Interactive-whiteboard-technology-supported collaborative writing: Writing achievement, metacognitive activities, and co-regulation patterns

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Abstract
Interactive whiteboard technology is a helpful tool for learning to write. However, collaborative writing among English language learners using this technology remains underexplored. This study considers the potential effects of collaborative writing supported by interactive whiteboard technology on students’ writing performance. A total of 120 students who learned English as a foreign language (EFL) participated in this study. Quantitative results revealed that interactive whiteboard technology integrated with collaborative writing instruction resulted in greater improvement in students’ writing performance, followed by traditional whiteboard-integrated collaborative writing and traditional collaborative writing instruction without whiteboard technology. Qualitative results further suggested that the patterns and timing of metacognitive activities varied across the three groups. Learners receiving interactive whiteboard-integrated collaborative writing instruction exhibited higher levels of metacognitive activities and were more engaged in coregulation. Implications for using interactive whiteboard-integrated collaborative writing to promote writing instruction are discussed.

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1. Introduction

Within the field of computer-assisted language learning, the benefits of technology-based collaborative writing have attracted substantial scholarly attention. Language educators and researchers have called for technology tools to be integrated into instructional strategies for collaborative writing. Technology tools for improving collaborative writing include wikis (Aydin & Yildiz, 2014), blogs (Arslan & Sahin-Kizil, 2010), and Web 2.0 technologies (Brodahl, Hadjerrouit, & Hansen, 2011). With the aid of technology-enhanced platforms, students may receive multimodal practice with feedback, engage in writing with large amounts of available language data, and produce higher quality essays (Bikowski & Vithanage, 2016; Elola & Oskoz, 2017). Teachers have also benefited from technology for tracking students’ collaborative writing processes (Elola & Oskoz, 2010). Collaborative writing through technology can thus be used to assist English learners by affording them more opportunities to practice English writing in an engaging environment (Vorobel & Kim, 2017).

Although the benefits of technology in enhancing collaborative writing are well documented, studies revealed that EFL learners had unfavorable perceptions towards technology-oriented EFL writing (e.g., Lin & Yang, 2011). Factors such as cognitive overload (Charney, 1994) and a lack of knowledge related to technological skills (MacArthur, 2006) may make it
difficult for learners to develop satisfactory writing proficiency. In addition, not all group activities led to satisfactory outcomes in writing because learners did not possess the self-regulatory skills necessary for collaborative writing (Chen & Hapgood, 2019). Effective collaborative writing outcomes, while desired, are not guaranteed. The need to foster students’ self-regulatory capacity has prompted efforts to incorporate metacognitive training to bolster learners’ self-regulatory skills in writing (Teng, 2016). Teng and Huang (2019) argued that learners must be provided opportunities to develop metacognitive awareness because learners should be encouraged to take control of their writing sessions and become more self-regulated in their written output.

Recent advances in interactive whiteboards provide a viable methodological alternative for studying collaborative writing (Bell, 2000; Schmid, 2010). Interactive whiteboards, which are increasingly available in language classrooms worldwide, may prove useful in EFL writing instruction. The present study explores the effects of interactive whiteboards on English writing. In particular, the purpose was to strengthen an understanding around students’ metacognitive awareness and co-regulation patterns vis-à-vis collaborative English writing supported by web-based interactive whiteboards (Wang, 2019). The present study triangulates quantitative and qualitative data to examine students’ writing achievement, metacognitive activities, and co-regulation patterns in a whiteboard-supported environment. Findings shed light on the extent to which group differences in metacognitive activities and patterns of co-regulation during collaborative writing can contribute to apparent differences in writing achievement.

2. Literature review

2.1. Collaborative writing

Collaborative writing has been defined as a writing activity involving two or more writers working together to reflect on their language use and reinforce each other in solving language-related problems while writing (Storch, 2013; Yim & Warschauer, 2017). Within this context, scaffolding has been conceptualized as immediate feedback provided via technology-supported communication tools to help individuals make decisions and enhance skills (Yeh, Lo, & Huang, 2011). The benefits of collaborative writing include support through modeling peers’ thinking strategies and writing styles (Dale, 1994), developing a sense of camaraderie and confidence (Yong, 2006), and enhancing “clarification requests, confirmation checks, and comprehension checks” (Fung, 2010, p. 21). In the present study, collaborative writing focused on learning to write individually using collaborative learning as a type of instructional design (e.g., feedback). Outcomes consisted of individual writing products (e.g., writing quality). Observations were based on perspectives gathered from individual utterances and group members’ interactions.

The adoption of collaborative writing as a means to develop EFL learners’ writing conventions can be interpreted from a sociocultural perspective (Lantolf & Poehner, 2014; Storch, 2005). In a collaborative situation, student writers are impelled to make decisions about the language needed to express their ideas as they produce a text together. In the process of collaborative writing, learners “come to recognize their limitations or gaps when trying to match their linguistic knowledge to the demands of formal academic writing” (Elola & Oskoz, 2010, p. 52). Learners’ progress towards their own understanding through the constructive and creative effort involved in saying and responding to what was said reflects the view that learning increases participation in communities of practice to interact with, complete things together with, negotiate new meanings with, and learn from each other in an ongoing, social, and interactional process (Lave & Wenger, 1991). In this learning context the teacher is no longer regarded as the only active agent of learning participating in transmitting knowledge to students; neither are learners perceived as the only receivers of knowledge. The classroom setting should be envisioned as a site where teachers and learners co-work to acquire new knowledge through meaningful and dynamic interaction.

2.2. Empirical studies on collaborative writing

In a collaborative writing environment, student writers need scaffolds to achieve better writing performance as they exchange ideas and reflect on their writing upon receiving feedback from others (Aydin & Yildiz, 2014). One would be remiss to assume that collaborative writing participation automatically indicates that group members can support each other. For instance, EFL students have diverse English proficiency levels, unique attitudes toward speaking and using English, and varying extents of English exposure; thus, convincing them to produce collaborative writing can be challenging. To overcome these challenges, learners should possess the required skills (e.g., metacognition and co-regulation) for collaborative writing. Evidence suggests that learners’ abilities to self- and co-regulate are positively associated with increased performance in collaborative learning environments (DiDonato, 2013). Relatedly, multiple group members who jointly assume responsibility for collaborative writing and co-construction of knowledge may sustain motivation during a collaborative writing task, which should help them cope with difficulties.

Various technologies have been employed to motivate learners to engage in collaborative writing, including computer-mediated communication. For example, wikis have been used as a platform for collaborative writing (Li & Kim, 2016). In one study, Li and Kim (2016) considered two groups, both of which included two Chinese students and a third student from a different cultural background. The authors focused on language functions, writing change functions, and scaffolding strategies demonstrated by the two groups. Results showed that when the two groups were asked to work on two academic writing tasks (i.e., writing a research proposal and an annotated bibliography based on selected sources), each group chose...
diverse approaches to task negotiation and text co-construction. Despite the merit of wikis as a collaboration tool in small-group writing, Li and Kim’s (2016) findings suggest that learners may not automatically take a collaborative approach. Multiple factors, including learners’ “life trajectories, the instructional context, members’ communicative strategies, personal circumstances, and the affordances of the technology” (Li & Kim, 2016, p. 39), influenced learners’ engagement in computer-based collaborative writing. As argued by Li and Storch (2017), writing is multimodal in the digital era, such that “multiple semiotic features, ecological resources, and modalities” contribute to production and interpretation (p. 3). In addition, L2 learners’ knowledge of collaborative writing can influence their interaction patterns during the collaborative writing process and their engagement in the same tasks. These learners require well-structured metacognitive training to promote their participation in learning to write (Chen & Hapgood, 2019).

Collaborative writing using real-time technology tools, such as wikis, to provide and receive immediate feedback can facilitate learners’ engagement in the learning-to-write process. Learners may find the collaborative writing experience more authentic and engaging and be able to produce more coherent texts. By contrast, traditional writing instruction often operates in isolation, in that students lack interaction and dialogue with peers. Technology-oriented collaborative writing may be difficult for EFL students who likely possess diverse English proficiency levels and may have had varying degrees of exposure to technology. Therefore, a key objective for researchers and language teacher educators is to implement teaching strategies that “address the coordinative, poly-contextual, cross disciplinary work that link together activities separated by time, space, organizations, and objectives” (Rice, 2009, p. 303). Such arguments highlight the potential effects of interactive whiteboard technology on collaborative writing.

2.3. Relevant studies on interactive whiteboard—supported learning

Research has highlighted the benefits of technology-supported collaborative writing in terms of text quality. Yeh et al. (2011) developed a computer-supported system, Process-Writing Wizard, for collaborative technical writing. Results showed that students who received system-based support produced better written content and organization and possessed more motivation and positive attitudes toward writing than students receiving traditional writing instruction. Arslan and Sahin-Kizil (2010) used blogs to investigate how Turkish university English language learners’ writing performance could be enhanced. By employing a control group and an intervention group using blog-based instruction, findings revealed that the blog-based intervention group exhibited greater improvement in written content and organization.

The above studies on the use of technology in collaborative writing provide insight about using interactive whiteboards. As another example, Bell (2000) employed a pre- and post-test design with 90 eighth-grade students. Those in the experimental group were exposed to an interactive electronic whiteboard learning setting, and those in the control group received the same exercises and instruction without whiteboard. Results indicated that using interactive whiteboard technology contributed to students’ acquisition of writing skills. Interactive technology platforms may build learners’ awareness of their writing performance, enabling them to achieve better output. However, the diversity and complexity of collaborative contexts, technology software, and measures used in previous studies may explain the mixed results regarding collaborative writing. Among software used for collaborative writing, interactive whiteboard technology has been acknowledged as challenging (Glover, Miller, Averis, & Door, 2005). For example, learners had limited opportunities to take control of their writing sessions (Schmid, 2010). Similarly, learners’ metacognitive awareness of self-regulated learning during interactive whiteboard—supported writing sessions was key to the success of such interventions (Malmberg, Jarvela, & Jarvenoja, 2017). Hence, while we attempt to explore the potential effects of interactive whiteboard technology on collaborative writing, it is essential to examine learners’ metacognitive awareness, including self-regulation and co-regulation, to better understand the effectiveness of interactive whiteboard technology on collaborative writing.

2.4. Metacognition, self-regulation, co-regulation, and scaffolding

Metacognition, defined as thinking about one’s own thinking (Flavell, 1979), connects to how learners regulate mental efforts for relevant activities. Typical metacognitive activities include those in which learners learn what to plan, determine goals to achieve performance, execute strategies to achieve pre-determined goals, and monitor and evaluate their successes and failures (Flavell, 1979). Learners who are better able to plan, monitor, and evaluate their learning are more likely to discover mechanisms for self-regulated learning (Baker & Brown, 1984). Self-regulated learning can be defined as one’s ability to monitor and think about their learning metacognitively, motivationally, and behaviorally (Teng, 2019; Zimmerman, 2013). Self-regulated learning includes three components: cognition (i.e., the mental process for knowing, understanding, and learning); metacognition (i.e., thinking about and regulating one’s own cognitive processes); and motivation (i.e., learners’ willingness to adopt metacognitive and cognitive skills) (Williamson, 2015).

Chan (2012) asserted that students who can self-regulate in a solo-learning situation may not be able to co-regulate their learning in a group. Co-regulation refers to learners’ strategic adaptation during collaborative planning, wherein each student supports other group members in regulating learning (Jarvela, Malmberg, & Koivuniemi, 2016). Jarvela et al. (2016) argued that individual self-regulation should be accompanied by co-regulation to promote productive collaboration.

Meanwhile, teachers must scaffold learners’ learning to facilitate students’ self-regulated learning skills (Blau & Shamir-Inbal, 2017). Scaffolding refers to “interventions that tutors or teachers make within the students’ ZPD to facilitate their learning and improve their current knowledge and skills” (Gonulal & Loewan, 2018, p. 2). In the present study, scaffolding
encompasses the aids or feedback provided by teachers, group members, or instructional tools to help students become competent writers. Scaffolding also facilitates monitoring, an important metacognitive process in self-regulated learning (Kim & Lim, 2019). Via scaffolding, learners can identify potential incongruity between pre-planned goals and their current knowledge. Students who recognize this incongruity may be able to plan and execute metacognitive strategies to reach their objectives for writing (Teng, 2020a). However, co-regulation behaviors were not explored, leaving issues related to self-regulation unknown.

2.5. Gaps in previous literature

As previously mentioned, an interactive, multi-task, multi-user, and technology-oriented environment (e.g., an interactive whiteboard—supported learning condition in the case of this study) may help EFL students practice real-time collaborative writing effectively. However, what we know about interactive whiteboard—supported collaborative writing is still limited (Bell, 2000; Glover et al., 2005). In addition, despite the importance of learners' metacognitive awareness in relation to collaborative writing, learners’ co-regulation behaviors during collaborative writing have not received sufficient attention. The present study is an attempt to bridge that gap through collecting both quantitative and qualitative data related to learners’ metacognitive activities, co-regulation behaviors, and writing outcomes in the context of interactive whiteboard technology. The focus was on how learners within a team conducted metacognitive activities and co-regulation during the processes of elaborating, interpreting, reasoning, building on ideas, explaining concepts in their own words, or seeking help with understanding under the interactive whiteboard—oriented learning condition. Independent variables included three groups, i.e., an interactive whiteboard—integrated collaborative writing group, traditional whiteboard—integrated collaborative writing group, and collaborative writing group. Dependent variables included a writing test, metacognitive activities, and co-regulation patterns. The present study seeks to address two research questions:

1. To what extent do the three treatment groups (i.e., an interactive whiteboard—integrated collaborative writing group, traditional whiteboard—integrated collaborative writing group, and collaborative writing group) differ in terms of writing achievement?
2. To what extent do the three treatment groups (i.e., an interactive whiteboard—integrated collaborative writing group, traditional whiteboard—integrated collaborative writing group, and collaborative writing group) differ in terms of metacognitive activities and co-regulation patterns?

3. Method

3.1. Research design

The research design was based on a mixed method design, which was deemed most appropriate for investigating (a) how interactive whiteboard technology might enhance writing performance in the research setting and (b) participants' learning-to-write processes relative to technology use. In particular, independent variables included the interactive whiteboard—integrated collaborative writing group (IW group), traditional whiteboard—integrated collaborative writing group (TW group), and collaborative writing group (CG group). Dependent variables included a post-study writing test as well as audio and video records of discourse collected during the cooperative learning process. The writing test was used to measure possible writing improvement, and the recordings served to characterize learners' metacognition and co-regulation.

3.2. Participants

This study involved 120 EFL students from an internal English academic writing program at a university in China (55 women: 45.8%; and 65 men: 54.1%). Students were 19.23 years old on average (SD = .98). A total of 198 students initially attended this program. Participants’ writing proficiency level was assessed prior to the study. An invitation was initially sent to 150 students whose scores fell within the range of 16–18 points out of 30 on a pre-test (see Measures section). Of those invited, 125 students agreed to participate in this study on a voluntary basis. Five students were excluded due to being unavailable during the scheduled study time. Participants were studying different majors and were native Chinese speakers. Analysis of variance (ANOVA) results suggested that the three groups were homogenous in terms of writing proficiency level (see Results section). According to an internal report, learners possessed intermediate writing proficiency; they could present main ideas and construct complex sentences, although some sentences were inaccurate or lacked sufficiently developed ideas. The students reported they did not have prior experience with technology-supported collaborative writing.

3.3. Instruction methods

Participants were divided randomly and equally into three groups, including two experimental groups (IW and TW) and one control group. The groups were identical in the following aspects: classroom setting, team number, lesson plan, time, writing exercises, topics, techniques of writing instruction, textbook and learning materials, writing assessment, and
instructor. Five-member teams were formed randomly. Although pairs can encourage greater learner involvement in decision making and provide each learner with more L2 speaking practice than small groups (Storch, 2017), the exchange of available resources, group member diversity, and group cohesion in small groups may better prepare learners to interact (Teng, 2016). An ideal group size was determined as four to five students (Teng, 2020b). For the current study, five students were assigned to each team for convenience when working with Ebeam software; five-member teams gave learners a chance to meaningfully practice what they had observed, whereas pair work may not have allowed for such practice when using such an online tool. Each group consisted of eight teams whose members worked together during instruction sessions in which they were asked to complete writing exercises. Table 1 summarizes the instruction each group received.

In the IW and TW conditions, the instructor used a main computer to document learners’ conversations. A traditional whiteboard was placed at the front of the class in the TW condition; students in the IW condition had access to an interactive whiteboard, laptop, and video projector during all class sessions. EBeam software was provided for students in the IW condition to interface information between the whiteboard and their individual laptops. Other instruments included a word-processing program, informational CDs, informational databases, and the internet. The interactive whiteboard allowed users to collaborate on documents; import information from other applications; and save, print, or e-mail compositions. In contrast to the other two conditions, texts in the IW condition could be highlighted, manipulated, edited, and revised using a variety of annotation tools. Information relevant to the writing topic could also be added and shared. Notes could be written on educational video clips. Presentation tools included with the interactive whiteboard could be used to enhance learning materials and showcase student presentations. A screenshot of the IW condition is presented in Fig. 1.

The IW condition included a form of groupware that enabled team members to collaborate for writing purposes by making collaborations and communication visible (Bell, 2000). Students in the TW condition and the CG communicated their ideas and arguments for writing. The teacher in the TW condition added this information to the whiteboard or used a computer as each team verbalized their main points. The teacher in the CG condition verbally summarized each team’s main ideas.

Each writing lesson lasted an hour (see details in Table 1). In the IW condition, the teacher and students used the board as they went through each step of the writing process during a lesson. The instructor introduced the writing topic at the beginning of each lesson (about 10 min) followed by writing practice (about 30 min), during which five students became a team and used the whiteboard to brainstorm ideas for the essay. They considered various prompts to get started with the writing assignments. As students worked on essays, they shared ideas and offered suggestions on how to improve their writing with an emphasis on elaboration. The final course component involved reflection (about 20 min), during which each team used the board as a shared space for editing and improving their work after drafts were completed. The teacher also displayed one or two papers using the main computer. Students discussed the strengths of the compositions and suggested revisions that could be made immediately on the board. Before the lesson, students completed a 90-min session to familiarize them with interactive whiteboard technology. Support for students in the IW condition involved the use of interactive whiteboards, through which students could receive online feedback from peers and teachers. Students’ feedback focused on writing topics, and teachers’ prompts concerned how to regulate writing (e.g., “What is the writing task about?”,” What is the rationale for making an argument?”), “What are the similarities and differences between the task at hand and tasks that I have completed in the past?”, and “How can I provide reasons and support them with examples?”). Such scaffolds, aimed at improving students’ writing skills, could potentially benefit collaborative writing.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Tools</th>
<th>Procedures</th>
<th>Sessions</th>
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<tbody>
<tr>
<td>IW</td>
<td>Ebeam, interactive whiteboard, laptop, video projector, a word-processing program, informational CDs, informational databases, and the internet.</td>
<td>The instructor introduced the writing topic (about 10 min). The students completed writing practice (about 30 min), during which five students formed a team and used the interactive whiteboard to exchange and brainstorm ideas. The students finally reflected on their writing practice (about 20 min), during which each team used the whiteboard as an online shared space for editing and improving their work.</td>
<td>Five weeks, with two sessions per week</td>
</tr>
<tr>
<td>TW</td>
<td>Computer, overhead projector, and traditional whiteboard.</td>
<td>The instructor introduced the writing topic (about 10 min). The students completed writing practice (about 30 min), during which five students formed a team. The students finally reflected on their writing practice (about 20 min). Writing instruction was based on teachers’ modeling through computer, projector, and traditional whiteboard. Discussion and sharing of ideas were in traditional classroom instruction.</td>
<td>Five weeks, with two sessions per week</td>
</tr>
<tr>
<td>CG</td>
<td>Chalkboard</td>
<td>The instructor introduced the writing topic (about 10 min). The students completed writing practice (about 30 min), during which five students formed a team. The students finally reflected on their writing practice (about 20 min). Writing instruction was based on teachers’ modeling through chalkboard. Discussion and sharing of ideas were in traditional classroom instruction.</td>
<td>Five weeks, with two sessions per week</td>
</tr>
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</table>
Students in the TW and CG conditions received the same instructional content as those in the IW condition. In the TW condition, teaching and learning were conducted using a main computer, overhead projector, and traditional whiteboard. In the CG, only a chalkboard was provided. Class discussion and sharing of ideas were encouraged in traditional classroom instruction. The teacher in the TW condition also displayed one or two papers using the main computer, whereas the teacher in the CG verbally explained one or two papers. Printed materials were handed out to students during class.

3.4. Tools

3.4.1. Pre- and post-writing tests

The pre- and post-writing tests were intended to evaluate the development of participants’ writing proficiency over the instructional period. Both the pre- and post-tests were measured at the individual level despite the study’s focus on collaborative writing; this approach aligned with EFL writing test requirements in China. Pre- and post-tests were internal writing tests modeled after the International English Language Testing System (IELTS). Each test included two parts: writing a summary in response to a graph (i.e., bar, line, or pie graph), table, chart, or process; and writing an argumentative essay. Two experienced raters, who were not members of the course-teaching faculty, were invited to mark the tests. The marking scheme for each test included five components: content, organization, punctuation, word choice, and grammatical accuracy. The total possible score per essay was 15 (three points per component) with a maximum of 30 points possible per test. Following IELTS requirements, the lengths of the summary and argumentative essay were roughly 150 and 250 words, respectively. Cronbach’s alpha values for the pre- and post-tests were 0.81 and 0.79, respectively, indicating acceptable reliability.

The raters held a meeting to arrive at a consensus regarding the scoring system prior to marking tests independently. In addition, the raters were not informed whether essays were from pre- or post-test situations. A third and equally experienced rater was appointed to rate the tests owing to scoring differences between the raters. Discrepant scores on test items were determined by majority opinion. For example, for one essay, the first rater awarded 1 point each for content, organization, punctuation, word choice, and grammatical accuracy; whereas, the second rater awarded 1.5 points for the same components. The third rater awarded 1 point for content and organization and 1.5 point for the other three components. Thus, the final...
number of points awarded for content and organization was 1; points awarded for punctuation, word choice, and grammatical accuracy were 1.5. In pre-test scoring, 30 discrepancies were observed out of 600 markings (5%). In post-test scoring, 35 discrepancies were observed out of 600 markings (5.8%). The final scoring scheme was considered reliable due to high inter-rater reliability.

3.4.2. Metacognitive activities and patterns of co-regulation

Records of discourses collected during the cooperative learning process were analyzed for evidence of metacognition and co-regulation. Qualitative analyses supplemented the evaluation of writing performance (i.e., based on quantitative data from the writing tests). The coding scheme for measuring metacognitive activities and patterns of co-regulation was based on Lajoie and Lu (2012). It included six superordinate categories of metacognition: planning, executing, monitoring, evaluation, orientation, and elaboration (Lajoie et al., 2015). Within each superordinate category, Meijer, Veenman, and van Hout-Wolters (2006) described a taxonomy of more specific activities. The focus of all superordinate categories in the present study was on types of metacognitive activities observed in writing tasks. Sub-codes unrelated to the specific writing situation were eliminated. For instance, Meijer et al. (2006) identified one task’s planning activity as “looking for particular information in the text.” Because writing tasks in the present study did not involve a text, this category did not apply and was thus revised to “looking for particular information in the writing task.” Coding definitions and examples reflecting them can be found in the Appendix.

Each transcript was coded for metacognitive activity, and the unit of analysis was a speaker turn. Each speaker turn that demonstrated more than one type of metacognitive activity was coded more than once. The frequency of planning, executing, monitoring, evaluation, orientation, and elaboration activities, as well as the sum of turns demonstrating one or more types of metacognitive activity, was calculated per protocol. These frequencies were then converted into percentages for convenient comparison. To calculate the percentage of overall metacognitive activity, the total number of coded turns was summed and divided by the total number of turns in the transcript. To calculate the percentages of metacognitive activity types, the sum of each type was divided by the total number of coded types in the transcript. The three groups were then compared in relation to their percentages of metacognitive activities and percentages of six superordinate metacognition types. Discourse patterns representing logical sequences of metacognitive activities and co-regulation were verified through peer checking; in other words, two L2 researchers familiar with studies of metacognition were invited to validate and ensure the trustworthiness of the analyzed data.

The two raters were invited to code the protocols independently for each condition for the six main metacognitive activities. Cohen’s kappa statistic suggested high inter-rater agreement on the metacognitive types ($k = .681, p = .031$; approximately 76% agreement). Chan’s (2012) stance on co-regulation was included in analysis segments (e.g., content and social interaction dimensions). These discourses reflected the degree of co-regulation as metacognitive activities were verbal acts shared among team members. Cohen’s kappa coefficient ($k = .592$) suggested high inter-rater agreement on co-regulation. Disagreements were resolved through negotiation.

3.5. Procedure

This study lasted 5 weeks at 2 h per week. The time allotted for completing the post-test was 60 min. During week three of the study, audio and video records of discourse during the summary and argumentative essay writing activity were collected to characterize and compare student metacognition and co-regulation among the three groups as students became familiar with each other. The researcher observed six writing lessons for each group and spoke briefly with the trainer and teacher after each observation. This check-in ensured that each respective instructional approach was consistent with the research design.

In terms of writing performance, one-way ANOVA was performed on students’ pre-test scores, and a repeated-measures ANOVA was performed on post-test scores. Discourse analysis was used to detect metacognitive activities and co-regulation patterns among the three groups (Lajoie & Lu, 2012). Writing scores were based on individual pre- and post-tests. Qualitative data included utterances during group work.

4. Results

This section includes three parts. The first part pertains to the ANOVA results for writing achievement. The second part summarizes learners’ metacognitive activities demonstrated during collaborative writing. The third part documents patterns of co-regulation during collaborative writing.

4.1. Writing achievement

Table 2 lists the mean scores, adjusted mean scores, and standard deviations of writing performance by time and condition. The mean scores represent average individual scores. On the pre-test, the IW group achieved a mean score of 15.55 out of 30 points, whereas the TW group earned a mean score of 15.95 and the CG attained a mean score of 15.92. On the post-test, the IW group achieved a mean score of 25.25 out of 30 points, whereas the TW group earned a mean score of 21.12 and the CG attained a mean score of 18.45. The one-way ANOVA results did not indicate significant differences between the groups prior
to the study: $F(2, 117) = 1.538, p = .083$. However, based on repeated-measures ANOVA, significant differences emerged between treatment groups at the end of the study: $F(2, 117) = 370.892, p < .001$, partial $\eta^2 = .75$. Post hoc pairwise comparisons indicated that students in the IW group significantly outperformed the TW group ($p < .05, d = .89$) which, in turn, significantly outperformed the CG ($p < .05, d = .95$).

4.2. Metacognitive activities

Table 3 presents the percentages of metacognitive activities among groups. Although all three groups participated in metacognitive activities, the IW group exhibited a greater percentage (44.8%) of activities than the TW group (27.2%), and the TW group exhibited a greater percentage than the CG (13.3%). Overall, learners exhibited the highest percentage of planning activities (11.2%), followed by monitoring (5.7%), executing (5.1%), orienting (3.5%), evaluating (1.9%), and elaborating (1%).

According to Table 4, the patterns and session times of metacognitive activities varied. The three groups were examined in terms of the distribution of metacognitive activities in which learners engaged early in, in the middle of, or toward the end of sessions. In the early stages of writing, the IW teams engaged in substantially more planning (27.1%), orienting (8.6%), and strategy execution (5.1%) than the TW teams, who participated in more planning (23.3%), orienting (3.1%), and executing (4.5%) than the CG teams (planning: 12.9%; orienting: 1.2%; executing: 3.5%). During the middle stage of writing, the IW teams engaged in substantially more monitoring (17.6%), planning (12.6%), executing (11.2%), and orienting (10.1%) than the TW teams (monitoring: 10.7%; planning: 6.2%; executing: 7.7%; orienting: 5.1%). The CG teams exhibited low levels of monitoring (4.1%), planning (4.1%), executing (5.6%), and evaluating (0.2%). During the late stage of writing, the IW teams engaged in substantially more monitoring (10.9%), evaluating (7.5%), executing (5.1%), and planning (8.6%) than the TW teams (monitoring: 4.1%; evaluating: 3.9%; executing: 3.1%; planning: 4.1%). The CG teams exhibited smaller proportions of monitoring (2%), evaluating (2.1%), planning (1.9%), and executing (0.2%).

4.3. Patterns of co-regulation

In this study, co-regulation is conceptualized as interactions between two or more peers who coordinate self-regulated writing processes. Co-regulation indicates that learners can apply strategies or knowledge internalized through teamwork to manage writing tasks. Several examples from the three groups illustrated different forms of co-regulation, thus improving understanding of learners’ awareness of metacognitive activities (e.g., planning, monitoring, and evaluating their writing). The qualitative analysis revealed differences in co-regulation across groups. The following examples are excerpts from groups and illustrate types of co-regulation learners used as they processed and managed their writing. As the learners tended to apply strategies learned through teamwork to co-manage the writing tasks, such activities were labeled co-regulation. The three selected excerpts were typical examples in each condition. To some extent, they were also representative of the other seven groups in the same condition. Although students were allowed to discuss writing activities among themselves, they occasionally halted their cooperative learning when problems arose during discussions, particularly in the CG. For instance, Students A and B had different plans when looking for information from a table; Student B told Student A to check the title, but Student A suggested that nothing could be written if the table information was not understood. The teacher (T) intervened accordingly.

Excerpt 1 (CG).
A: I think the information for this table is quite misleading.
B: Look at the title here, “Water consumption in two different countries.”
A: Yes, I have read it. But how do we find the information for our writing?

Table 3
Percentages of metacognitive activities by group.

<table>
<thead>
<tr>
<th></th>
<th>Execute</th>
<th>Elaborate</th>
<th>Evaluate</th>
<th>Monitor</th>
<th>Orient</th>
<th>Plan</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>IW</td>
<td>7.1%</td>
<td>2.1%</td>
<td>3.2%</td>
<td>9.8%</td>
<td>6.5%</td>
<td>16.1%</td>
<td>44.8%</td>
</tr>
<tr>
<td>TW</td>
<td>5.1%</td>
<td>0.8%</td>
<td>1.7%</td>
<td>5.2%</td>
<td>3.2%</td>
<td>11.2%</td>
<td>27.2%</td>
</tr>
<tr>
<td>CG</td>
<td>3.1%</td>
<td>0.2%</td>
<td>0.8%</td>
<td>2.1%</td>
<td>0.8%</td>
<td>6.3%</td>
<td>13.3%</td>
</tr>
<tr>
<td>Overall</td>
<td>5.1%</td>
<td>1%</td>
<td>1.9%</td>
<td>5.7%</td>
<td>3.5%</td>
<td>11.2%</td>
<td></td>
</tr>
</tbody>
</table>
Students A and B had a brief discussion after the teacher’s instructions and held different opinions about their writing. The same pattern occurred when Students A and B talked about how to write arguments. Using a co-regulation framework, evidence of explanations or ideas was not apparent; individuals came up with ideas independently, but the ideas did not reflect sound arguments. Evidence of elaborating, interpreting, reasoning, building on ideas, explaining in one’s own words, or helping identify thorough information was also not observed. Even though each group contained multiple members, verbal contributions were limited, as were social regulation and co-regulation. Similar patterns appeared in the other writing episodes. Overall, learners did not engage in spontaneous discussion, and the teacher often needed to intervene.

The TW discussions involved fewer teacher interventions. More students shared their opinions. Learners also collaborated on various grammatical points, but discussions were quite brief. See below for an example.

Excerpt 2 (TW).
A: Because of media influence, sports professionals are paid good salaries. They become stars.
B: Ah ha, sports professionals have become stars. We need to use “have become,” right?
A: Do we need to highlight “in my country”?
B: I don’t think we need it.
C: Mmmm.
B: What about “those at the top are paid huge salaries”?
A: Great.
D: Mmmm.

In this excerpt, Students C and D did not provide in-depth explanations. Students A and B deliberated and sought confirmation for their choices, corrected each other, and at times provided explanations for why a particular form should or should not be used. For example, Student B recalled that the present perfect tense should be used to indicate that attention given to sports professionals was caused by the media. Student B also recalled that the phrase “at the top” related to “those” and suggested a better adjective, “huge,” to replace “good.” To a certain extent, working in pairs in the TW condition provided learners more opportunities to evaluate their language use and pool their knowledge for better writing accuracy. Students A and B possessed personal strengths. After re-reading their joint essay, they re-evaluated on syntax and suggested more sophisticated expressions.

The IW learners demonstrated more turn taking and contributed more equally to the exchange of ideas. The teacher was seldom involved in pushing the students to collaborate. Ideas from annotations prompted the learners to work together. The following excerpt exemplifies how the learners demonstrated co-regulation during a writing activity.

Excerpt 3 (IW).
A: OK … actually, that’s fine. Just change it to “The media pressure is intense, and privacy is a concern under the spotlight.”
B: Here, “This may justify the huge earnings.” It’s too plain. Just the pressure and a little privacy does not justify that they should get huge money, right?
C: I think we have annotated a lot on the topic. Why don’t we return back to our annotations?
D: Yes, I have noted some here. “Talent,” “dedication to the society,” “bring fame to the country.”
B: Great. We can make several sentences with the annotations and then state that “These factors may justify the huge earnings.”
E: I have also highlighted some annotations on my computer. I think you guys should have noticed my highlights on your computer. Check here. “Society places value on sport.”
A: Right, I have also added “more than on other essential professions and achievements.”
E: The teacher asked us to think about the similarities and differences between the task and tasks that we have solved in the past. I think it is closely related to the argument in the last task, “The advantages and disadvantages of being a celebrity.”
Some expressions, like “it is commonly thought that,” “drawbacks,” “beyond any doubt,” “lack of intimacy, lack of free time,” can still be used.

A: Right.

In this excerpt, Students A, B, and E mentioned the annotations made on their computers or whiteboards. They then attempted to evaluate and incorporate this information into their writing. Pair work conferred clear advantages: Student A initiated the conversation; Student B offered alternative expressions and suggested more information; and Students C, D, and E pointed out a wider range of arguments and expressions by referencing the annotations and highlights. Throughout their interactions, the learners read the annotations and elaborated on possible arguments for the writing. Hence, these discourses revealed co-regulation built on previous annotations, interpreted in a way that led to elaborate arguments about why sports professionals should earn generous salaries. Multiple participants were involved, and learners tended to share information through technology. This pattern exemplified collaborative argumentation, showing that team members in the IW condition were engaged in the activity. Annotations made in the learning environment provided students with chances to monitor, evaluate, and reflect on their written notes. Consequently, learners in this condition conducted dynamic role-plays during which they consulted and referred to previous tasks; as such, they became more open to others’ opinions or ideas and finalized their intended writing output more elaborately.

5. Discussion

Overall, findings supported the IW condition, a real-time communication environment with procedural facilitation, from which team members received scaffolds to work synchronously and collaborate while learning (Bell, 2000; Yeh et al., 2011). By employing a mixed method, this study revealed a potential effect of the technology-supported interactive whiteboard condition on writing achievement, wherein learners exhibited more metacognitive activities and co-regulation patterns during collaborative writing.

Students in the IW condition outperformed the TW and CG groups in writing performance. These results suggest that scaffolds using interactive whiteboard technology could be beneficial to EFL students’ writing performance. In the IW condition, learners may have received more scaffolds (especially the annotation tool and support from the teacher and IW trainer) than students in other groups. These learners could then share expertise and exchanging feedback may have enabled group members to assume a collective responsibility for helping each other develop regulatory skills. Interactive feedback among students, which was an advantage of the IW condition, could also help students develop new strategies or modify existing ones while collaborating with peers on joint writing tasks. Exchanging feedback could inspire the learners to evaluate their own and each other’s performance as well, leading to self- and co-regulated processes (Kim & Lim, 2019; Li & Kim, 2016). Students’ engagement in self- and peer evaluations may be conducive to a cooperative setting in which learners “treat evaluations as opportunities to deepen understanding and share/refine regulatory strategies” (DiDonato, 2013, p. 40). These findings thus highlight the potential benefits of organizing writing activities through interactive whiteboards.

As a medium, interactive whiteboards appeared to offer certain scaffolds compared to using a traditional whiteboard and collaborative writing without a whiteboard. Providing scaffolds seemed to support student writers in enhancing writing performance (Bell, 2000). An important element of scaffolding is the gradual release of responsibility to students who are expected to internalize skills and thinking that are modeled and prompted by a more knowledgeable resource; eventually, these learners will require fewer or no supports (Benko, 2013). The interactive whiteboard used in the present study could engage students in helpful thinking and idea generation by encouraging them to assume different viewpoints to develop ideas for writing. Referring to sociocultural theory (Lantolf & Poehner, 2014), peer interaction may help learners co-construct contexts because the collaborative construction of opportunities can enhance their capacity to think about and take control of the learning process (Storch, 2005). In line with Yeh et al. (2011), technology-supported collaborative writing can also help English learners with systematic yet dynamic and rhetorical engagement with English writing. For example, learners could be encouraged to compose or edit their writing, create team agendas and plans, participate in team brainstorming, devise shared outlines, and co-produce articles.

Given the advantages of the IW condition, learners were better able to plan, discuss, and review the writing process in a collaborative setting. When switching to collaborative writing, the IW condition facilitated participants’ adoption of writing strategies that could “lead [to] cognitive functions that are newly emerging, and prompt routines and processes in a timely way” (Englert, Zhao, Dunsmore, Collings, & Wolbers, 2007, p. 11). Team members pooled their linguistic knowledge, tracked the writing process, and decided on a process for aligning strategies or corrective feedback to create the intended writing output (Storch, 2017; Teng, 2016). Hence, learners in the IW group produced significantly better written products than those in the TW and CG groups.

Examining the types and timing of metacognitive activities across groups revealed that technology-supported cooperative learning boosted learners’ metacognitive awareness. Findings also indicated that planning and orienting was required for successful action execution (e.g., Lajoie et al., 2015), and strategy execution contributed substantially to writing outcomes (Teng, 2016, 2020a). Overall, in the early stages of writing, participants in the IW group devoted more effort to interpreting the writing situation (e.g., determining planning activities, orienting the writing process, and executing appropriate writing strategies). During the middle stage, these participants focused more on monitoring, orienting, and executing their writing process. In the later stage, once the writing situation became more urgent, students in the IW group paid more attention to
managing the writing product than interpreting the situation; for instance, teams spent more effort evaluating their written products.

Participants in the TW and CG conditions spent less time on related metacognitive activities in each stage compared to the IW condition. This finding could partially explain why learners in the IW condition were more aware of when to plan, orient, execute, monitor, and evaluate their writing process. Interestingly, students in the CG condition made no noteworthy progress whereas students in the other two conditions did. In terms of the underlying mechanism, students in the TW condition achieved better scores on the post-test compared to the pre-test. The patterns of their metacognitive activities were extremely similar. Students in the TW condition also appeared to engage in more metacognitive activities that enabled them to seek a consensus about what they did or did not know. These findings suggest that traditional whiteboard instruction could have inspired metacognitive activities and yielded co-regulatory actions when students discussed writing strategies and exchanged ideas with peers.

Findings also identified differences in co-regulatory actions between groups. For example, the presence of orienting dialogue in the IW condition implied that IW learners were helping their peers activate prior knowledge; establish task demands; carefully examine writing strategies; and hypothesize, identify, and repeat established frameworks. These students determined which scaffolds (e.g., annotations) were beneficial to their writing. Khosa and Volet (2014) asserted that the co-construction of high-level knowledge is greatly desirable in peer learning, in which learners are required to identify individual and contextual aspects that might contribute to group engagement. In response to this knowledge, the IW group learners interacted dynamically with the writing process because they could share information face-to-face as well as through their connected laptops and whiteboard where they were free to highlight their arguments, make additions, and read and reread annotations at any time (Lajoie et al., 2015). Learners therefore self-regulated their own process of learning to write, co-regulated others’ writing practices, and became aware of what group members did or did not understand. With scaffolds from peers, they co-regulated their writing process and changed arguments to suit their needs, thus supporting early metacognitive activities of planning and orienting so they could proceed to subsequent metacognitive activities of evaluating. This finding is in line with previous studies (e.g., Greene & Azevedo, 2009; Schraw, 2007), in which co-regulation processes affected collaborative inquiry and determined self-regulatory processes that were related to writing outcomes. This pattern might explain why students in the IW condition performed best on the writing test.

Several theoretical considerations arose from these findings. Metacognitive regulatory processes in planning, monitoring, and evaluating learning content initially led to writing execution (Lajoie et al., 2015; Teng & Huang, 2019). The most dominant metacognitive activities—planning, orienting, monitoring, and evaluating—are necessary throughout a collaborative writing process. The stages of co-regulation, spanning forethought, execution, self-reflection, and adaptation, were associated with collaborative writing outcomes. Co-regulation may also help learners recognize, refine, and modify inconsistencies in their use of regulatory strategies, leading to stronger self-regulated writing practices. Interactive whiteboard technology can lead to productive writing outcomes due to greater awareness of metacognition and co-regulation; in essence, these whiteboards enable learners to communicate, make inferences and predictions, and arrive more quickly at an understanding of writing.

6. Concluding remarks

Overall, the present study provides support for better writing achievement, higher levels of metacognitive activities, and co-regulation in a quasi-experimental, time-framed collaborative writing condition supported by interactive whiteboard technology. Learners in the other two conditions, in which interactive whiteboards were not provided, demonstrated less improvement in writing performance, lower levels of metacognitive activities, and less engagement in co-regulation. Group differences in writing performance were linked to discrepancies in metacognitive activities and co-regulation processes.

Several limitations tempered our findings. First, relevant research has argued for different methods and units of analysis when examining co-regulation (Chan, 2012). For this study, each utterance within all episodes was coded for a specific task, which may be insufficient for identifying high-level co-regulatory processes. Varied approaches are needed to examine individuals and teams as entities (e.g., how group-level processing may be connected to individual processes and writing achievement). Second, the nature of co-regulation, with its similarities to and differences from self-regulation, was not analyzed. Third, five students randomly formed each team for this study; some learners may not have been familiar with each other, which could have affected their performance and cooperation. Fourth, the pre- and post-test measures assessed two skills and products, namely a summary and an argumentative text. Future studies can measure whether the scaffolds in each condition might exert different effects on the collaborative texts written by the students. Finally, participants in this study only included Chinese students; similar results may not apply to learners in other contexts.

Despite these limitations, the present study provides recommendations for future research. First, the findings underscored the importance of guiding learners’ co-regulation of metacognitive activities (Schraw, 2007). These results also emphasized the importance of social dynamics and a group as an entity in classroom instruction. Future studies can further explore the nature and types of metacognitive activities and how they influence writing. Second, findings from the present study suggest allowing more time for planning, orientation, monitoring, and evaluating, all of which are prerequisites to developing an understanding of a writing task and building common ground to initiate appropriate writing strategies. Future studies could adopt a qualitative approach to explore learners’ interpretation of their planning, monitoring, and evaluating behaviors during collaborative writing. Third, interactive whiteboard technology provided a communal place to display learners’ explicit ideas and help students regulate their thoughts. These factors are essential in learning to write because such tools can
help learners capture, synthesize, examine, and interpret dynamic collaborative writing processes. Future studies can explore the various individual and group factors that may influence how learners interact in the online collaborative writing context. Finally, the interactive whiteboard was a very useful tool for collaborative writing. However, the technology did not automatically lead to all participants taking a collaborative approach. Future studies could explore how various factors, such as the motivation, use of strategies, and the perception of the technology, mediate learners’ interactive whiteboard-based collaborative writing outcome.

Author statement

This article is completed by a single author. The author is responsible for ensuring that the descriptions are accurate. This article has not been published in English or any other languages before, and it is not under consideration for publication in any other journals. I, as the author, hereby agree to transfer all rights to the publisher.

Declaration of competing interest

The author declares that he has no conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.system.2020.102426.

References
