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Research on personalized support model of constructivist learning environment based on metacognitive modulation

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Abstract Inadequate writing skills prevent learners from improving their writing performance and interfere with their subsequent writing performance in real-life scenarios. This study aimed to analyze the effect of metacognitive regulation on authentic writing performance in a web-based constructivist learning environment. The environment maximized the presentation of authentic writing problems that learners faced in their studies and lives. The study used random cluster sampling to draw samples for a single-group pre-test and post-test experiment with 45 students. After that 45 students experimented around two authentic writing topics. The researchers used repeated measures ANOVA to assess the results of the learning achievement data, showing that there was no significant difference between pretest 1 and pretest 2. Posttest 1 and posttest 2 were significantly higher than pretest 1 and pretest 2. In addition to this, the researchers measured the use of metacognitive regulation to intervene in authentic writing learning through metacognitive interviews (process evaluation). The researchers collected and analyzed interview data from the 45 participants mentioned above. The results of the analysis of the metacognitive regulation interview data were consistent with the participants' learning performance. From the interview transcripts, it was clear that participants perceived metacognitive regulation significantly contributed to authentic writing learning performance. A limitation of the study is that the group of participants in the experiment were all grade 10 students, and the experiment was not conducted among learners of different ages and experiential backgrounds.

Index Terms Metacognitive Regulation, Authentic Writing, Constructivist Learning Environment, K12, Instruction Design

I. Introduction

Writing is an extremely important skill for people, whether it is in study, life or work scenarios [1]. Mastering writing, however, is a demanding process that requires structured guidance, practice, and the ability to think critically and reflectively [2]. Poor writing skills not only prevent learners from improving their academic performance, but also interfere with their subsequent relevant job performance [3]. Unlike speaking, which often develops naturally, writing requires deliberate cognitive engagement, including planning, organizing, and revising ideas, which makes it especially challenging for students [4]. Likewise, in China, writing teaching is also often neglected, teachers don't using a constructivist approach to organize writing learning and writing learning detached from learners' real life. Ever since, students lack the motivation to write, don't have the materials to write, and don't have skills to write well (Development Report on Chinese Language Education in China, 2021-2022). Due to learners' negative attitudes towards writing learning, few students will use metacognitive regulation (orientation, planning, monitoring, evaluation) during the writing learning process. Students struggle with learning to write, and their writing skill still in the lower level (Development Report on Chinese Language Education in China, 2021-2022). Obviously, Clearly, the development of writing skills depends on the ability of learners to think clearly about substantive issues, in addition to teaching the basics of writing.

The facilitating effect of metacognition on writing learning has been verified from multiple perspectives. Some recent studies corroborate the central role of metacognitive regulation in writing. In English writing learning, students with strong metacognitive ability have good self-regulation learning ability, which enables learners to set reasonable writing goals, plans, and strategies to improve their writing ability [5]-[9]. Unfortunately, however, almost all of these studies have focused on the EFL (English as a Foreign language Learners) group.

In addition to this, the researchers' pairs have also tried to change the way writing is learned from innovative writing genres and approaches, such as using metacognitive moderation in science writing [10]; experimenting with metacognitive training for peer-to-peer assessment, and exploring the impact of metacognition on writing learning.

Despite the well-documented benefits of metacognitive regulation, there is a significant gap in its systematic integration into online constructivist learning environments to support authentic writing. While many educational

programmes promote collaborative learning and authentic tasks to facilitate metacognitive reflection self-regulation. This inconsistency could hinder students' ability to engage deeply in writing and limit their potential for self-directed learning. Further research is also needed on how metacognitive strategies can be explicitly taught, supported and assessed in web-based constructivist contexts in order to maximise their impact on writing achievement. Addressing this gap is critical because integrating metacognitive regulation into a web-based constructivist framework can greatly improve the efficiency of the writing process. By creating an environment in which students actively plan, monitor, and evaluate their writing, educators can improve students' writing skills and overall learning outcomes. This approach is consistent with modern educational goals to equip students with essential skills for lifelong learning and positions writing as a dynamic, reflective process that is critical to developing writing competence.

This study is a pre-experimental study to verify whether metacognitive regulation has a significant facilitating effect on authentic writing performance in a web-based Constructivist Learning Environment model in the following two objectives:

1) To examine whether the use of metacognitive regulation has had an impact on the content, structure, and quality of essays, by assessing the outcomes of authentic writing learning.

2) To investigate learners' use of metacognitive regulation in the writing learning process, through semi-structured in-depth interviews.

II. Literature review

II. A. Metacognitive regulation on writing learning

Since Flavell (1979) suggested that metacognition contributes to writing learning. There have been many studies conducted by researchers around the two core elements of metacognition: metacognitive knowledge and metacognitive regulation [11]. In recent years, the facilitation of metacognitive regulation for academic writing has gradually been brought to the attention of researchers. Their studies focused on the EFL (English as a Foreign Language learners) population. Linda Allal's (2015) study drew a positive correlation between metacognitive regulation skills and writing performance by analyzing the textual shifts student writers make between successive versions of their texts (notes, drafts, final versions). Teng 's (2019) empirical study further confirmed the mediating role of metacognitive moderation on university EFL learners' writing performance. The results of Teng 's study suggest a positive and significant relationship between metacognitive knowledge and regulation and between metacognition and writing performance. Based on these results, metacognition should be a useful tool for developing writing-related skills and qualities. These findings support the central role of metacognitive regulation in writing (Teng & Huang, 2018). Sumarno et al. (2021) investigated the correlation between students' writing ability with cognitive knowledge and cognitive regulation. The results showed that metacognitive regulation influenced English writing ability to a high extent of 82.2%. Thus, in English writing learning, students with strong metacognitive ability have good self-regulation learning ability, which enables learners to set reasonable writing goals, plans, and strategies to improve their writing ability. In addition to the studies mentioned above, Van Opstal and Daubenmire (2015) and Bui and Kong, (2019), analyzed the facilitation of metacognition for other types of writing. A study by Mary T. van Opstal and Patrick L. Daubenmire (2015) explored the use of science writing heuristics (SWH) in an experimental classroom. The experiment demonstrated that both peer collaboration and metacognitive regulation can help solve open-ended experimental problems. Bui, G., and Kong, A. (2019) study also concluded that metacognitive training interactions in peer review helped to change the perceptions of these young learners and improve their writing.

Overall, the above study demonstrated the facilitating effect of metacognitive regulation on writing learning. And it proves that learners' collaborative learning approach is more conducive to the effectiveness of metacognitive regulation in enhancing writing learning. Unfortunately, the above studies mainly focus on academic writing learning in a second language, and there is no authentic writing learning based on students' mother language to cope with real-life needs. Learning methods are also mostly traditional writing learning methods (teacher lectures, students writing with pen and paper) and simple group collaborative learning methods. Teachers didn’t create a web-based constructivist learning environment that is conducive to students' collaborative learning. In terms of the study population, most of the participants were college students or junior high school students, and there was no experimental group of students at the high school level. This study is different from the above studies in that it bridges the gap of using online technology to construct authentic writing problem situations, allowing learners to use metacognitive regulation to solve authentic writing problems that they may encounter in future learning, life and work scenarios, and to enhance learners' ability to solve authentic writing problems. Constructivist learning environments maximise student engagement and collaborative learning patterns, which are more conducive to metacognitive regulation.

Previous researchers have noted several elements about metacognition, such as metacognitive strategies, metacognitive awareness [12], [13], metacognitive knowledge and self-regulation facilitates writing but is limited to domain-specific writing learning, and once removed from the classroom environment, the transferability of writing skills is difficult to ensure. More importantly, problems in real-life situations are far more complex than writing training, and traditional writing classroom training provides learners with a relative dearth of problem-solving support cases. Therefore, this study developed a constructivist learning environment that incorporated the concept of metacognitive conditioning to build real-life writing problem situations. The model aims to integrate metacognitive regulation into a web-based constructivist learning environment, allowing students to contextualize the breaking of cognitive equilibrium in a real-life problem situation. Students can proactively complete knowledge construction and contextualize mental development through online learning resources, collaborative learning activities, and scaffolding support, thus enhancing learners' authentic writing performance.

II. B.Authentic writing and authentic writing learning performance

Authentic writing is a learning process of writing based on real task situations, with real writing motivation and emphasis on a real object of writing communication [14]-[15]. Real task situations are the contexts in which students engage in real-life writing learning, which originate from or simulate the real-life world and provide learners with the opportunity to engage in real-life or simulated tasks directly [16]. Real writing motivation refers to the learner's desire to write based on desire to write based on real task situations [17]. The real object of writing communication refers to the reader in a real task situation, who indirectly influences the author to create the article's tone style, and content.

There are five steps to the authentic writing process: prewriting, outlining, drafting, revising, and publishing or sharing. 1) In the prewriting step, students analyze the information in the task instructions by reading, brainstorming, researching, gathering and outlining ideas. 2) In the outlining step, students can organize their ideas of task instructions into a list in a logical and coherent order. They can make hierarchy and structure of essay by profound planning. 3) In the draft step, students create a draft based on the outline. 4) In revising step, students try to improve their drafts. 5) After students get the final writing version, they get feedback from teachers, peers, and readers who they are communicating with in real task situations and evaluate the writing learning outcomes [18].

Assessment of learning performance in authentic writing also differs significantly from traditional writing. Authentic writing emphasises the need for writing learners to engage in authentic writing problem situations, solve authentic writing problems, and receive authentic reader feedback. Therefore, assessment of authentic writing performance should involve teachers, peers, and readers. Teachers, peers, and readers must check the correctness of the writing content and structure, completeness of the writing structure, and the effectiveness of the writing strategies. When students get feedback from teacher, peer, and reader, students can evaluate their writing learning outcomes.

II. C.The web-based constructivist learning environment

The constructivist learning environment in this study refers to a web-based authentic writing learning platform developed using constructivist learning concepts to promote metacognitive regulation. The constructivist learning environment integrated the concepts and methods of metacognitive regulation to help students learn authentic writing. Figure 1 presents a comprehensive model for a Constructivist Learning Environment aimed at enhancing metacognitive regulation in students' authentic writing skills. The model integrates both cognitive constructivist, situated learning and metacognitive regulation [19] principles, focusing on the activation of cognitive structures and regulation skills. In one corner, cognitive constructivist strategies, such as eliciting prior knowledge and presenting cognitive conflicts, are applied in an authentic context to foster metacognitive regulation. This process involves four key metacognitive steps: orientation, planning, monitoring, and evaluation, which guide students through problem-solving tasks within the 'Problem Base'. Adjacent to this, cognitive resources and models—including SOI [20], CLE [21], and Cognitive Load Theory [22]—help maintain cognitive equilibrium and structure. The 'Learning Resource Center' houses both static and dynamic resources, while models like OLEs [23] and Information Processing Theory assist in managing memory and cognitive load, facilitating structured knowledge acquisition and application in writing.

The model also incorporates social constructivist elements in another corner, such as cognitive apprenticeship [24] and scaffolding [25], which provide tailored support to enhance knowledge construction. The 'Coaching Center' offers stimulation, hints, tracking, and prototypes to facilitate learning, while the 'Scaffolding Center' includes various forms of scaffolding—conceptual, metacognitive, procedural, and strategic—to meet diverse student needs. In the final corner, the model emphasizes authentic writing processes and problem-solving skills, supported by cognitive tools. Students utilize 'Cognitive tools' to seek, organize, integrate, and communicate ideas. This process is underpinned by metacognitive regulation, enabling students to manage and enhance their writing independently. In the Collaboration Center, learners can engage in authentic writing learning with their peers, solve authentic writing

problems, and receive evaluation and feedback from their peers to improve writing outcomes. The'Enhance Metacognitive Regulation Center' is integral to supporting students in improving their metacognitive skills, enabling them to monitor, plan, and evaluate their writing strategies more effectively. Authentic writing tasks, such as expressing or explaining viewpoints, encourage students to apply their learning meaningfully, while generative learning fosters cooperative, engaged learning and critical thinking skills, as shown in Figure 1.

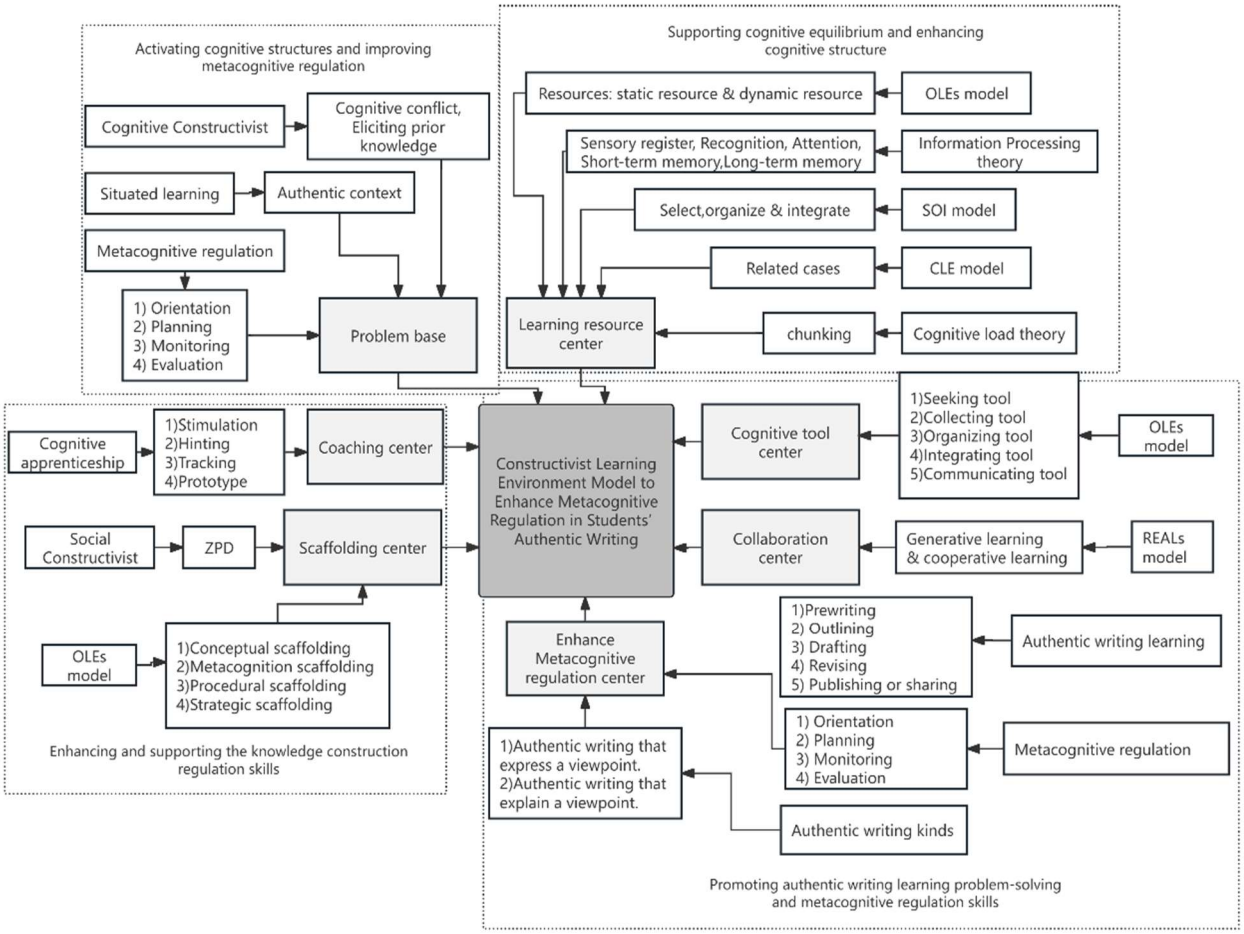

Figure 1: The seven components of the Constructivist Learning Environment Model

The theoretical framework of the Constructivist Learning Environment Model for enhancing metacognitive regulation in authentic writing has been evaluated by nine experts with more than five years of experience in model design and development. The experts agreed that the theories and principles selected for the theoretical framework of the model are beneficial for metacognitive regulation in authentic writing, for the development of students' level of metacognitive regulation, and for the construction of knowledge and improvement of cognitive structures.

III. Methodology

III. A. Research design

This study is an external validation in Phase 2 of the model design and development. The study used a mixed research methodology to evaluate the effect of metacognitive regulation on the promotion of authentic writing in terms of learning outcomes and learning process dimensions. (1) Evaluation of learning outcomes: a single-group pretest and posttest experiment was used to analyze the differences in the writing performance of the students through the collection of quantitative data (mean, standard deviation, percentage) from the authentic writing test. (2) Evaluation of learning process: the researcher also conducted post-experimental semi-structured interviews with the sample group of students Semi-structured interviews were conducted and the data analysis followed some of the key stages of thematic analysis proposed by Braun & Clarke (2006) in their seminal work as a way to understand the students' use of metacognitive regulation in the writing process [26]. The experiment aimed to (1) study students'

learning achievement scores pretest and postest learning with the Constructivist Learning Environment. (2) To examine students' metacognitive regulation on the authentic writing learning with the Constructivist Learning Environment.

III. B. Participants

Participants in the experiment were all from a public high school in Northwestern China. The region selected for the experiment has a relatively backward level of educational development and the students' writing level grades are relatively low. The students have more confusion in writing learning. All the students register in Chinese authentic writing study, 2024 academic year, first semester. 180 Grade 10 students come from 4 classrooms in a public high school, Shaanxi Province, China. In order to ensure that the sample group drawn was representative, the researcher conducted an F-test on the sample drawn before random sampling. The sample of 1 cluster students can be summarized and referenced to the population of the other 3 clusters. 45 Grade 10 students (26 males, 19 females) come from 1 cluster by using cluster random sampling (Cluster Random Sampling, N=4, n=1). They learned with the Constructivist Learning Environment.

III. C. Research instruments

(1) Authentic writing learning achievements test

The Authentic Writing Learning Achievements test is used to assess pretest-posttest learning achievement scores of Grade 10 high school students in Northwest China, who use the Constructivist Learning Environment Model to enhance the Metacognitive regulation of authentic writing learning. The Authentic Writing Learning Achievements test evaluates the outcomes of Grade 10 high school students' authentic writing learning. There are 2 writing topics on the authentic writing learning. Writing topic ①is authentic writing that expresses a viewpoint. It focuses on letting students express his/her own opinion based on his/her understanding, experience, knowledge, information, and evidence available to him/her. In addition, the material generally won't have an obvious viewpoint before students have analyzed it. Writing topic②is authentic writing that explains viewpoint. It means that students must specifically elaborate, explain, and argue for the stated view. The stated view is presented based on the material. The total score for each topic is 60 points. Students are given 60 minutes to complete each topic. These writing topics and assessment criteria are designed based on Writing Learning Quality Description (Ministry of Education of the People's Republic of China, 2017), writing framework for the National Assessment of Educational Progress (NAEP, 2017), Authentic writing theory. The topics of the Authentic Writing Test have been examined by three experts in measurement and assessment, and it has been confirmed that the instrument is useful for measuring learning achievement in authentic writing.

(2) Metacognitive regulation enhances authentic writing learning interview form

The metacognitive regulation enhances authentic writing learning interview form is used to allow researchers to assess metacognitive regulation enhances authentic writing learning process of Grade 10 high school students in Northwest China, who use the Constructivist Learning Environment Model to enhance Metacognitive regulation on the authentic writing learning. The metacognitive regulation interview form is designed based on Metacognitive regulation theory, Metacognitive writing strategies questionnaire, and Authentic writing theory. This interview form contains questions in four parts. Part 1 is orientation enhance authentic writing learning. Part 2 is planning enhance authentic writing learning. Part 3 is monitoring enhance authentic writing learning. Part 4 is evaluation enhance authentic writing learning.

III. D. Data collection

(1) Authentic writing learning achievement test

The researchers use authentic writing learning achievement test to study the differences in students' authentic writing achievement scores pretest and posttest using the Constructivist Learning Environment. The two authentic writing test topics are specified below. Topic 1 was used in the pre-test 1 and post-test 1 experiments, and topic 2 was used in the pre-test 2 and post-test 2 experiments. The teacher organize the Constructivist Learning Environment enhances metacognitive regulation on the authentic writing learning as follows (Figure 2):

1)Pre-test. In these Pre-testing, teacher uses traditional lecture methods and students use paper and pencil writing. The 45 students (sample group) complete two learning achievements test. The students will have 60 minutes to finish each test by themselves.

2)Post-test.

Warm-up activity: The teacher introduces the components and functions of the Constructivist Learning Environment and guide students to use the Constructivist Learning Environment for writing learning. Students learn the steps of authentic writing by watching an animation video and participating in some mini-games.

Writing topic 1 is same with the first pretest writing topic. However, unlike the pretest, the constructivist learning environment provides learners with authentic writing problem situations that require them to follow the prompts, solve the problem step-by-step, and complete the writing. For example, "*You are a graduate student of Fuxing High School. You need to write a letter to the freshmen, help them make plan for high school life.*"

Writing topic 2 is same with the second pretest writing topic. Different from the pretest, learners are confronted with authentic writing problem situations that require them to follow a prompt, solve the problem step-by-step, and complete the writing. For example, *"if you are participating in a debate competition, you have to write a debate paper explaining your viewpoint."*

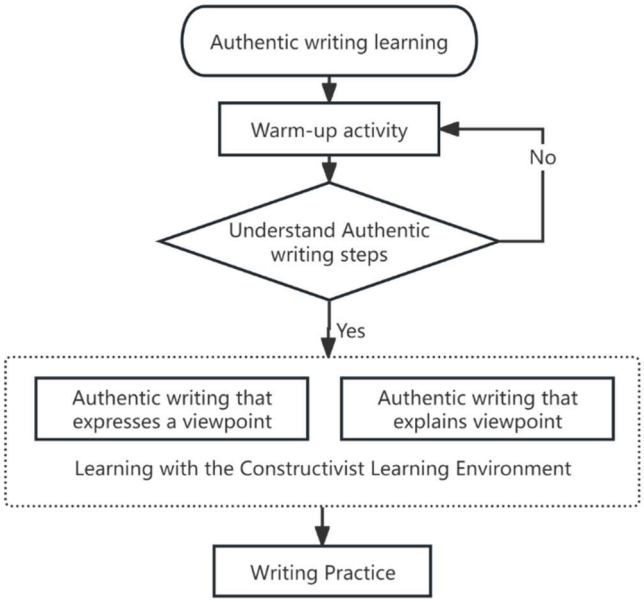

Figure 2: Authentic writing learning process

(2) Metacognitive regulation enhance authentic writing interview

The researchers use the metacognitive regulation interview form to examine students' metacognitive regulation of authentic writing promotion when using the Constructivist Learning Environment. The researchers conducted semi-structured interviews in November and December 2024, with each interviewee being interviewed for 20-25 minutes, and the interview data was recorded and stored in text format.

III. E. Data analysis

The data analysis consisted of two parts: the analysis of authentic writing learning achievement (quantitative data) and the analysis of metacognitive regulation enhance authentic writing interviews (qualitative data). In analyzing authentic writing learning achievement, descriptive statistics (means and percentages) of pretest and posttest scores of a single sample group were used. Next, a repeated measures ANOVA was conducted to perform an assessment of whether there was a significant difference between the pretest and posttest data.

Interview data analysis for metacognitive regulation was conducted using thematic analysis. The data analysis process consisted of the following six steps, 1) In the initial stage, the researcher familiarized herself with the interview data.2) Codes for initial recognition were then generated.3) Codes were merged into potential themes and all data related to each potential theme were collected.4) Themes were then examined for relevance to the coding extracts (level 1) and the entire dataset (level 2) to generate a theme for analysis "maps".5) During the analysis, the details of each theme were refined and clear definitions and names were generated for each theme.6) Finally, a summary report was completed. The codes and themes generated according to the Theme Analysis Theory are shown in Figure 3.

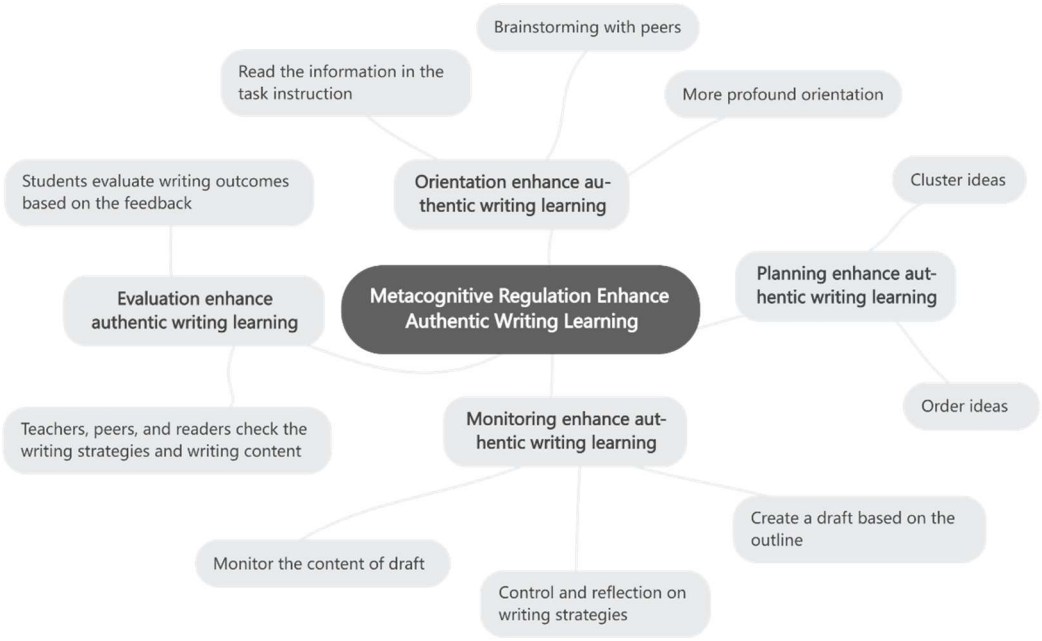

Figure 3: Coding structure of interview data on metacognitive regulation for authentic writing

IV. Findings

IV. A. Authentic writing learning achievements test

We conducted two pretest experiments and two posttest experiments. The results of the data analysis showed that the participants in pretest 1 had a mean score of 43.69 with a standard deviation of 4.28. Meanwhile, the participants in pretest 2 had a mean score of 42.84 with a standard deviation of 3.57. The participants in posttest 1 had a mean score of 46.89 with a standard deviation of 3.68. The participants in posttest 2 had a mean score of 47.04 with a standard deviation of 4.18. Participants in Posttest 2 had a mean score of 47.04, standard deviation of 4.18. Students' academic performance improved using a web-based constructivist learning environment to promote metacognitive regulation. There was a significant difference between the scores. Details are presented in Table 1.

Table 1: Descriptive Statistics of Performance on Pretest and Posttest Authentic Writing

Test	Gender	Mean	SD	Sample
pretest 1	Male	43.08	4.78	26
	Female	44.53	3.44	19
	Total	43.69	4.28	45
pretest 2	Male	42.35	4.23	26
	Female	43.53	2.34	19
	Total	42.84	3.57	45
posttest 1	Male	46.58	3.88	26
	Female	47.32	3.45	19
	Total	46.89	3.68	45
posttest 2	Male	46.46	4.56	26
	Female	47.84	3.56	19
	Total	47.04	4.18	45

A repeated-measures ANOVA was conducted to assess. The results showed a significant difference in authentic writing scores [$F(3,132)=53.520, P<0.001, \eta 2=0.549$]. Further post hoc tests revealed no significant difference between pretest 1 and pretest 2. There was no significant difference between posttest 1 and posttest 2. Pretest 1 and pretest 2 were significantly lower than posttest 1 and posttest 2. Detailed information is provided in Table 2.

Table 2: Post hoc analyses of scores on pretest and posttest of authentic writing

Test (I)	Test (J)	Mean (I-J)	SE	Pb
pretest 1	pretest 2	.884	.333	.090
	posttest 1	-3.200*	.440	.000
	posttest 2	-3.356*	.533	.000
pretest 2	pretest 1	.884	.333	.090
	posttest 1	-4.044*	.383	.000
	posttest 2	-4.200*	.420	.000
posttest 1	pretest 1	3.200*	.440	.000
	pretest 2	4.044*	.383	.000
	posttest 2	-.156	.373	1.000
posttest 2	pretest 1	3.356*	.533	.000
	pretest 2	4.200*	.420	.000
	posttest 1	.156	.373	1.000

Note b means the Bonferroni correction.

Through a series of data analysis, it can be clearly found that the learners' authentic writing scores in the post-test compared to the authentic writing scores in the pre-test were significantly improved by using the constructivist learning environment model for learning. The results of the study can prove that the metacognitive learning concepts in the constructivist learning environment have a facilitating effect on the improvement of learners' writing skills.

IV. B. Metacognitive regulation enhances authentic writing learning interview

The researcher collected and organized interview data from 45 participants. The researcher coded and analyzed the interview data based on the content of the interview transcripts and the four procedures of metacognitive regulation (Orientation, Planning, Monitoring, and Evaluation). The frequency of occurrence of thematic codes is shown in Figure 4.

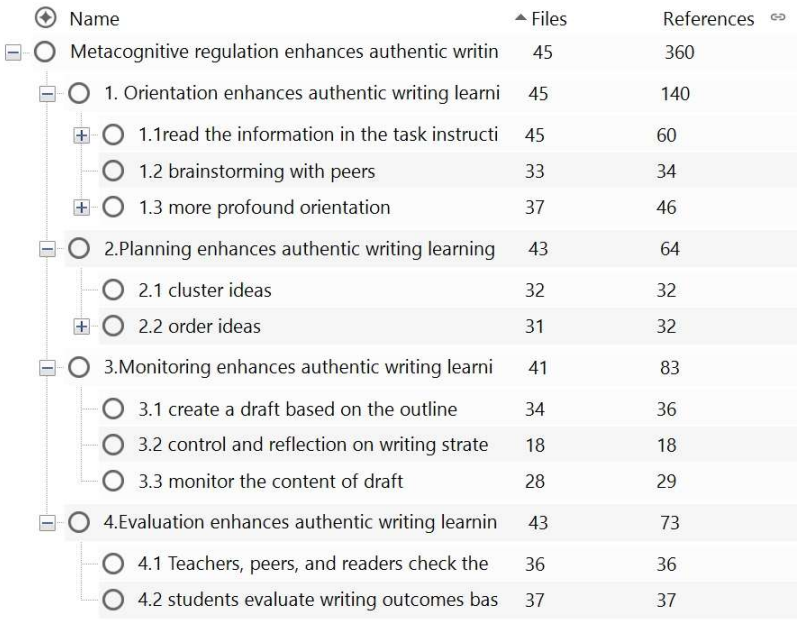

Figure 4: The frequency of occurrence of thematic codes -a screenshot in Nvivo

The researchers analyzed the interview data using Nvivo 15. The results showed that 1) 100% learners chose to read the task instructions to enhance authentic writing learning through orientation. In addition, 73.33% of the learners brainstormed with their peers to clarify the requirements of the task instructions. 82.22% of the learners quoted, reread, or paraphrased to deepen their understanding of the task instructions. Orientation to the task description is a step that most learners do before writing, and they all reported that orientation has a significant positive effect on authentic writing. 2) In terms of enhancing authentic writing learning through planning the results

indicated that 71.11% of learners use the categorization of ideas to set up the structure of an essay, and 68.89% of learners use the ordering of ideas to map out the content of an essay hierarchy. Additionally, Learners mentioned that planning is important to improve the hierarchy and structure of the essay and contributes to the success of the writing. 3) Regarding enhancing authentic writing learning through monitoring, 75.56% of learners mentioned that they write drafts based on outlines. 40% of learners talked about controlling and reflecting on their writing strategies. Moreover, 62.22% of learners pay extra attention to the content of their drafts when writing. 4) Meanwhile 80% of the learners talked about teachers, peers, and readers checking their writing content and writing strategies. Furthermore, 82.22% of the learners felt that assessment and feedback from teachers, peers, and readers help to assess authentic writing learning. Relevant themes, definitions, and selected cases are presented in Table 3.

Table 3: Excerpt From Code book

Theme & Definition	Example
Orientation enhances authentic writing learning Orientation refers to whether or not the student has undertaken goal orientation and task analysis before writing in order to understand the learning objectives or task requirements. What was the goal orientation and analysis based on? How did students ensure that they completely comprehend the task demands?	S13 Before writing, I will read the information in the task description, including reading the text material and the writing requirements S44 Before writing, I will understand the information in the task description based on the text material and the broad headings and on-screen tasks. S18 Before writing, I will talk with my desk or other students to analyze the purpose of writing about our writing S21 I will reread and carefully guess what the task requires. When rereading, I will catch the keywords and understand the meaning of the whole paragraph of the task description from the words.
Planning enhances authentic writing learning Planning means that students plan ahead and organize their ideas about authentic writing to learn problem-solving approaches in a logical and coherent sequence.	S11 I will plan before I write and categorize ideas to make the essay more structured. S13 And, I will put the ideas in an order according to what I want to write about. I will put the ideas in order from small to large, or from simple to profound. This is a crucial factor that contributes to the success of the writing.
Monitoring enhances authentic writing learning Monitoring refers to monitoring students' choices of writing strategies and content writing as they create their initial compositions.	S17 I will analyze the task situation repeatedly before I put pen to paper and start writing the introduction writing body part. Usually, I will write three paragraphs for the main body section. Then the conclusion section, I will often summarise the points made throughout the text. Finally, I will check the suitability of the content of my essay based on the outline. S3 I usually adjust the structure of the essay, such as the order of the paragraphs, to make the essay more fluent. I will check that the content of the essay meets the requirements of the task description, the purpose of the writing, and the information that the reader wants to know.
Evaluation enhances authentic writing learning Evaluation refers to the ways and means by which students assess authentic writing learning outcomes.	S15 After the writing is finished, I will exchange reading with my classmates and check each other. Teacher, classmates, including readers, they will also help me to check. I will make revisions based on my teacher's and classmates' suggestions. I think they are helpful in assessing my writing. S18 After I finish writing, my teacher and classmates will help me to check the lines of thought and whether the structure is correct or not. If I have structural deficiencies, the teacher will help me to point them out their comments and feedback will help me to reflect on my writing. Also, discussions with other students can help us improve our writing skills.

The findings of the study can be summarised in two parts. The first part summarises the results of the ANOVA on learners' writing performance. The second part summarises the metacognitive regulation activities demonstrated by learners in learning to write using the constructivist learning environment model. Through these two analyses, it was determined that the improvement in students‘ writing performance was associated with the improvement in metacognitive regulation skills, further supporting that the use of the Constructivist Learning Environment Model helped to improve the students’ metacognitive regulation skills.

V. Discussion

This study examined the impact of incorporating metacognitive regulation theory into a constructivist learning environment model to promote authentic writing learning among Grade 10 high school students. Findings indicated that this approach significantly facilitated students' authentic writing learning. In addition, the intervention

strengthened the students' metacognitive skills in authentic writing learning. This is because the students used metacognitive regulation (orientation, planning, monitoring, and evaluation) during authentic writing learning. Notably, learners focused more on goal orientation and planning during the writing process, monitoring their entire writing process to make writing strategies and writing content more appropriate. The final multifaceted assessment of writing learning (from teachers, peers, and readers) also contributed to the learners' authentic writing learning.

V. A. Students' performance of pretest and posttest authentic writing

The data in Table 1 shows that there was a significant difference between the authentic writing skills of the students in the pretest and posttest experiments as indicated by the results of the descriptive analyses of their performance before and after authentic writing learning. This could be attributed to the use of process metacognitive regulation in writing learning. Learners learned in a constructivist learning environment model incorporating the concept of metacognitive regulation, where learners were given sufficient freedom and resources to help them solve writing problems in authentic situations. They can search for needed information, discuss and collaborate with their peers, and communicate with the teacher by using each component of the constructivist learning environment. Learners collaboratively construct knowledge and generate more compelling ideas in a constructivist learning environment. Students' metacognitive regulation performance improved in the constructivist learning environment, which is consistent with Machmud et al.'s (2023) study. And, more importantly the present study bridges the gap between Machmud et al. (2023) in terms of practice [27]. Furthermore, the current study extends Wang and Wang's (2024) research by investigating the effect of the composing environment on the quality of authentic writing. The constructivist learning environment model, which includes the concept of metacognitive regulation, is beneficial to the development of authentic writing skills [28].

V. B. Interview Results of Students' Metacognitive Regulation for Authentic Writing Learning

The researchers interviewed the learners about their learning process, and the results of the thematic analysis showed that the students were very positive about the facilitating role of metacognitive regulation in authentic writing. 1) Students analyzed and understood the task requirements through reading, brainstorming, rereading, and paraphrasing to clarify the goals of the writing process. 2) Profound planning led to a more organized and logical writing process. 3) Students' monitoring of writing strategies and writing content also led to a significant improvement in the quality of the writing process. 4) After assessment based on teachers' assessment and peer and reader assessments, the quality of the writing process was significantly improved. This finding also supports the research of Allal, L. (2000), Van Opstal, M. T., & Daubenmire, P. L. (2015) that metacognitive regulation significantly contributes to writing learning. In addition, the particular steps and broadness of metacognitive regulation's impact on writing are being refined.

VI. Conclusion

The purpose of this study was to look at how metacognitive regulation affects authentic writing performance in a web-based constructivist learning environment. The environment facilitates the presentation of authentic writing challenges encountered by students in their academics and lifestyles. The researchers used repeated measures ANOVA to analyze the learning achievement data, which revealed no significant difference between Pre-test 1 and Pre-test 2, while Post-test 1 and Post-test 2 were considerably greater than Pre-test 1 and Pre-test 2. Furthermore, the researchers assessed the application of metacognitive conditioning to intervene in the learning of authentic writing using metacognitive interviews (process evaluation). The findings from the metacognitive regulation interview data were consistent with the participants' learning outcomes. The interview transcripts revealed that participants evaluated metacognitive regulation as having a major impact on authentic writing learning performance.

The limitation of the study is that the participant group consisted of 10th-grade students, and the participation of learners of different ages and experience backgrounds in the experiment is more conducive to demonstrating the ability of metacognitive regulation to influence students' authentic writing learning performance in a web-based constructivist learning environment, with a view to providing a rationale for optimising the instruction of writing and enhancing students' writing ability.

Author Contributions

The first author designed the study, collected and analyzed the data, drafted and completed the manuscript; the second author critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

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Institutional Review Board Statement

The study was approved by the Human Research Ethics Center Khon Kaen University (protocol code : HE673312. date of approval: 9 September 2024). This research can be contacted at Human Research Ethics Center Khon Kaen University, 17th floor, 17th floor, Sor Vor 1 building, Faculty of Medicine, Khon Kaen University. 123 Mittraphap road, Nai Muang Subdistrict, Muang District, Khon Kaen, Thailand 40002. Tel. 043-366621-3 Mobile 089-7141177, 089-7141913

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare no conflict of interest.

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