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The Relationship between Cognitive Load and Learning Satisfaction in Synchronous Live Broadcast Classrooms: The Mediating Role of Social Presence

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Abstract

This study recruited 225 college students online to participate in a synchronous live broadcast course on hypnosis to explore the relationship among cognitive load, social presence, and learning satisfaction, and to propose educational strategies suitable for live broadcast teaching to improve students' learning satisfaction. Data analysis was conducted using SPSS 23.0 for statistical analysis of valid data, employing Pearson correlation analysis to examine the relationships among cognitive load, social presence, and learning satisfaction, and using the SPSS macro program Process plugin to analyze the mediating role of social presence. The results revealed that external cognitive load scores were significantly higher in males than in females (P<0.05); internal cognitive load scores were also significantly higher in males than in females; relevant cognitive load can positively predict social presence; relevant cognitive load can positively predict learning satisfaction; social presence can positively predict learning satisfaction; the mediating effect of social presence between relevant cognitive load and learning satisfaction is significant, with a mediation effect accounting for 23.54% of the variance. Therefore, in synchronous live broadcast teaching, teachers and students can intervene from both cognitive load and social presence to improve learning satisfaction.

Keywords

Online Live Broadcast Classroom; Cognitive Load; Social Presence; Learning Satisfaction.

1. Introduction

With the development of the Internet and mobile devices, education has gradually entered the digital age. Synchronous live classrooms refer to a new form of teaching where teachers and students interact in real-time through an Internet live broadcast platform, overcoming the limitations of traditional educational models such as geographical restrictions and inconvenient scheduling[1]. They also address issues like insufficient teacher resources and unequal educational opportunities. Online live classrooms can utilize the Internet and multimedia technologies to provide richer and more diverse teaching resources and forms, which help to optimize educational content and methods, thereby improving teaching effectiveness and learning experience. They also enable real-time interaction and online Q&A, which aids in enhancing learning outcomes. The outbreak of the pandemic has led to wider acceptance and application of online synchronous live classrooms, promoting the development of online education[2]. However, online live teaching may also have some drawbacks, such as

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insufficient teacher supervision, poor student self-learning ability, and lack of classroom concentration, all of which limit the effectiveness of synchronous live classrooms. Therefore, this study analyzes the factors affecting students' learning subjective experience—learning satisfaction—in online live classrooms to provide reliable strategies for improving the quality of college students' online live classroom learning.

1.1. Cognitive Load and Learning Satisfaction

In recent years, with the popularization of online learning, research on cognitive load has become a hot topic. Cognitive load refers to the total amount of thinking and memory resources required to perform a task within a certain period, including the complexity of the task itself and the working memory required to perform the task[3]. Cognitive load theory posits that an individual's cognitive resources are limited, and various cognitive activities consume cognitive resources. Changes in the learning environment and tasks affect the way students process cognition, the amount of information, and the type of information, thereby affecting the consumption of cognitive resources[4]. Cognitive load theory divides cognitive load into three categories: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. Intrinsic cognitive load refers to the load brought about by the learning content itself, which is mainly determined by learning materials and prior knowledge[5]. Extraneous cognitive load refers to the additional load outside the learning content and is directly related to teaching design, mainly associated with the way information is presented and learning activities[6]. Germaine cognitive load refers to the load formed when learners make connections and analyze new learning content with related information during learning activities[7]. Cognitive load can accumulate and stack up; therefore, in the teaching process, to improve the learning experience, teachers should try to reduce students' intrinsic and extraneous cognitive loads and increase germane cognitive load.

Learning satisfaction refers to students' subjective judgment of whether learning meets expectations by comparing actual learning experiences with learning expectations[8]. In this study, satisfaction with the synchronous live classroom refers to the subjective judgment of live learning formed by comparing the actual perceived effects with the expected value after students experience the live classroom.

Some studies have confirmed the complex results of the impact of cognitive load on learning satisfaction. Bradford found that in the online learning environment, cognitive load is positively correlated with online learning satisfaction[9]. However, other scholars have found that when learners have limited cognitive resources, excessive cognitive processing can lead to cognitive overload, thereby negatively affecting satisfaction[10]. At the same time, Li Jing and others pointed out that a moderate level of cognitive load allows students to maintain enthusiasm for learning and higher learning satisfaction. Therefore, the impact of cognitive load on learning satisfaction still needs further exploration. In online live classrooms, students need to process multiple types of information at the same time, such as listening to the teacher's explanation, viewing courseware, and interacting[11]. According to cognitive load theory, the more information learners process in an online live classroom, the higher the cognitive load, and correspondingly, the worse the learning experience. Therefore, cognitive load may be an important factor affecting learning satisfaction.

1.2. Social Presence and Learning Satisfaction

Social presence refers to the ability of learners to authentically map their social and emotional identities within a community of learners. The theory of social presence was first proposed by Short et al. in 1976[12], which explains the theoretical assumptions of how electronic media affect communication. In multimedia situations, communication methods are limited, and the social presence of individuals within a group may decrease. At this time, individuals can convey information not only through speech and text but also through facial expressions, gestures, and

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body movements. Combining verbal and non-verbal information for communication can enhance learners' social presence. Social presence focuses on learners as the main subjects, focusing on the psychological mechanisms of learners, and is an important psychological factor affecting learners' motivation and learning outcomes[13].

Social presence theory posits that social cues from teachers in online live classrooms can enhance students' social presence, thereby increasing learning satisfaction. Social presence theory explains the impact of teachers on students' subjective experiences in online live classrooms and also explains the relationship between students' social presence and learning satisfaction.

Gunawardena and Zittle's (1997) [14]research found that social presence can positively predict learning satisfaction not only in offline classroom environments but also in online live classroom environments. When learners perceive the presence of teachers and other learners in online live classrooms, they tend to have a more satisfactory learning experience. Steffey [15]pointed out that in multimedia teaching, there is always a positive correlation between learners' social presence and their satisfaction. Arbaugh[16] believes that the reason why an increase in social presence has a positive effect on learner satisfaction may lie in the fact that social presence can establish stronger peer relationships and reduce learners' feelings of loneliness. Richardson and Swan [17]also reached similar conclusions: the higher the social presence of learners in a course, the higher their satisfaction with the teacher. Therefore, social presence may be an important predictor affecting learning satisfaction.

1.3. The Relationship between Cognitive Load and Social Presence

Bandura's [18]social cognitive theory points out that an individual's cognition, behavior, and environmental factors and their interactions affect human behavior. Social cognitive theory explains the role of learners and teachers in the same social environment during the process of participating in online live teaching. Therefore, learners' perception of teachers' social presence (environment) may be affected by cognitive load, a cognitive factor. Hrastinski's (2008)[19] research indicates that the lower the cognitive load of learners in a synchronous online learning environment, the higher the social support they will have. Research by Yang Shufeng[20] and others shows that social support can enhance social presence. Therefore, cognitive load may be a reliable factor affecting social presence. When students find the classroom too complex or difficult to understand, that is, when extraneous cognitive load increases, they may reduce their cognitive engagement, thereby affecting their interaction with other students and reducing social presence. Therefore, reducing extraneous cognitive load may be an effective measure to improve students' social presence. In live teaching, cognitive load may be an effective factor affecting individual social presence.

1.4. The Relationship between Cognitive Load, Social Presence, and Learning Satisfaction

Existing research shows that there are fewer studies on the relationship between cognitive load, social presence, and learning satisfaction, and most researchers use these three as indicators to measure classroom learning outcomes without exploring the interrelationship among them. For example, Bu Caili and others [21]used meta-analysis methods to select cognitive load, social presence, learning satisfaction, etc., as subjective indicators to evaluate the effectiveness of teaching video design. According to cognitive load theory, cognitive load can effectively predict students' learning satisfaction, but research on the impact mechanism of cognitive load on learning satisfaction has not yet been seen. Social cognitive theory tells us that learners' cognitive load has a significant impact on the interactive environment between learners and teachers (social presence). At the same time, the social agency theory proposed by Mayer and others [22]states that the social cues of teachers present in the learning process can stimulate

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learners' cognition, activate learners' deep cognitive processing strategies, and thus improve learners' learning satisfaction. Therefore, cognitive load may affect learning satisfaction by affecting social presence, and social presence may play a mediating role in the relationship between cognitive load and learning satisfaction. Therefore, this study, based on existing research, deeply explains the relationship between cognitive load and learning satisfaction and further explores the mediating role of social presence.

To explore the mechanism by which cognitive load affects students' learning satisfaction, this study, based on social presence theory and social cognitive theory, uses a questionnaire survey method to examine the relationship among cognitive load, social presence, and learning satisfaction in synchronous online live classrooms, and explores the mediating role of social presence. The research is expected to: 1. Cognitive load in online live classrooms can negatively predict learning satisfaction; 2. Social presence in online live classrooms can positively predict learning satisfaction; 3. Cognitive load in online live classrooms can negatively predict social presence; 4. The mediating effect of social presence between cognitive load and learning satisfaction in online live classrooms is significant.

2. Research Method

2.1. Research Subjects

A total of 225 college students were recruited online to participate in an online course of interest, with the course duration being approximately 15 minutes. Among them, there were 63 male and 162 female participants, with an average age of 19.37±1.38. Participants signed an informed consent form and were compensated with a small gift at the end of the experiment.

2.2. Measurement Tools

Cognitive Load Questionnaire

The questionnaire was developed by Leppink et al. (2013) [23], and in 2014, they validated and revised this scale under different situations. The scale uses a 10-point scoring system with 13 items across three dimensions: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load. In this study, the internal consistency reliability coefficients for the dimensions of the cognitive load questionnaire ranged from 0.82 to 0.93.

Social Presence Questionnaire

The questionnaire was developed and revised by Jia Yangyang (2020) [24], consisting of 20 items across five dimensions: sense of co-presence, sense of involvement and attention, emotional contagion, sense of understanding and communication, and sense of behavioral dependence. The questionnaire uses a 5-point scoring system, with good reliability and validity, and internal consistency reliability coefficients ranging from 0.76 to 0.91.

Learning Satisfaction Questionnaire

This study employed the online learning satisfaction questionnaire used by Mayer and Estrella (2014) [25], which uses a 7-point scoring system. The following question was used to directly measure the participants' learning satisfaction: "Overall, how satisfied are you with your learning?" This questionnaire is a commonly used method for assessing learners' satisfaction during the online learning process.

2.3. Course Content

The live teaching materials referred to the content of hypnosis in the national quality course "Psychology: I Speak Without Reserve, It's Wonderful" on the Chinese University MOOC website. The live teaching was conducted by a fourth-year student majoring in normal education, who had already acquired good teaching skills through internships and had obtained a national

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teacher qualification certificate. The teaching materials and interactive sessions were determined after three trial lectures.

2.4. Experimental Procedure

Participants were recruited online to join a live course on the psychology of hypnosis. Before the course, a pretest questionnaire on hypnosis knowledge was used to screen college students. Those scoring below 60 points, indicating a lack of prior knowledge about hypnosis, were eligible to learn and thus selected as the 225 participants meeting the experimental conditions. After entering the experiment, the participants were taught by the same instructor through online live classroom teaching. Upon completion of the class, participants filled out the cognitive load questionnaire, social presence questionnaire, and learning satisfaction questionnaire.

2.5. Data Statistics and Analysis

Data were statistically analyzed using SPSS 23.0, including descriptive statistics for demographic variables, differential statistical analysis, and correlation analysis; intergroup differences were compared using independent samples t-tests, one-way ANOVA, and linear regression analysis. The mediation effect was tested using Hayes's SPSS macro program Process, mode 4.

3. Results

3.1. Common Method Bias Test

This study employed self-report methods, which may be subject to common method bias. To test for common method bias, Harman's single-factor factor analysis was conducted [26]. The results indicated that there were 12 factors with eigenvalues greater than 1 before rotation, with the first factor accounting for 19.37% of the variance, which is less than the critical threshold of 40%. This suggests that common method bias in this study is not significant.

3.2. The Impact of Demographic Variables on Cognitive Load, Social Presence, and Learning Satisfaction

Gender Differences in Variables

An independent samples t-test was conducted to examine the differences in cognitive load total scores, external cognitive load, intrinsic cognitive load, germane cognitive load, social presence, and learning satisfaction among students in online live classrooms, using gender as the variable. The results showed that scores for external cognitive load were significantly higher for male students than for female students ($P<0.05$). Similarly, scores for intrinsic cognitive load were significantly higher for male students than for female students ($P<0.05$). However, there were no significant gender differences in scores for germane cognitive load, total cognitive load, social presence, and learning satisfaction ($P>0.05$). For details, see Table 3.1.

Table 3.1. Comparison of Gender Differences

Variables	Male (n=63)	Female (n=162)	t	p
Total Cognitive Load	65.98±15.84	62.84±13.83	1.47	0.143
External Cognitive Load	10.71±7.52	8.55±6.05	2.25	0.026
Intrinsic Cognitive Load	17.57±8.51	14.12±7.69	2.93	0.004
Germaine Cognitive Load	37.70±8.71	40.17±8.65	-1.92	0.056
Social Presence	69.78±11.83	69.06±13.55	0.37	0.711
Learning Satisfaction	6.03±0.95	6.15±0.93	-0.84	0.404

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3.3. Examination of Differences in Variables by Age

A one-way ANOVA was conducted to assess the differences in cognitive load total scores, external cognitive load, intrinsic cognitive load, germane cognitive load, social presence, and learning satisfaction among students in online live classrooms, using age as the variable. The results indicated no significant differences in cognitive load, social presence, and learning satisfaction across different age groups.

3.4. The Impact of Cognitive Load on Learning Satisfaction: The Mediating Role of Social Presence

Correlation Analysis of Cognitive Load, Social Presence, and Learning Satisfaction.

Pearson correlation analysis was utilized to explore the strength of the relationships between cognitive load, external cognitive load, intrinsic cognitive load, germane cognitive load, social presence, and learning satisfaction. The findings revealed that the total cognitive load score was significantly positively correlated with social presence ($r=0.35$, $p<0.01$) and learning satisfaction ($r=0.20$, $p<0.01$). The external cognitive load was not significantly correlated with social presence ($r=0.01$, $p>0.05$) but was significantly negatively correlated with learning satisfaction ($r=-0.26$, $p<0.01$). The intrinsic cognitive load showed a significant positive correlation with social presence ($r=0.13$, $p<0.05$) but was not significantly correlated with learning satisfaction ($r=-0.04$, $p>0.05$). Germaine cognitive load exhibited significant positive correlations with both social presence ($r=0.44$, $p<0.01$) and learning satisfaction ($r=0.56$, $p<0.01$). Additionally, social presence was significantly positively correlated with learning satisfaction ($r=0.44$, $p<0.01$). For details, see Table3.2.

Table 3.2. Correlation Analysis Among Variables

	Total Cognitive Load	External Cognitive Load	Intrinsic Cognitive Load	Germaine Cognitive Load	Social Presence
Social Presence	0.35**	0.01	0.13*	0.44**	1
Learning Satisfaction	0.20**	−0.26**	−0.04	0.56**	0.44**

*indicates p<0.05, **indicates p<0.01

Mediation Effect Test

Further regression analysis was conducted with learning satisfaction as the dependent variable and the standardized Z-scores of external cognitive load, intrinsic cognitive load, germane cognitive load, total cognitive load, and social presence as independent variables. The results indicated that the model with total cognitive load and social presence as independent variables was significant but had low explanatory power ($R2=0.191$, $F=27.396$, $p<0.001$), the impact of total cognitive load on learning satisfaction was not significant ($p>0.05$), while the impact of social presence on learning satisfaction was significant ($p<0.001$). On the other hand, the model with germane cognitive load as an independent variable was significant and had stronger explanatory power ($R2=0.356$, $F=62.836$, $p<0.001$), where germane cognitive load and social presence both significantly affected learning satisfaction ($p<0.001$).

According to the regression analysis results, germane cognitive load and social presence significantly affected learning satisfaction, while the total cognitive load had no significant impact on learning satisfaction. This study employed Wen Zhonglin's [27] mediation effect test procedure, using the standardized Z-scores of germane cognitive load as the independent variable, social presence as the mediator variable, and learning satisfaction as the dependent

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variable. Hayes's SPSS macro program Process plugin was utilized, with mode 4, setting the number of bootstrap samples to 5000 and selecting a 95% confidence interval to test the mediating effect of social presence. The results showed that the pathway with germane cognitive load as the independent variable, social presence as the mediator variable, and learning satisfaction as the dependent variable was significant, with the path being: germane cognitive load → social presence → learning satisfaction. See Figure 3.1 for details.

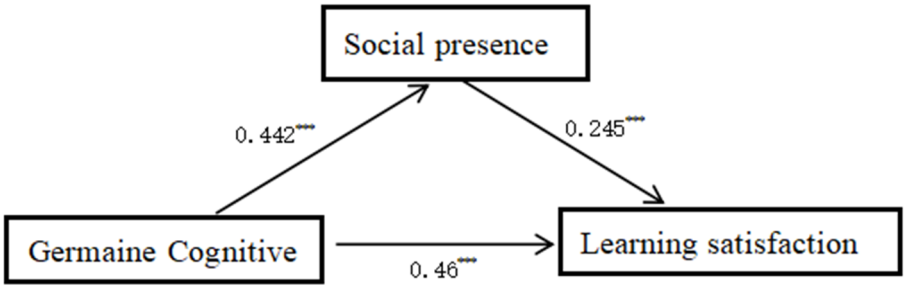

Figure 3.1 Mediation Model of Germaine Cognitive Load, Learning Satisfaction, and Social Presence

Analyzing the mediating role of social presence in the impact of germane cognitive load on learning satisfaction, the results indicate that germane cognitive load can positively predict social presence (β=0.442, t=7.394, p<0.001), social presence can positively predict learning satisfaction (β=0.245, t=4.027, p<0.001), and germane cognitive load can predict learning satisfaction (β=0.46, t=7.588, p<0.001). For details, see Table 3.3.

Table 3.3 Regression Analysis of Variable Relationships in the Mediation Model

Model	Standardized Regression Equation	Criterion Variable	Predictor Variable	R2	F	β	t
1	Y = 0.568X	Learning Satisfaction	Germaine Cognitive Load	0.315	102.459	0.568	10.122***
2	M = 0.442X	Social Presence	Germaine Cognitive Load	0.197	54.676	0.442	7.394***
3	Y = 0.46X + 0.245M	Learning Satisfaction	Germaine Cognitive Load	0.361	62.836	0.460	7.588***
			Social Presence			0.245	4.027***

Note: *** indicates P < 0.001

Mediation effect analysis indicates that the indirect effect value generated by social presence is 0.11, accounting for 19.30% of the total effect of germane cognitive load on learning satisfaction, with the confidence interval excluding 0 (95% CI=[0.06, 0.17]). Meanwhile, the direct effect

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value is 0.46, and the direct effect is significant (p<0.01), accounting for 80.70% of the total effect of germane cognitive load on learning satisfaction, with the confidence interval also excluding 0 (95% CI=[0.34, 0.58]). This suggests that social presence has a significant mediating effect between germane cognitive load and learning satisfaction, and it is a partial mediating effect, with the mediating effect accounting for 23.54% of the total effect. See Table 3.4 for details.

Table 3.4 Analysis of Significance Test and Effect Size Proportion of Mediating Effects

Effect Type	Effect Size	Standard Error	t-value	p-value	Proportion of Effect	95% Confidence Interval
Total Effect	0.57	0.06	10.12	0.00	100%	0.46 - 0.68
Direct Effect	0.46	0.06	7.59	0.00	80.70%	0.34 - 0.58
Indirect Effect	0.11	0.03			19.30%	0.06 - 0.17

Note: *** indicates p < 0.001.

4. Results

4.1. Analysis of the Impact of Demographic Variables on Cognitive Load, Social Presence, and Learning Satisfaction

The results of this study indicate that in online live classrooms, male students experience significantly higher intrinsic cognitive load than female students, a finding consistent with previous related research. Research by Chinese scholar Song Jinrong (2021) [28] also showed that in surveys of obstacles to solid geometry learning, male students had higher intrinsic cognitive load than female students. The finding that male students in this study had significantly higher external cognitive load than female students is not similar to previous conclusions. For instance, Li Jia Xin's research [29] indicated that there was no significant difference in external cognitive load between male and female students for mathematical modeling abilities. So why do male students in this study have higher external and intrinsic cognitive loads than females? There are several possible reasons: 1. Physiologically, males have advantages in spatial perception and visual memory, which may lead them to invest more cognitive resources when completing certain tasks, thus generating greater cognitive load. 2. From a socio-cultural perspective, in some cultures, males are given more responsibilities and pressures, which may lead to greater cognitive load when processing information. 3. In terms of cognitive strategy, males tend to use comprehensive thinking and inductive reasoning to complete learning tasks. In this study, there was no significant difference in germane cognitive load between male and female students. This is consistent with previous research, where Li Jia Xin's study [29] showed no significant difference in germane cognitive load between male and female students for mathematical modeling abilities. This suggests that there is no difference in the familiarity with classroom content between male and female students before entering live classrooms.

In addition to cognitive load, this study also focused on students' social presence and learning satisfaction. However, there were no significant differences between genders in these two aspects, indicating that gender does not significantly affect students' social presence and

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learning satisfaction. This is also consistent with recent research findings. For example, Zhou Qiao's (2021) research [30] found that in online classrooms, gender made no significant difference in students' social presence. Wang Jordan's (2020) research [31] also found that in online classrooms, gender made no significant difference in students' learning satisfaction.

Overall, this study provides new insights into the gender differences in cognitive load, social presence, and learning satisfaction among students in online live classrooms. These findings can help teachers better understand the needs of students and design more effective personalized educational strategies according to the needs of students of different genders.

4.2. The Impact of Cognitive Load on Learning Satisfaction: The Mediating Role of Social Presence

Building upon previous research and based on data results, this study found that among the various dimensions of cognitive load, germane cognitive load is significantly higher than external and intrinsic cognitive loads and plays a dominant role in promoting information processing. Therefore, a mediation effect model was proposed with germane cognitive load as the independent variable, social presence as the mediating variable, and learning satisfaction as the dependent variable. The results revealed that social presence plays a partial mediating role between germane cognitive load and learning satisfaction.

Firstly, this study found that germane cognitive load can positively predict learning satisfaction. Although this did not confirm Hypothesis 1 of this study, the result is consistent with Gao Miaomiao's research findings [25], where germane cognitive load is positively correlated with learning satisfaction in multimedia teaching environments. Germaine cognitive load refers to the load formed when learners connect and analyze new learning content with related information during learning activities, which also indicates that the more learners understand the content related to live classrooms, the higher the germane cognitive load will be, and consequently, learning satisfaction will increase.

Secondly, this study found that social presence can positively predict learning satisfaction, confirming Hypothesis 2 of this study. This indicates that when students feel recognized and supported by the social group in online live classrooms, they are more likely to gain a sense of satisfaction and happiness. The online learning process often lacks face-to-face interaction and non-verbal communication, which can easily make students feel lonely and helpless, reducing their motivation and participation in learning. Social presence can compensate for this deficiency, helping students recognize their importance in online learning, and enhancing their sense of participation and confidence in learning. Some foreign studies have also shown this, such as Richardson and Swan's (2001) [32] meta-analysis, which showed that social presence can significantly improve students' satisfaction with online learning. The study explained that social presence can reduce students' feelings of loneliness and helplessness and enhance their sense of participation and belonging, thereby improving learning satisfaction.

Furthermore, this study found that germane cognitive load can positively predict social presence. Although this did not confirm Hypothesis 3 of this study, the result is consistent with Zhang Xuemin's findings [33], where learners completing cognitive tasks generate a sense of achievement or satisfaction that increases germane cognitive load. This feeling is closely related to social presence. Other studies have also shown [34] that when students face higher cognitive loads, they may feel anxious and frustrated, which reduces their social presence.

Finally, the results of this study indicate that social presence has a significant mediating effect between germane cognitive load and learning satisfaction and is a partial mediating effect, confirming Hypothesis 4 of this study. This result also shows that social presence plays a crucial role in the mediation process, increasing germane cognitive load and improving learning satisfaction. Learners obtaining social support and recognition during the online learning process helps to improve learning outcomes. Therefore, to improve students' learning

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outcomes and satisfaction, it is necessary to pay attention to the comprehensive application of learners' germane cognitive load and social presence, adopting corresponding educational methods or strategies to improve online learning satisfaction.

4.3. Recommendations for Online Synchronous Live Classrooms

Enhance Germaine Cognitive Load

(1) Simplify course content. To avoid redundant information, when designing online education courses, some multimedia teaching aids such as images and videos should be used to present course content more intuitively.

(2) Reasonably arrange task order. The difficulty of different learning tasks varies, and the presentation order should follow from simple to complex.

(3) Provide effective feedback. Online learning lacks face-to-face communication, and learners cannot immediately feedback their learning situation. Teachers should provide timely evaluation and feedback to help students identify and correct mistakes.

(4) Guide autonomous learning. Online learning classrooms lack teacher supervision, and it is necessary to improve students' self-management and control abilities. Teachers can guide students to engage in mutual questioning and answer, using open-ended questions to cultivate students' autonomous learning abilities.

(5) Increase mutual communication. Online learning lacks communication between teachers and students as well as among students. Teachers can initiate real-time online discussions, online groups, and other methods to increase interactivity between students and teachers.

Increase Social Presence

(1) Establish a positive learning environment. Encourage students to share with each other and establish a positive learning environment.

(2) Provide personalized support. Online education platforms should provide personalized support, such as online tutoring, regular Q&A services, etc., to solve students' problems.

(3) Organize interactive activities. Organize students to participate in online games, parties, and other activities to increase opportunities for students to interact with each other and help establish connections.

5. Limitations and Improvements of the Study

The results of this study are limited to specific situations in online live classrooms, and other types of online education models, such as self-paced learning or blended learning, may produce different mediation effect mechanisms. In future research, more situations and environmental factors should be considered, targeting different types of online education models, different age groups, and cultural backgrounds, to fully reveal the mediation effect mechanisms.

Secondly, this study lacks control over other variables. In this study, in addition to social presence and cognitive load, there may be other variables affecting learning satisfaction, such as students' learning motivation, personality traits, family environment, etc. Therefore, the failure to fully control these variables may lead to distortion or bias in the results. In future research, as many other variables as possible should be controlled. In addition to social presence and cognitive load, introduce other variables affecting learning satisfaction, such as learning motivation, personality traits, family environment, etc., and strictly control and statistically analyze these variables.

6. Conclusion

In online live classrooms, male students' external and intrinsic cognitive loads are significantly higher than those of female students, and germane cognitive load is significantly positively

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correlated with social presence and learning satisfaction. Furthermore, germane cognitive load can positively predict social presence, and social presence can also positively predict learning satisfaction. There is a partial mediating effect of social presence between germane cognitive load and learning satisfaction among students in online live classrooms. That is to say, future interventions to improve learners' learning satisfaction can be made from two aspects: increasing germane cognitive load and increasing social presence.

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