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PAPER

Influence of Teacher Intervention on College Students' Metacognition in an Online Collaborative Learning Environment

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ABSTRACT

The rapid development of the Internet, big data, and mobile Internet technology has resulted in the emergence of online collaborative learning as the primary mode of collaborative learning. Although online collaborative learning is flexible and autonomous, the learning performance of learners is not high. One of the main problems that perplexes teachers in online teaching is the high dropout rate but low completion rate. Online education has become increasingly important for improving the quality of students' learning. Teachers' rational use of resources, strategies, and other intervention techniques can significantly enhance the quality of online education. Exploring the effect of teacher-led classroom interventions on college students' metacognition under the collaborative learning mode can further integrate information technology with classrooms and promote the improvement of classroom learning and teaching effectiveness. Two parallel classes, consisting of 80 students each, were selected as research subjects at Harbin University of Science and Technology in Heilongjiang Province, China. The aim of the study was to investigate the impact of teacher intervention on college students' metacognition (specifically, metacognitive planning, metacognitive monitoring, metacognitive regulation, and metacognitive evaluation) in an online collaborative learning environment. Results show that there is no significant difference in the online collaborative learning experience between the experimental class and the control class ($P = 0.3542 > 0.05$). Nonetheless, the experimental and control groups differ in their metacognitive planning ($t = 3.943$, $p = 0.000$), metacognitive monitoring ($t = 2.464$, $p = 0.016$), metacognitive regulation ($t = 2.024$, $p = 0.046$), and metacognitive evaluation ($t = 3.675$, $p = 0.000$). These findings indicate that teacher intervention promotes metacognition among college students. The findings have significant reference value for the seamless integration of online teaching resources and teachers' instruction, the customization of students' individualized learning paths, and the enhancement of online collaborative learning performance.

KEYWORDS

online collaboration, teacher intervention, college students, metacognition

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1 INTRODUCTION

Evaluation methods and students' learning styles have changed due to the rapid development of network technology. Online learning evaluation is evolving towards a student-oriented approach with a focus on the learning process. With the continuous emergence of large-scale, massive open online courses (MOOC) platforms, teachers and students are separated in time and space in online learning. Accordingly, teachers are unable to provide learners with timely feedback, resulting in learners not receiving feedback information in time to correct their learning process. Therefore, creating a collaborative learning environment to assess the learning process of students will not only assist them in enhancing their learning outcomes but also foster the development of their critical thinking skills. At present, universities advocate problem-oriented learning methods, such as self-learning and personalized learning. Among these methods, group cooperative learning is a common mode in classroom teaching. For individuals or groups engaged in an interactive situation, one party facilitates the other party in reaching their goal while also achieving their own goal. This interdependent relationship is commonly referred to as "collaboration." Collaborative learning means that knowledge is not directly transferred to students but is formed through active dialogue and communication among them in the process of understanding concepts and applying skills. Students are the subject of learning. In the broad context of educational informatization, the significance of students as primary learners has become increasingly prominent. Teachers have transformed from simply imparting knowledge in traditional classrooms to playing a guiding role in information-based classrooms. With the rapid development of the internet, online collaborative learning has emerged as a prominent form of collaborative learning facilitated by computer technology. Online collaborative learning, which effectively combines offline and online teaching, has become a new teaching mode. This mode not only helps learners search for and master more knowledge but also facilitates interaction among them.

Metacognitive ability is both the foundation and a crucial manifestation of learning. Metacognition refers to the understanding of cognition, which is essentially the process of human self-awareness and self-regulation in cognitive activities. Metacognitive activities are integral to students' learning processes. During the entire learning experience, learners need to accurately comprehend their learning objectives, continuously monitor the learning process, and adapt their learning strategies as needed to enhance advanced learning abilities, such as learning transfer. With the development of society and the reform of education, learning has evolved from being solely an individual behavior to becoming a collective and cooperative endeavor, garnering increasing attention. Among them, teacher intervention has always been of great importance to educators and scholars as an important factor affecting the process of collaborative learning. Teachers play an important role in facilitating group cooperation. According to the teaching objectives of the group, team cooperative learning can be adopted to solve various difficulties encountered in group learning. It can motivate learners to provide guidance for the group based on the task objectives and historical situation. It can also help them clarify task details and group rules and deepen their understanding and thinking about the problems encountered, thereby promoting group cooperation. Situational learning theory holds that students' learning is constructed and acquired in specific situations. It emphasizes the interaction between knowledge and the context in which it is applied. In online collaborative learning, teachers create problem situations for students and actively guide them in exploring and thinking about the problems. Teachers need to monitor and guide students in their interactions, carefully adjusting the learning strategies and task progress for each group of students and providing timely intervention to meet their diverse needs. In the process of group cooperation, teachers not only need to monitor the interaction between students at all times but also accurately evaluate and adjust the intervention measures to meet the needs of students. Many empirical studies have shown that teacher intervention plays a significant role in promoting students' metacognitive knowledge and experience, the level and depth of knowledge construction, and the degree of participation in collaboration.

2 STATE OF THE ART

Human cognitive development is not only reflected in the growth of knowledge but also in the improvement and development of the cognitive structure. The level of schema development has become an important indicator for measuring an individual's cognitive development level. This is because the schema serves as both the foundation and the outcome of cognitive development. Schema sheds light on this study as follows: In the online collaborative learning environment, students frequently propose new ideas and methods, and teachers must assess the work of others. When the disparity between the learners' existing cognitive structure and the new ideas is too great to fit within their zone of proximal development (ZPD), they are unable to bridge this gap. In such cases, teachers should intervene promptly to enhance learners' capacity to analyze tasks and to foster self-motivation and belief within collaborative teams. Moreover, the teachers facilitate the monitoring of the student team's progress during the collaboration process. They evaluate the effectiveness of the collaboration results and intervention effects and provide feedback after the completion of collaborative tasks.

The ZPD theory is also an important theoretical basis for this study. This theory, which is centered on the ZPD, posits that teaching intervention is effective by implementing practical and effective measures to assist students in bridging the ZPD and attaining the developmental level of the subsequent stage. The intervention measures provided by teachers to help students cross the ZPD include two aspects. On the one hand, students are provided with training before engaging in peer evaluation activities, and adequate support is established to facilitate their participation in activities. On the other hand, effective teacher intervention strategies are designed to align with the potential level of achievement for students. These strategies provide timely learning support to help students in successful completion of school and enable learners to correct their learning cognition promptly. Furthermore, these strategies can assist in reconstructing their knowledge system, ultimately facilitating the development of higher-level critical thinking skills among learners.

The study on teacher-led classroom intervention is very comprehensive and thorough. As often mentioned in the context of digital education, collaborative inquiry learning remains a significant challenge for traditional teaching methods. Among the studies on the influence of teacher intervention on college students' metacognition in collaborative learning environments, Langdon et al. [1] evaluated the impact of various metacognitive interventions on cognitive knowledge and regulation. Results showed that these interventions had no significant interaction or major impact on the cognitive regulation, test scores, or final scores of students.

Amzil [2] pointed out that the metacognitive and reading abilities of students in the experimental group improved, while the performance of the control group did not change from the pre-test to the post-test. Zan [3] analyzed the effect of training on metacognition and emotional characteristics. The results showed that the teaching intervention was successful, and all the students passed the exams they had previously failed. Soicher and Gurung [4] tested whether using test wrapping paper could improve students' metacognition and academic performance. Their results showed that the metacognitive awareness of all students significantly improved throughout the entire semester. Zepeda et al. [5] conducted a study on the four characteristics of metacognitive support and discovered that the high-concept growth classroom offered greater metacognitive support for the overall framework of personal knowledge, monitoring, evaluation, and guidance methods compared to the low-concept growth classroom. Thomas and McRobbie [6] indicated that students' metacognition can be significantly improved by using metaphors in chemistry class. Ramadhanti et al. [7] revealed that the use of a reflective diary guide can effectively monitor the development of students' writing metacognition. They also suggested that teachers should consistently encourage students to write reflective diaries in order to track the progress of metacognition in writing. Briesmaster and Etchegaray [8] analyzed the effect of metacognitive skills on students' ability to write paragraphs in English. The results showed that after the intervention, students used more metacognitive strategies when writing in English. Abd-El-Khalick and Akerson [9] assessed the influence of training and the use of metacognitive strategies on the development of primary school quasi-teachers' views on the nature of science (NOS). Data analysis revealed that a greater number of students in the intervention group expressed more informed views on the goal of NOS. Additionally, a correlation was observed between the improvement of metacognitive awareness and the development of a well-informed understanding of NOS. Inriyanti et al. [10] utilized a quasi-experimental research method, implementing a mixed learning environment in the experimental group and a conventional learning environment in the control group. Their results showed that the two groups of students had different levels of metacognitive progress, which could be attributed to variations in learning experiences and inadequate preparation of the students for blended learning. Sandi-Urena et al. [11] analyzed the influence of network tools on learners' metacognition. The results showed that the students in the experimental group improved their ability to solve challenging non-algorithmic chemistry problems, and their accuracy rate was higher. Khosa and Volet [12] pointed out that teachers could significantly improve students' self-report on personal goals, the perceived difficulty of assignments, group and task challenges, and learning evaluation in the experimental group by adopting dual metacognitive strategies. Vrieling et al. [13] discussed the relationship between self-regulated learning opportunities, learning motivation, and the use of metacognitive learning strategies among primary school teachers. The results showed that intern teachers increasingly used metacognitive skills, which were accompanied by enhanced learning motivation. August-Brady [14] investigated the influence of metacognitive intervention, specifically concept mapping, on the learning style and learning self-regulation of undergraduate nursing students. The results showed that, compared with students who did not use concept maps, the nursing students demonstrated improvement in deep learning methods and learning self-regulation. Loizidou and Koutselini [15] evaluated the development and application of an intervention program aimed at improving students' metacognitive monitoring in daily teaching. Their results confirmed a clear correlation between knowledge-monitoring skills and children's performance. Cook et al. [16] delivered a 50-minute lecture on learning strategies to approximately 700 first-year students who were pursuing a science major. Statistics show that the students who participated in the lecture changed their behavior as a result of acquiring new information. Milliner and Dimoski [17] conducted a quasi-experimental study to measure the effectiveness of a metacognitive intervention on low-level English learners in Japanese universities. The results showed that the students who accepted the intervention exhibited a more confident attitude towards their second language listening. Volet [18] discussed the potential of the metacognitive strategy-based teaching method in the university environment and conducted a 13-week comparative experiment with 28 experimental students and 28 control students in the course "*Introduction to Computer Science*." The results showed that the metacognitive strategy-based teaching method could enhance students. The development of metacognitive strategies related to computer programming resulted in significant short-term and long-term effects on the students' cognitive and emotional learning outcomes. The existing studies reveal that the collaborative learning mode functions by encouraging team members to actively participate in a goal-oriented cognitive process with the support of information technology. In this process, each member shares their knowledge, contributes to problem understanding, and utilizes their skills to solve tasks, thereby constructing and shaping a conceptual space that is shared by multiple individuals. As more information technologies are integrated into the field of education, modernized learning methods are increasingly transitioning from individual learning to collaborative learning. This shift aims to foster the acquisition of lifelong learning and working skills. However, collaborative learning cannot completely solve the problem of personalized learning, and it requires effective teacher participation. Strong intervention from teachers can significantly enhance students' engagement in online learning, their achievement of learning goals, and their performance in collaborative learning.

3 METHODOLOGY

3.1 Research process

In this study, two parallel classes at Harbin University of Science and Technology in Heilongjiang Province, China, were selected as the research subjects. At the start of the study, a questionnaire was used to pre-test the online cooperative learning willingness of students in both classes. If no significant difference was found, then both classes demonstrated a willingness for online cooperative learning. In this study, Class One was designated as the experimental class with 80 students, while Class Two was designated as the control class with 80 students. Intensive teacher intervention was adopted in Class One, where the teacher organized students to engage in learning discussions through Microblog, We Chat, and QQ, and assigned tasks. Teacher intervention in Class Two was weak. Only a notice was distributed to arrange for students to finish school independently, and scores were assigned during the course assessment. The teaching content, hours, and progress were consistent between the two classes. This study was started on September 6, 2022. After engaging in online collaborative learning for nearly 12 weeks, a semi-structured online questionnaire survey was conducted. Subsequently, the metacognition of the students in the two classes was measured using independent sample T-tests to examine the aforementioned research hypotheses.

3.2 Research tools

Closed-ended questions and a multiple-choice coding method were adopted for the questionnaire. The items in this section were measured using the Likert five-point scale. Scores of "1," "2," "3," "4," and "5" were given, corresponding to the respondents' answers of "never," "seldom," "sometimes," "often," and "always." The questionnaire data were analyzed and processed using SPSS 26.0.

3.3 Research questionnaire

Regarding the measurement of willingness to engage in online collaborative learning, the research of Weinberger [19] utilized five measurement questions. According to previous studies, metacognitive ability includes students' capacity for metacognitive planning, metacognitive monitoring, metacognitive regulation, and metacognitive evaluation. In addition, the scales used in previous studies typically measure and assess whether students engage in corresponding metacognitive behaviors, providing tangible indicators for the abstract concept of metacognitive ability. In reference to the research literature of Schraw and Dennison [20] and Mokhtari and Reichard [21], metacognition mainly consists of four components: metacognitive planning, metacognitive monitoring, metacognitive regulation, and metacognitive evaluation. Therefore, five, four, five, and four questions were set for each variable in the pre-questionnaire of this study, totaling 18 measurement items.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Questionnaire reliability and validity

In this study, Cronbach's α coefficient was used to assess the reliability of the collected questionnaire items. Cronbach's $\alpha > 0.7$ indicates good reliability of the scale. The reliability analysis results of the scale are listed in Table 1.

Table 1. Reliability results

Measured Variable	Number of Measurement Questions	Cronbach's α Coefficient
Collaborative Learning Willingness	5	0.857
Metacognitive Planning	5	0.775
Metacognitive Monitoring	4	0.717
Metacognitive Regulation	5	0.787
Metacognitive Evaluation	4	0.816

Table 1 indicates that the Cronbach α coefficients of the five variables in this study are all greater than 0.7, indicating the high reliability of the scale.

Validity is one of the important methods to test whether the data collected by a questionnaire is valid. In this study, construct validity was analyzed by measuring the KMO index. A KMO value greater than 0.7 indicates good construct validity of the questionnaire, while a KMO value less than reflects poor validity of the scale result.

Table 2. KMO and Bartlett test

KMO		0.771
Bartlett's sphericity test	Approximate Chi-square	1499.444
	Degree of freedom	253
	Significance	0.000

Table 2 shows that the overall KMO value of the questionnaire in this study is 0.771, indicating good validity. Bartlett's test ($p < 0.001$) reflects the good construct validity of the scale questions.

4.2 Analysis of willingness to engage in collaborative learning

Before conducting the experiment, the researches assessed the willingness to engage in cooperative learning in the experimental and control classes using an independent sample t-test.

Table 3. Independent sample T-test

Group	Experimental Group	Control Group
Sample Size	80	80
Arithmetic mean	21.9236	21.6315
95% confidence interval for the mean	21.4951–22.3522	21.1755–22.0875
Variance	3.7082	4.1978
Standard Deviation	1.9257	2.0489
Standard Error of Mean	0.2153	0.2291
Difference	–0.2921	
Combined Standard Deviation	1.9882	
Standard Error	0.3144	
95% confidence interval of the difference	–0.9130 –0.3288	
T value	–0.929	
Degree of freedom (DF)	158	
Two-tailed probability	P = 0.3542	

The results are shown in Table 3, where $p = 0.3542 > 0.05$, indicating no significant difference between the experimental class and the control class in terms of the level of the online collaborative learning experience. The standard deviations are 1.9257 and 2.0489, respectively, indicating a small difference in the students' willingness to engage in intra-class collaborative learning between the two classes. This suggests that further experiments can be conducted.

4.3 Paired-samples T-tests of the experimental group and control group

Table 4. T-tests of samples

Pair No.	Item	Mean	Standard Deviation	t	p
Pair 1	Metacognitive Planning of the Experimental Group (E Group-1)	20.35	2.95	3.943	0.000**
	Metacognitive Planning of the Control Group (C Group-1)	18.71	1.94		
Pair 2	Metacognitive Monitoring of the Experimental Group (E Group-2)	17.69	2.76	2.464	0.016*
	Metacognitive Monitoring of the Control Group (C Group-2)	16.44	3.81		
Pair 3	Metacognitive Regulation of the Experimental Group (E Group-3)	19.07	2.7	2.024	0.046*
	Metacognitive Regulation of the Control Group (C Group-3)	18.24	2.52		
Pair 4	Metacognitive Evaluation of the Experimental Group (E Group-4)	17.44	3.09	3.675	0.000**
	Metacognitive Evaluation of the Control Group (C Group-4)	15.69	2.72		

Notes: *indicates a significance level of 5%; **indicates a significance level of 1%.

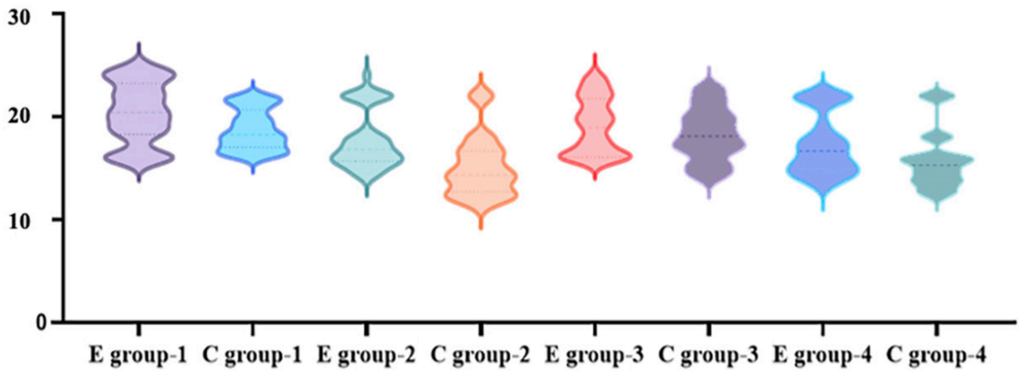

Fig. 1. Paired-samples t-tests of the experimental group and control group

The difference in experimental data is investigated using paired-samples T-tests. Table 4 and Figure 1 show that significant differences are observed in all four groups of paired data ($p < 0.05$).

Through a concrete analysis, the following results have been determined:

1. A significance level of 0.01 was observed between the experimental group and control group in terms of metacognitive planning ($t = 3.943$, $p = 0.000$). Through a concrete comparison of differences, it is evident that the mean (20.35) of metacognitive planning in the experimental group is higher than that (18.71) in the control group. The main reason is that classroom interventions by teachers focus more on reminding or managing learners and improving their academic performance, thereby encouraging learners to develop their problem-solving abilities. Through

teaching interventions, teachers provide suggestions for personalized learning paths for learners and offer recommendations to help them choose learning resources effectively. In a collaborative environment, teachers can assist learners in establishing suitable learning objectives, choosing appropriate reading materials, finding the optimal solution to problems based on the potential outcomes of cognitive activities and strategy selection, and evaluating the teaching based on the learners' cognitive needs prior to a specific instructional task. Through the explicit intervention of teachers, learners can monitor their learning progress and compare it with the established plan. This allows them to identify problems in a timely manner and improve their metacognitive planning skills.

2. A significant difference of 0.05 was observed between the experimental group and the control group in metacognitive monitoring ($t = 2.464$, $p = 0.016$). According to the specific comparison, the average value of metacognitive monitoring in the experimental group (17.69) is significantly higher than that in the control group (16.44). The main reason is that in teaching, teachers supervise and monitor students' use of various learning tools. The deep-seated teaching intervention is evident in teachers intervening with learners' mobile devices when using teaching equipment. Therefore, through a series of monitoring behaviors by teachers, learners can evaluate the outcomes and limitations of cognitive activities in a timely manner. They can provide feedback based on their cognitive objectives in the actual process of cognitive activities and accurately assess the extent and level of their cognitive objectives. According to the standard of teaching effectiveness, teachers can scientifically evaluate the effects of learners' cognitive actions and strategies more accurately. In this way, learners can be aware of potential issues in their attention and understanding and then recognize and address them.
3. A significant difference at the 0.05 level is observed between the experimental group and control group in metacognitive regulation ($t = 2.024$, $p = 0.046$). The specific comparison reveals that the average metacognitive regulation in the experimental group (19.07) is significantly higher than that in the control group (18.24). This is mainly because the teacher always emphasizes to the learners that the entire collaborative team is the focal point in the collaborative learning environment, encouraging them to focus on the collective participation and interaction among group members. Meanwhile, regulatory sharing emphasizes collective achievements and concerns individual knowledge construction. Attention is paid to both the team's regulatory behaviors and individual cooperation performance. In shared regulatory learning, teachers can guide students at different levels by giving equal attention to students, groups, and classes so that there is room for intimate dialogue with each student and group. Through the aforementioned measures, learners can timely correct and adjust their cognitive strategies by assessing the impacts of these strategies. Regulatory strategies can help students correct their learning behaviors and compensate for their lack of understanding.
4. A significant difference level of 0.01 was observed between the experimental group and control group in metacognitive evaluation ($t = 3.675$, $p = 0.000$). The specific comparison shows that the average value of metacognitive evaluation in the experimental group (17.44) is significantly higher than that (15.69) in the control group. A possible reason is that teachers should reduce the difficulty of obtaining resources, create more avenues for obtaining resources, diversity the types of resources available, and offer support for students to engage in peer evaluation activities. Platforms and gauges are tools that support peer evaluation activities, with platforms specifically providing hardware support. The platforms

selected should have user-friendly interfaces and be easy for students to operate. Gauges usually refer to evaluation tables or evaluation rules, which are a series of standards or index systems used to assess students' academic level. These gauges measure various aspects, including learning behavior, cognitive level, and learning achievements. Before initiating peer evaluation activities, teachers should provide training to learners on the rules, resources, and tools of the activities, taking into consideration the learners' characteristics and the content being assessed. These efforts will help learners prepare for participating in peer evaluation activities, clarify the purpose and significance of participating in peer assessment activities, master the requirements of peer evaluation, standardize their participatory behavior, and ultimately improve their metacognitive evaluation.

In this investigation, we discuss the influence of teacher-led classroom intervention on college students' metacognition level in the context of collaborative learning. Furthermore, some suggestions are proposed to help teachers change their roles, realize the deep integration of information technology in the classroom, promote the optimization of the classroom learning environment and teaching effectiveness, and elevate the development level of teachers' specialization in informatization. In a collaborative learning environment, teachers actively employ various intervention strategies to assist students in comprehending the complexity, familiarity, and proficiency of the task. Teachers can enhance students' metacognitive experience by guiding them, allowing students to experience the satisfaction of achieving their learning goals and the motivation to complete unfinished tasks. This role also indicates that teachers continue to be a significant source of emotional support for students in classroom learning, even in group cooperative learning with technical assistance. Teachers can enhance metacognitive monitoring by assisting learners in collaboratively creating plans, managing the cognitive process, evaluating cognitive outcomes, and promptly addressing any issues that arise. In collaborative learning, teachers should not just be bystanders but should actively engage with each group, attentively listening to everyone's contributions and facilitating effective communication among group members. Teachers should familiarize themselves with certain principles of group collaboration with technical support, such as determining the group size and allocating tasks, and establish clear and actionable expectations for group members based on the nature of the activities. This includes utilizing technology, assigning cooperative tasks, ensuring a fair division of labor, and promoting active. In summative evaluations, teachers should not only focus on the aspect of group cooperation but also encourage students to reflect on their position and role within the group.

5 CONCLUSIONS

With the widespread use of mobile devices, portable gadgets, and other technological tools in education and teaching, technology is revolutionizing education. Online learning is rapidly gaining popularity due to its convenience and accessibility. Under the general trend of the deep integration of science, technology, and education, educators, and researchers have expressed widespread concern about the subjective status and personalized development of students. Many schools advocate for the innovation of classroom teaching, with the aim of transforming teaching from a teacher-centered approach to a learner-centered practice. In collaborative learning, however, the guidance of teachers is essential due to the varying levels of prior knowledge among students. In this study, two parallel classes consisting of

80 students each (one experimental class and one control class) were selected as the research subjects at Harbin University of Science and Technology in Heilongjiang Province, China. The aim of the study was to investigate the impact of teacher intervention on college students' metacognition in an online collaborative learning environment. The results show that there is no significant difference in the level of experience with online collaborative learning between the experimental class and the control class. The metacognitive planning, metacognitive monitoring, metacognitive regulation, and metacognitive evaluation of the students in the experimental group and the control group were found to be significant at the levels of 0.01, 0.05, 0.05, and 0.01, respectively. This suggests that teachers can enhance learners' metacognition by implementing active and appropriate intervention strategies in the online collaborative learning environment. In the future, there is potential to delve deeper into the impact of learning behavior data on students' learning effectiveness, the development of personalized learning paths with teacher assistance, and the correlation between varying levels of teacher intervention strategies and students' engagement in the learning process.

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