-regulatory learning and social presence" and "self-regulatory learning and social presence" are theoretically correlated. Thus, the initial model was revised and formed into a structural equation model. All indicators met the criteria, and the models fit well. Table 7 lists the indicators for each model. It should be noted that the chi-square value increases with

Table 7 Model fitting degree

Name of indicator	Evaluation criterion	Primary synchronization	Primary asynchronous	Middle school synchronization	Middle school asynchronous	High school synchronization
P	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
GFI	> 0.9	0.982	0.977	0.982	0.964	0.976
AGFI	> 0.9	0.949	0.938	0.950	0.901	0.934
RMR	< 0.05	0.011	0.010	0.013	0.012	0.011
RMSEA	< 0.08	0.067	0.071	0.065	0.080	0.072
ECVI	The smaller the better	0.104	0.187	0.116	0.408	0.206
NFI	> 0.9	0.991	0.988	0.989	0.979	0.985
CFI	> 0.9	0.991	0.990	0.990	0.986	0.988
TLI	> 0.9	0.979	0.976	0.978	0.968	0.973
CMIN/DF		27.836	6.405	13.061	3.027	5.607

sample size, thus rejecting any model (Wen et al., 2004; Hu & Bentler, 1999). The sample size of this study was large; therefore, the cardinality value indicator was not used to determine the model fit.

4.2.2 Results of path analysis of the fitted model

The path coefficients of the structural equations reflect the interrelationships and degree of influence between the latent variables and between the latent and observed variables (Qin et al., 2021). There were five models in this study, and the specific path coefficients for each model were as follows (Table 8):

The paths "teacher teaching support → student involvement," "teacher teaching support → technical environment support," and "technical environment support → student involvement" have significant path coefficients in each school period and in both online teaching methods. There is thus a direct relationship between the three methods. A comparison of the path coefficients showed no significant differences among the three paths.

The path coefficients of "student involvement → perceived learning effect" and "technical environment support → perceived learning effect" are significant and positive in all academic periods and both online teaching methods, student involvement and technical environment support significantly and positively affect the perceived learning effect: "teacher teaching support → perceived learning effect." The path coefficients of "teacher teaching support → perceived learning effect" are significant and negative in all academic periods and both online teaching methods, showing that teacher teaching support significantly and negatively affects perceived learning effect. A comparison of the path coefficients showed no significant differences among the three paths.

Table 8 Path coefficients

Research questions	Path	Elementary school		Junior high school		Senior high school
		Online synchronization	Online asynchronous	Online synchronization	Online asynchronous	Online synchronization
Q1	TTS → SI	0.025*	−0.074*	0.058***	0.31**	0.197***
	TTS → TES	0.824***	0.853***	0.789***	0.822***	0.849***
	TES → SI	0.937***	1.023***	0.869**	0.661***	0.757***
Q2	TTS → PLE	−0.355***	−0.345***	−0.355***	−0.3**	−0.409***
	SI → PLE	0.278***	0.331**	0.388***	0.578***	0.383***
	TES → PLE	0.803***	0.763***	0.674***	0.471***	0.824***
Q3	TTS → SAT	0.122***	0.118*	0.131***	0.35***	0.066
	SI → SAT	0.141***	0.205	0.1*	0.187	0.141
	TES → SAT	0.361***	0.239	0.388***	0.034	0.431***
Q4	TTS → CI	−0.17***	−0.291***	−0.245***	−0.454***	−0.32***
	SI → CI	−0.465***	−0.548***	−0.366***	−0.182	−0.253*
	TES → CI	0.417***	0.564**	0.343***	0.387*	0.353**
Q5	PLE → SAT	0.263***	0.264***	0.214***	0.263***	0.156**
	PLE → CI	0.409***	0.365***	0.369***	0.306***	0.347***
Q6	SAT → CI	0.411***	0.452***	0.438***	0.486***	0.52***

[b]*B* non-standardized path coefficient, *S.E.* standard error, β standardized path coefficients, *C.R* is the critical ratio

*** means $p < 0.001$; ** means $p < 0.01$; * means $p < 0.05$

The path "teacher teaching support → satisfaction" has significant positive path coefficients in the elementary and middle school levels and in each online teaching method, teacher teaching support significantly and positively affects satisfaction. In the high school online synchronous model, the path coefficient of "teacher teaching support → satisfaction" is not significant; that is, in the high school live streaming, students think that teacher teaching support has no influence on satisfaction. A comparison of the path coefficients showed that there was no difference in online teaching methods, but there was a difference between school stages.

The path "student involvement → satisfaction" has a significant positive path coefficient in online synchronous teaching in elementary schools and online synchronous teaching in middle schools, student involvement has a significant positive effect on satisfaction. The path coefficients of "student involvement → satisfaction" were not significant in online asynchronous teaching in elementary school, online asynchronous teaching in middle school, or online synchronous teaching in high school, so there was no effect of student involvement on satisfaction. A comparison of the path coefficients revealed differences between the online teaching methods and school stages.

The path "technical environment support → satisfaction" has a significant positive path coefficient in online synchronous teaching methods of elementary, middle, and high schools, technical environment support has a significant positive effect on satisfaction. The path of "technical environment support → satisfaction" is not significant in the online asynchronous teaching methods of elementary and junior high schools, that is, there is no effect of technical environment support on satisfaction. A comparison of the path coefficients revealed that there were differences between online teaching methods, but not between school stages.

The path "teacher teaching support → continuance intention" has significant negative path coefficients in each school period and in both online teaching methods, teacher teaching support has a significant negative effect on continuance intention. The paths of "teacher teaching support → continuance intention," "perceived learning effect → satisfaction," "perceived learning effect → continuance intention," and "satisfaction → continuance intention" have significant positive path coefficients in each academic period and in the two online teaching methods, showing that there are significant paths between technical environment support and continuance intention, perceived learning effect and satisfaction, and perceived learning effect and continuance intention. A comparison of the path coefficients revealed that none of the five paths differed significantly.

The path coefficient of the path "student involvement → continuance intention" was significant and negative in the online synchronous teaching approach in elementary, middle, and high school, showing that for the online asynchronous teaching approach in elementary school, student involvement has a significant negative influence on continuance intention; while the path coefficient of "student involvement → continuance intention" in the online asynchronous teaching method of junior high school is not significant, that is, student involvement did not affect continuance intention.

4.2.3 Bootstrap analysis

On the basis of structural equation modeling, to further investigate the mediating variables affecting the relationship between teacher teaching support, student involvement, technical environment support and learning effect, this study used the Amos 26.0 Bootstrap analysis to test for the mediating effects present, with a sample size of 5000 selected and a confidence interval of 95%,. The results of the runs are shown in Table 9.

In the Bootstrap method, if the 95% confidence interval does not include zero, the product of the coefficients is significant (Wen et al., 2012), indicating that the mediating effect is significant, and conversely, if it includes zero, this indicates that the mediating effect is not significant. Table 9 shows that the path "teacher teaching support → satisfaction → continuance intention" has a significant mediating effect in the elementary and middle school sections. It showed that satisfaction played a significant mediating role in the relationship between teacher teaching support and continuance intention in the elementary and middle school stages, while the mediating role was not significant in online synchronous teaching in high school, showing a significant segment difference. Meanwhile, the three paths of "teacher teaching support → student involvement → perceived learning effect," "teacher teaching support → student involvement → continuance intention," and "teacher teaching support → technical environment support → student involvement → continuance intention" showed significant school-segment differences; "student involvement → satisfaction → continuance intention" showed significant differences between school sections and online teaching methods; and "technical environment support → satisfaction → continuance intention" and "teacher teaching support → technical environment support → satisfaction" showed significant differences between online teaching methods.

5 Discussion

This study analyzes the effects of two online teaching approaches and their school-segment differences in K-12 from an instructional systems perspective. Based on the results obtained from the structural equation tests, the following conclusions were drawn:

5.1 Teachers and students negatively predicted the partial learning effect

1. The results of the study showed that student involvement significantly and negatively affected continuance-intention in the online teaching environment, and student involvement negatively affected students' continuance-intention in all academic periods and for both online teaching methods. Based on the results of this survey, the means of the two variables of teacher teaching support had the highest means among the ten variables, so there was no lack of teacher support and guidance. This may be because the ability to regulate the learning process is a key skill in achieving

Table 9 Bootstrap mediated effects test

Research questions	Category	Path			Bias-corrected 95%CI		
			Estimate	SE	Lower	Upper	P
Q7	Primary Online synchronization	TTS → PLE → CI	−0.145	0.011	−0.166	−0.125	***
		SI → PLE → CI	0.114	0.026	0.062	0.167	***
		TES → PLE → CI	0.328	0.029	0.272	0.386	***
Q8		TTS → SAT → CI	0.05	0.009	0.034	0.068	***
		SI → SAT → CI	0.058	0.021	0.017	0.099	**
		TES → SAT → CI	0.148	0.023	0.105	0.196	***
Q9		TTS → PLE → SAT → CI	−0.038	0.004	−0.046	−0.032	***
		SI → PLE → SAT → CI	0.03	0.007	0.016	0.045	***
		TES → PLE → SAT → CI	0.087	0.009	0.07	0.106	***
Q10		TTS → TES → CI	0.772	0.016	0.742	0.804	***
Q11		TTS → SI → SAT	0.004	0.003	−0.001	0.011	0.108
		TTS → SI → PLE	0.007	0.006	−0.002	0.019	0.133
		TTS → SI → CI	−0.012	0.008	−0.027	0.004	0.139
Q12		TTS → TES → SAT	0.297	0.047	0.21	0.396	***
		TTS → TES → PLE	0.66	0.056	0.555	0.779	***
		TTS → TES → CI	0.344	0.056	0.241	0.462	***
Q13		TTS → TES → SI → CI	−0.359	0.047	−0.457	−0.274	***

Table 9 (continued)

Research questions	Category	Path	Estimate	SE	Bias-corrected 95%CI		
					Lower	Upper	P
Q7	Primary Online Asynchronous	TTS → PLE → CI	−0.126	0.028	−0.191	−0.078	***
		SI → PLE → CI	0.121	0.061	0.012	0.252	*
		TES → PLE → CI	0.278	0.07	0.162	0.442	***
Q8		TTS → SAT → CI	0.053	0.027	0.005	0.109	*
		SI → SAT → CI	0.093	0.06	−0.018	0.218	0.1
		TES → SAT → CI	0.108	0.069	−0.026	0.247	0.104
Q9		TTS → PLE → SAT → CI	−0.041	0.012	−0.071	−0.023	***
		SI → PLE → SAT → CI	0.04	0.02	0.005	0.086	*
		TES → PLE → SAT → CI	0.091	0.029	0.047	0.164	***
Q10		TTS → TES → CI	0.872	0.043	0.798	0.964	***
Q11		TTS → SI → SAT	−0.015	0.014	−0.059	0.003	0.093
		TTS → SI → PLE	−0.025	0.017	−0.074	0	0.052
		TTS → SI → CI	0.041	0.033	−0.004	0.127	0.075
Q12		TTS → TES → SAT	0.203	0.132	−0.051	0.472	0.109
		TTS → TES → PLE	0.65	0.156	0.371	0.981	***
		TTS → TES → CI	0.481	0.173	0.204	0.889	***
Q13		TTS → TES → SI → CI	−0.478	0.152	−0.838	−0.242	***

Table 9 (continued)

Research questions	Category	Path	Estimate	SE	Bias-corrected 95%CI		
					Lower	Upper	P
Q7	Middle School Online Synchronization	TTS → PLE → CI	−0.131	0.015	−0.162	−0.104	***
		SI → PLE → CI	0.143	0.027	0.094	0.203	***
		TES → PLE → CI	0.249	0.031	0.194	0.315	***
Q8		TTS → SAT → CI	0.057	0.016	0.026	0.091	**
		SI → SAT → CI	0.044	0.028	−0.01	0.099	0.12
		TES → SAT → CI	0.17	0.034	0.105	0.239	***
Q9		TTS → PLE → SAT → CI	−0.033	0.006	−0.046	−0.023	***
		SI → PLE → SAT → CI	0.036	0.008	0.023	0.054	***
		TES → PLE → SAT → CI	0.063	0.012	0.042	0.09	***
Q10		TTS → TES → CI	0.685	0.026	0.636	0.738	***
Q11		TTS → SI → PLE	0.022	0.012	0.002	0.048	*
		TTS → SI → SAT	0.006	0.005	0	0.018	0.069
		TTS → SI → CI	−0.021	0.01	−0.041	−0.002	*
Q12		TTS → TES → SAT	0.532	0.06	0.414	0.651	*
		TTS → TES → PLE	0.306	0.063	0.186	0.434	***
		TTS → TES → CI	0.271	0.053	0.168	0.376	**
Q13		TTS → TES → SI → CI	−0.251	0.04	−0.34	−0.18	***

Table 9 (continued)

Research questions	Category	Path	Estimate	SE	Bias-corrected 95%CI		
					Lower	Upper	P
Q7	Middle School Online Asynchronous	TTS → PLE → CI	− 0.092	0.086	− 0.265	− 0.025	**
		SI → PLE → CI	0.177	0.129	0.029	0.487	*
		TES → PLE → CI	0.144	0.082	0.02	0.336	*
Q8		TTS → SAT → CI	0.17	0.097	0.028	0.385	*
		SI → SAT → CI	0.091	0.121	− 0.092	0.378	0.309
		TES → SAT → CI	0.016	0.096	− 0.192	0.185	0.819
Q9		TTS → PLE → SAT → CI	− 0.038	0.036	− 0.12	− 0.009	**
		SI → PLE → SAT → CI	0.074	0.054	0.014	0.213	*
		TES → PLE → SAT → CI	0.06	0.037	0.008	0.161	*
Q10		TTS → TES → CI	0.544	0.094	0.361	0.728	**
Q11		TTS → SI → PLE	0.179	0.148	0.016	0.555	*
		TTS → SI → SAT	0.058	0.089	− 0.046	0.293	0.211
		TTS → SI → CI	− 0.056	0.127	− 0.291	0.068	0.278
Q12		TTS → TES → SAT	0.387	0.185	0.032	0.777	*
		TTS → TES → PLE	0.028	0.156	− 0.309	0.303	0.83
		TTS → TES → CI	0.318	0.173	0.046	0.703	*
Q13		TTS → TES → SI → CI	− 0.099	0.155	− 0.483	0.12	0.375

Table 9 (continued)

Research questions	Category	Path	Estimate	SE	Bias-corrected 95%CI		
					Lower	Upper	P
Q7	High School Online Synchronization	TTS → PLE → CI	−0.142	0.038	−0.232	−0.081	***
		SI → PLE → CI	0.133	0.061	0.032	0.276	*
		TES → PLE → CI	0.286	0.069	0.178	0.46	***
Q8		TTS → SAT → CI	0.034	0.052	−0.074	0.131	0.523
		SI → SAT → CI	0.073	0.06	−0.039	0.206	*
		TES → SAT → CI	0.224	0.079	0.097	0.419	**
Q9		TTS → PLE → SAT → CI	−0.033	0.017	−0.071	−0.004	*
		SI → PLE → SAT → CI	0.031	0.019	0.002	0.077	*
		TES → PLE → SAT → CI	0.067	0.032	0.009	0.136	*
Q10		TTS → TES → CI	0.643	0.072	0.522	0.805	***
Q11		TTS → SI → PLE	0.075	0.049	0.003	0.199	*
		TTS → SI → SAT	0.028	0.027	−0.007	0.109	0.126
		TTS → SI → CI	−0.05	0.034	−0.146	−0.003	*
Q12		TTS → TES → SAT	0.7	0.143	0.478	1.048	***
		TTS → TES → PLE	0.366	0.135	0.152	0.694	**
		TTS → TES → CI	0.299	0.148	0.046	0.625	*
Q13		TTS → TES → SI → CI	−0.163	0.09	−0.375	−0.017	*

[c] *** means $p < 0.001$; ** means $p < 0.01$; * means $p < 0.05$

personal learning goals (Kizilcec et al., 2017). The lack of external pressure and clear completion of relevant social norms with low-cost support and guidance requires learners to be highly self-directed to achieve course goals (Kizilcec & Halawa, 2015; Zheng et al., 2015). In a national study on online education in the United States, online learning required more discipline from students, which represented a barrier to the continued growth of online education (Allen & Seaman, 2010). At the same time, the lack of direct teacher-student contact and lack of teacher management of students in online instruction makes online instruction very much a test of student self-management skills and requires strong self-discipline, which also requires greater student involvement as well as physical and mental commitment in many ways. Moreover, online teaching during the pandemic is often conducted in multiple subjects simultaneously, which requires students to have a large amount of learning engagement in each subject to achieve a better learning effect; this large amount of input in multiple subjects may take up much of the students' energy, while requiring them to absorb a large amount of knowledge in multiple subjects for a short period of time. This may place a large cognitive load on students, reduce their motivation to learn online, and lead to a decrease in their continuance intentions. Second, without effective pedagogical support from teachers, students may overestimate their ability to comprehend learning materials (Baars et al., 2018), which may negatively affect the subsequent learning process (Dunlosky & Rawson, 2012). Thus, student involvement without effective teacher support may cause students to overestimate their abilities and produce unmet learning outcomes in subsequent learning, thereby affecting their continuance intentions in online learning.

2. Unlike most studies, this study found that teacher-teaching support negatively affected perceived learning effect and continuance intention. Some studies have shown that the perceived learning effect predicts continuance intention, and continuance intention remains synchronized with the perceived learning effect (Li et al., 2022a); therefore, the negative effect of teaching support on perceived learning effect also has the same effect on continuance intention. The reason for the negative effect of teacher teaching support on the perceived learning effect and continuance intention may be that, first, in an online teaching environment, elementary and middle school students agree with the teaching support provided by teachers, but too much direct instruction in class and the provision of learning resources in and out of class can take up too much time and energy, crowding out learning time, and thus reducing their perceived learning effect. This finding was similar to that reported by Guo et al. (2021a). Second, in online instruction, teachers find it difficult to adapt their lesson plans and tailor learning to each individual in K-12 online asynchrony (Oliver et al., 2009), making it difficult to create the right "teaching presence" for students. Students tend to be individual, and the level of interaction in synchronous live streaming can be limited by network environment factors and the inherent "interaction distance" of online asynchrony (Ma & Bu, 2022). The teacher's inability to focus on each student makes it impossible for the teacher to achieve a better perceived learning effect despite the high level of effort invested in the immediacy of the teacher's words, and direct instruction in the teaching presence may affect student autonomy. In online teaching, teachers are unable to understand students in a timely manner and their direct instruction may be biased and not tai-

lored to students' needs, thus decreasing students' learning effects and continuance intention. Third, Lai (2015) argued that high teacher input does not necessarily lead to high student learning performance, and that the effect of instructional input on learning performance is affected by factors such as student motivation. Li and Zhong (2020) found that the "quality" of instructional inputs is more important than the "quantity," and that teachers' teaching skills, wisdom, and experience can enhance or diminish the effect of instructional inputs on learning performance by affecting the quality of instructional inputs. Therefore, the mean value of students' perceived water for teacher teaching support (4.44 for elementary school, 4.47 for middle school, and 4.21 for high school) is high, but it only rests on the quantity rather than quality of teaching, which does not play an effective role in influencing students' learning effect, thus making teachers' large amount of teaching input negatively affect students' perceived learning effect. Fourth, the negative effect of teacher teaching support on perceived learning effect and continuance-intention may be due to the following points: (1) the peculiar nature of online teaching during the epidemic to advance in a rush causes poor teaching results. (2) Online education during the epidemic is such that all courses are advanced online, causing society, teachers, parents, students, and other parties to have overall anxiety about online education and have a negative effect on the effectiveness of online teaching, and show an overall distrust of online education, which in turn will affect students' perceptions. (3) Online instruction during an epidemic is usually compressed, resulting in insufficient class time and an accelerated class pace. Some students even suggested that the problem of fast-paced classes could be adjusted by appropriately increasing class time (Yu et al., 2021). (4) The specificity of the overall advancement of online teaching in each course during the pandemic caused poor teaching and learning outcomes, resulting in a larger teaching workload for teachers, a heavier learning task for students, and a larger cognitive load (students take several online courses per day). This caused teachers to be unable to effectively create teaching presence and difficulty in verbal teacher immediacy behaviors.

In addition, some studies have found that teachers are more concerned about the impact of motivation on learning performance, while learners are more concerned about the impact of independent learning ability on learning performance (Li & Zhong, 2020); however, in online teaching, teachers focus on teaching support and teacher-student interaction to get better teaching results, while neglecting the guidance and development of students' independent learning ability, especially in Chinese exam-oriented education and traditional teaching contexts.,this "teacher-led, student-passive" learning is almost a mainstream situation, especially in Chinese teaching contexts.

5.2 Analysis of school stages differences in the paths of influence between factors of teaching effectiveness and their mediating effects

1. The influence of student involvement on continuance-intention showed significant school segment differences in the online, asynchronous instructional approach. The

results of the study showed that in online synchronous learning, student involvement significantly and negatively influenced continuance intention at all school levels, while in online asynchronous learning, significant school level differences were shown; that is, elementary students perceived student involvement as significantly and negatively influencing continuance intention, while junior high school students perceived no significant effect of student involvement on continuance intention. The reason for this may be that elementary students are more likely to be strictly required and managed by teachers or accompanied and supervised by parents for a long time, even though they are inevitably absent from curriculum instruction and have a poor learning effect (especially elementary students who perceive the lowest learning effect among the three school stages). Most elementary school students feel more nervous every time the teacher calls on them to answer a question than they do in an offline classroom, and therefore, elementary school students have lower continuance intention and a negative effect.

In terms of the influence of online synchronous teaching and online asynchronous teaching on student involvement on continuance intention in the middle school section, middle school students are in the rebellious stage of adolescence, and the control and discipline of teachers and the accompanying of parents are far less than those in the elementary school section, and the academic pressure in the middle school section is not much compared with that in the elementary school section (this study mainly involved middle school students). In addition, compared with the primary school, the academic pressure in the junior high school is not so great (this study is mainly included first- and second-year students), and the self-restraint ability of junior high school students is appropriately enhanced, so the student involvement in junior high school does not have a negative effect on continuance intention. At the same time, because the age and psychological characteristics of middle school students are more concerned with learning in interpersonal interaction, and the social interaction in online asynchronous teaching is easier than online synchronous teaching, students' perception of self-regulatory learning, learning engagement is also more significant, and students' independent learning ability is stronger; thu,s for online asynchronous teaching, compared to online synchronous teaching, student involvement does not have a negative effect on continuance intention. Of course, the role of student involvement in various factors are compared to online synchronous teaching function, so that there is also no significant positive effect. Through the mediation effect, we found that the chain mediator of "teacher teaching support → technical environment support → student involvement → continuance intention" was influenced by the path of "student involvement → continuance intention," and showed significant segmental differences in online asynchronous teaching. This shows that in online asynchronous teaching in junior high schools, technical environment support and student involvement do not affect the relationship between teacher-teaching support and continuance-intention.

2. The path of student involvement in satisfaction showed a significant difference between school levels. The comparison between school stages showed that ele-

mentary and junior high school students perceived student involvement as having a significant positive influence on satisfaction, whereas senior high school students' student involvement had no significant influence on satisfaction. The reason for this may be that compared to elementary and junior high school groups, high school students are mainly motivated by academic pressure and the motivation to advance to higher education. The age of high school students also makes them have higher self-management and cognitive abilities, better self-discipline, and the influence of teachers on students gradually fades; the dominance of teachers decreases, and the pressure brought by the college entrance examination, so students have higher self-regulatory learning and learning engagement regardless of their teaching method. and they are able to master their own learning pace at all learning stages; therefore, compared to the elementary and middle school groups, the high school group believes that student engagement does not affect the satisfaction of online learning.

3. Teachers' support showed a significant difference in the path of influence on their satisfaction. By comparing school stages, we found that for elementary and junior high school levels, teacher-teaching support had a significant positive effect on satisfaction, whereas for high school levels, teacher-teaching support did not. The reason may be that high school students do not rely as much on teachers as elementary and middle school students do, but prefer free and personalized learning; when they engage in online learning, they are more likely to immerse themselves in their own learning plans than listening to teachers living online. Kupczynski et al. (2010) found that lower school grades are more pedagogical than higher school grades. Therefore, high school students, compared with elementary and middle school students, have stronger independent learning abilities and their own learning methods and plans and are no longer influenced by teachers. Therefore, we can give high school students more time for personalized learning when teaching online, for example, by using online asynchronous teaching methods. Based on the comparison of the mediating effects, we found that the path of "teacher teaching support → satisfaction" showed significant segmental differences that influenced the mediating path of "teacher teaching support → satisfaction → continuance intention" and made it show segmental differences. Thus, in elementary and middle school groups, satisfaction plays a significant mediating role in the relationship between teacher teaching support and continuance intention. In contrast, in the high school group, satisfaction had no significant effect on the relationship between teacher-teaching support and continuance-intention.
4. The effect of satisfaction on the relationship between student involvement and continuance-intention showed significant differences across school periods. The reason for this may be that the junior high school group is in the middle of adolescence, and they pay more attention to interpersonal interaction, hope to establish good interpersonal relationships, and pay attention to emotional communication, so compared with the high school group, they have less pressure to study and less motivation to study. Therefore, even if student involvement could influence student satisfaction, it would not necessarily increase middle school students' continuance intention toward online teaching.

5. The mediating effect of student involvement on teacher teaching support and continuance intention showed significant differences by school level. In middle school as well as high school online synchronous instruction, teacher teaching support influenced student involvement and thus continuance intention, whereas the mediating effect of student involvement on the relationship between teacher teaching support and continuance intention was not significant in the elementary school group and middle school online asynchronous instructional approaches. The reason for this may be that elementary school students have weaker self-control and cognitive ability than secondary school students, and their continuance intention for online teaching relies more on the external environment and external motivation to be maintained, rather than their own internal physical and mental commitment and internal motivation, which makes the mediating effect of student involvement in elementary school group on the relationship between teacher teaching support and continuance intention insignificant. Combining the path coefficients, we can see that the reason for the insignificant mediating effect of online asynchronous teaching in junior high school may lie in the path of "student involvement → continuance intention." Student involvement had no significant effect on continuance-intention in asynchronous online instruction in middle school, making its mediating effect insignificant.
6. The path of "teacher teaching support → student involvement → perceived learning effect" was significantly mediated in the middle school and high school stages, but not in the elementary segment. In other words, in the middle school and high school stages, teacher-teaching support can affect the perceived learning effect by influencing student involvement, while in the elementary school segment, there was no effect of student involvement on the relationship between teacher-teaching support and perceived learning effect, showing a significant school section difference, perhaps because the degree of student involvement in the elementary school group was more influenced and constrained by external factors, such as cooperative group learning and parental accompaniment, and the change in perceived learning effect is also influenced by external conditions, so the mediating effect is not significant.

5.3 Analysis of the differences in online teaching methods that influence the path between teaching effectiveness factors and their mediating effects

1. The path of student involvement to satisfaction showed significant differences in the online teaching styles. A comparison between the two online teaching styles in elementary and middle schools found that student involvement had a significant positive impact on satisfaction with online synchronous teaching, while student involvement did not have an impact on satisfaction with online asynchronous teaching. The reason may be that online synchronous teaching tends to enhance the interaction between teachers and students, prompting students to continuously self-regulate learning, emotionally, cognitively, and behaviorally engage in learning, and teachers can respond and give feedback in a timely manner, thus positively influencing students' satisfaction, while online asynchronous teaching has

untimely teacher-student interaction; in the current online asynchronous teaching in primary and secondary school contexts, student–student interaction is inadequate; at the same time, students are hardly involved in learning, thus not having an impact on students' satisfaction. We found that the "student involvement → satisfaction" path influenced the "student involvement → satisfaction → continuance" mediated path, which showed significant differences between online teaching methods.

2. The path of the effect of technical environment support on satisfaction showed significant differences between the online teaching methods. We found that there was a significant effect of technical environment support on satisfaction in online synchronous instruction for each academic period. That is, technical environment support significantly and positively influenced satisfaction, while in online asynchronous instruction, technical environment support did not have a significant effect on satisfaction in online asynchronous instruction, possibly because online synchronous teaching is a kind of real-time synchronous interactive teaching. The teacher teaching and interaction between teachers and students needs technology to support, and this interaction is a kind of collective synchronous interaction, whereby technology environment will directly affect technology presence, social presence, and learning immersion, which will lead to missing specific teaching information. Therefore, live teaching requires a stronger technological environment, and technical environment support significantly affects student satisfaction. In online asynchronous teaching, K-12 students have technological literacy to support online learning, and in the case of problems with the technological environment, they can adjust it by controlling the learning pace on their own to ensure that the technical environment support remains unaffected. Guaranteeing that technical environment support remains unaffected, there is no significant effect of technical environment support on students' satisfaction in online asynchronous instruction. Jiang et al. (2017) found that the quality of the online learning platform on learners' satisfaction differed significantly between live and recorded contexts, and the findings of this study are consistent with this. At the same time, we found that the difference in the path of "technical environment support → satisfaction" may affect the mediated paths of "technical environment support → satisfaction → continuance intention" and "teacher teaching support → technical environment support → satisfaction," causing significant differences between online teaching styles, with significant mediating effects in the online synchronous teaching style in elementary and middle schools, and insignificant mediating effects in the online asynchronous teaching style in elementary and middle schools. That is, in online synchronous teaching technical environment support can influence continuance intention by influencing satisfaction, teacher teaching support can influence satisfaction by influencing technical environment support, while in online asynchronous teaching, satisfaction has no effect on the relationship between technical environment support and continuance intention, and technical environment support has no effect on the relationship between teacher teaching support and satisfaction. Asynchronous learning is less interactive than synchronous learning (Ashley, 2003), and the teacher-student interaction, student–student interaction, and the construction of online interaction communities in online synchronous instruction place higher demands on technical

support to meet the needs of student interaction. In addition, students emphasize that the online synchronous teaching environment and technological environment can simulate the real immersion of traditional classroom teaching, thus making the technical environment support has a significant impact on students' satisfaction.

5.4 Masking effects in intermediary differences

1. The path "teacher teaching support → student involvement → perceived learning effect" has a significant mediating effect in the middle and high school stages, in which teacher teaching support can influence perceived learning effect by affecting student involvement. Cliff and Earleywine suggested that in the mediation model, a masking effect occurs when the direct and mediating effects of the independent variable on the dependent variable have opposite signs (Cliff & Earleywine, 1994; Tzelgov & Henik, 1991). It can be seen that in the process of teacher teaching support affecting perceived learning effect, student involvement plays a masking effect: That is, through the direct effect, teacher teaching support negatively affects the perceived learning effect, while the mediating effect shows the opposite sign to the direct effect. In other words, the negative effect of teacher teaching support on perceived learning effect is offset to some extent by the effect of teacher teaching support on student involvement, so that teacher teaching support has a positive effect on the perceived learning effect in the context of student involvement. McManus (2000) explored the role of SRL (self-regulatory learning strategies) as a potential moderator of the link between instruction (called treatment) and outcomes, and Li, (2019) found that the use of SRL strategies (goal setting and environmental structure) significantly predicted learners' perceived learning. Shea and Bidjerano (2012) proposed that learners' self-regulatory learning can be considered as a modifying mechanism rather than as an explanatory variable. Teachers can influence students' self-regulatory learning and learning engagement through teaching presence and communication immediacy to better engage students in the classroom, modifying the influence mechanism through the improvement of students' self-regulatory learning, which in turn improves students' perceived learning and counteracts the negative influence of teacher teaching support on students' perceived learning.
2. The path of "teacher teaching support → technical environment support → continuance intention" mediates significantly across school levels and online teaching methods. It means that teacher teaching support influences continuance intention by affecting technical environment support. By comparing the direct effect with the mediating effect, it was found that in the process of teacher teaching support influencing continuance intention, technical environment support played a masking effect; thus, through the direct effect, teacher teaching support negatively influenced continuance intention, while the mediating effect showed the opposite sign to the direct effect. That is, the negative effect of teacher teaching support on continuance intention is offset to some extent by the effect of teacher teaching preparation on technical environment support, it causes teacher teaching support to play a positive role in continuance intention under the role of technical environment support. Some studies have found that teaching presence directly influences

the perception of social presence, as indicated by students' perceptions (Garrison et al., 2010). Enhancing the central role of teaching can establish and sustain the online learning environment and achieve the desired learning outcomes (Shea & Bidjerano, 2009). By playing the role of teaching presence and adopting effective social media for communication (Lan, 2018), teachers create an appropriate online learning environment to immerse students and improve their sense of the online learning experience. In online teaching, teachers can use teacher-teaching support to build a good community environment in which students can interact and experience group cohesion, improve their sense of technological presence, and immerse themselves in the online learning environment. In turn, the students' continuance intentions toward online teaching were enhanced.

6 Limitations

Firstly, the sample of this study was mainly focused on a district in Beijing, and should be extended to other places and students to better improve the usefulness of the findings. Secondly, the data for this study was collected only once and no follow-up survey was conducted. Finally, this study was based primarily on students' self-reported data, and future studies should include more objective measures.

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Declarations

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

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