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Exploring the effectiveness of integrating Augmented Reality-based materials to support writing activities

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Abstract

In this study, whether using Augment Reality (AR)-based learning materials could benefit high school students in the process of Chinese writing was explored, along with the pros and cons of using AR for acquiring Chinese writing skills. In order to reduce the gap between the designers and practitioner teachers, Chinese instructors were invited to co-design the AR-based writing materials to achieve the integration of learners, teachers and educational system technology developers in a collaborative process. The AR-based writing support system was provided to a total of 30 twelfth-grade students who participated in the experiment. The students in the experimental group participated in the writing activity using both AR-based learning material and paper-based supports, while the control group worked with only paper-based writing support materials. The results revealed that the AR techniques helped the intermediate-level students the most in their writing performance of content control, article structure and wording. The students, especially the low-achievers, reflected that the functions of the AR system supported them to start writing the first paragraph more quickly, and enriched their ideas. A possible mode for integrating AR techniques in writing courses is proposed. This paper could serve as a reference for educators and learning technology researchers who wish to design AR-guided writing learning materials or courses with the goal of encouraging learners to experience the writing process in a variety of settings.

Keywords

Augmented Reality; Technology Supported Learning; Writing Activity

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Abstract

In this study, whether using Augment Reality (AR)-based learning materials could benefit high school students in the process of Chinese writing was explored, along with the pros and cons of using AR for acquiring Chinese writing skills. In order to reduce the gap between the designers and practitioner teachers, Chinese instructors were invited to co-design the AR-based writing materials to achieve the integration of learners, teachers and educational system technology developers in a collaborative process. The AR-based writing support system was provided to a total of 30 twelfth-grade students who participated in the experiment. The students in the experimental group participated in the writing activity using both AR-based learning material and paper-based supports, while the control group worked with only paper-based writing support materials. The results revealed that the AR techniques helped the intermediate-level students the most in their writing performance of content control, article structure and wording. The students, especially the low-achievers, reflected that the functions of the AR system supported them to start writing the first paragraph more quickly, and enriched their ideas. A possible mode for integrating AR techniques in writing courses is proposed. This paper could serve as a reference for educators and learning technology researchers who wish to design AR-guided writing learning materials or courses with the goal of encouraging learners to experience the writing process in a variety of settings.

Keywords: Interdisciplinary projects; Applications in subject areas; Improving classroom teaching; Interactive learning environments

Introduction

Several years ago, the augmented reality (AR) techniques had just begun to appear, and AR applications were limited to using huge pieces of equipment such as head-mounted displays or a whole suit of wearable devices (Sutherland, 1968). Today, the AR hardware and AR development tools have matured and have become flexible with the evolution of information technology, and even basic smart phones or tablets with camera devices can now be used for AR interaction (Chen et al., 2013). Researchers (Bitter & Corral, 2014) have revealed that AR applications (AR apps) are available in large numbers with the increasing pervasiveness of apps utilized through mobile learning devices for commercial, advertising or educational purposes. The AR techniques merge elements of the real-world environment with virtual-generated imagery, and present interactive visualizations and simulations next to 2D-based contents (Botella et al., 2011; Specht, Ternier, & Greller, 2011). Researchers have stated that the use of mobile-based AR apps in education has been proven to be more effective than the use of traditional textbooks (Bitter & Corral, 2014), and benefits students' learning motivation in the learning process (Matcha & Awang Rambli, 2011). Besides, the features of presenting learning information, textual, video, audio, and three-dimensional learning contents together in real-time interaction might stimulate learners to learn abstract ideas more than only reading a text-based book (Specht, Ternier, & Greller, 2011). For example, Chen, Huang and Hsu (2013) adopted the situation learning strategy with the AR technique to provide students with an interactive interface and learning media for an outdoor geography course activity, and Chang et al. (2016) integrated a game-based learning activity with AR interaction to allow learners to collect virtual data and to experience interviewing virtual characters on a campus for learning about the issues of radiation energy and pollution.

On the other hand, College Entrance Examination Center in Taiwan indicated that senior high school students' Chinese writing ability and motivation to practice writing need to be improved in Taiwan, and research (Chen, 2004; Tsai, 2003) has indicated that the problems may be that students lack the ability to organize information and find connections between their previous experience and the targeted writing topics. Besides, in senior high school Chinese writing classes, teachers have very limited time to present all the related writing scenarios for learners in the classroom (Liu, 2002), and learners face the problem of not knowing how to begin the writing due to their lack of related writing experience or unfamiliarity with suitable vocabulary and sentences to describe their feelings (Chen, 2004; Tsai, 2003). Researchers (Hayes & Flower, 1980) have suggested that instructors could arouse learners' long-term memory related to writing topics, and guide them to organize the information through providing writing materials that might help them transmit abstract ideas into specific writing scripts, enhance the richness of the content (Hsueh & Lai, 2014) and produce a complete composition (Xie & Cen,1995).

Research purpose and questions

Based on the above brief introduction to AR characteristics and problems that instructors and students meet in Chinese writing, the aim of this study was to utilize the mature AR techniques to not only provide students with a variety of writing materials, but also to create self-practice opportunities for Chinese writing. Researchers have indicated that while integrating AR techniques into the design of learning applications, there may be a gap between designers and practitioner teachers due to differences in conceiving learning and learning artifacts (Tobar-Muñoz, Baldiris, & Fabregat, 2016). Better design of AR educational applications could be achieved by integrating learners, teachers and educational technology experts and technique developers in a collaborative process of development (Bacca et al., 2015). Besides, more quantitative and qualitative evidence-based research related to AR applications should be implemented to explore various effects of learning via AR-based activities compared with learning from existing contents (Wu et al., 2013; Ke & Hsu, 2015). Hence, in this study, Chinese instructors were invited to participate in the development stage to co-design the AR-based writing materials, and to explore whether using AR-based learning materials could benefit high school students in the process of Chinese writing, and further to explore the pros and cons of using the state-of-the art AR for acquiring Chinese writing skills. This paper could serve as a reference for educators and learning technology researchers who wish to design AR-guided writing learning materials or courses with the goal of encouraging learners to experience the writing process in a variety of settings. The following research questions were investigated:

1. How could the AR-based learning materials affect students' Chinese writing performance?
2. What are the students' and instructors' perceptions of using AR-based learning materials in Chinese writing?
3. How can AR-based learning materials be used to assist students in the process of Chinese writing?

Literature Review

Writing Instruction

Writing skills are an important part of language learning because learners are trained to transform the language they learn in class into specific words for expressing their feelings and opinions through writing (Chen, 1997; Liu, 2002). The process of writing includes collecting writing materials, structuring ideas, and starting writing (Tung, 1997). Researchers have indicated that lacking the ability to organize and plan the structure of a writing article and being unable to refer to related information and experience from long-term memory so as to incorporate it into their writing might be the main difficulty faced by learners (Pressley & McCarmick, 1995). Besides, Kellogg (1994, 2008) emphasized the importance of assisting students with collecting writing materials (source), producing writing plans, transforming their ideas from working memory into textual words, and then describing their knowledge in textual words during the writing process. Several methods have been proposed for writing instruction (Hillock, 1984); for example, in the presentational mode, teachers assign writing topics and guide learners to start writing step by step; in the environmental mode, instructors provide students with related writing materials and encourage them to produce their writing through discussion; while in the linear model, teachers prepare learning materials for students who are then required to complete the writing in the given time after reading the materials provided to them (Huang, 2007). In the meantime, learners' thinking will be affected by environmental, internal and operational factors during the process of writing (Xie & Lin, 1992). The internal factors refer to how learners collect related materials from the brain and reproduce the context of the image as a source of inspiration for writing (Flower & Hayes, 1980; Xie & Cen, 1995). The environmental factors are those external factors which influence learners such as the praise of teachers or the relationship with classmates or instructors. The operational factors are the process from prewriting, planning, writing and reviewing during which learners have to organize the wording and sentences, and then produce a complete piece of writing. Hayes and Flower (1980) suggested that instructors provide learners with writing instruction through assisting them to recall the experience related to the writing topics, then produce writing plans to achieve the writing goals accordingly, and lastly, to write down their ideas in textual form. More recently, a revised model was provided which has two components: the task environment and the individual (Hayes, 1996; Hayes, 2012). The task environment consists of a social component and a physical component, and the individual incorporates motivation and affect, cognitive processes, working memory, and long-term memory. The newly revised model put more emphasis on the role of working memory in writing as well as the functions of the text interpretation process. Besides, the process of writing transcription and writers' motivation were also discussed in the revised model. Meanwhile, Sperling and Freedman

(2001) revealed that teachers should evaluate students' writing cognition ability and provide learners with suitable learning scaffolding to transform inner thinking into specific words, and to give learners organized writing procedural knowledge including sample rhetoric and syntax as references for completing the writing exercises (Zhao, 2006; Hayes & Flower, 1980；Chuang, 2004). Besides teachers preparing various forms of writing instruction to assist students' writing, how to transform the oral language into textual writing and explain the abstraction through refined words and sentences are the challenges that learners have to overcome (Cole, 2004).

Related studies of using learning technology in writing

Several studies have applied learning technology to assist writing. Chu (2013) explored the effects of using traditional instruction, animation and an instruction video compact disc to assist writing. The findings revealed that learners in the animation group had better writing attitudes compared to the other two groups, but learners in the traditional group had better writing performance. Chu (2013) indicated that presenting too many multimedia modes at a time may have overloaded the students, and hence, they performed worse than the traditional group in which each key learning point was given one by one. Zaini and Mazdayasna (2015) used computer-based instruction to assist college students in developing their English writing skills. In their study, one group learned with the traditional method and one with the Microsoft Word Office software as a tool for writing. The findings revealed that the learners in the computer-based instruction group outperformed those in the other group in terms of using appropriate articles, tense, plural forms and spelling; besides, the learners were able to produce high-quality paragraphs. In another study, Jeong (2016) adopted the cloud-based platform, Google Docs, to assist college students in Korea with their English writing. In the experiment, the learners were encouraged to submit their English writing via the cloud system, allowing them to get instant feedback from teachers and peers. The research finding showed that the learners enjoyed the experience of receiving learning feedback through the platform, and it also enhanced active communication and autonomous class participation. Ti (2015) integrated AR techniques to assist elementary school students learning Chinese writing. The study compared the learning effects of using AR instruction and picture-based instruction for guiding learning. The findings indicated that both groups improved their writing performance. The learners in the AR group had better attitudes towards learning writing, while no differences were found in the performance of the learners' writing content and skills. Ti (2015) mentioned that the limited time of the experiment may have been the reason why no differences were seen between the two groups. The above studies revealed the benefits of using learning technology for assisting writing, but currently there exist only a handful of attempts to examine the effectiveness of the applied AR techniques for writing purposes.

Using AR techniques to assist learning

In the related research in recent years, there has been a variety of technology-enhanced learning from computer-assisted learning, mobile-based learning, multimedia materials to AR-based learning environments (Ivanova, Aliev, & Ivanov, 2014). Specht et al. (2011) defined AR as a system that enhances a person's primary senses (vision, aural, and tactile) with virtual or naturally invisible information made visible by digital means, and in the growing dossier of research on technology for enhancing learning, studies have begun to shed light on how learners' skills could be improved by the integration of AR (Bacca et al., 2015; Cifuentes et al., 2016). The characteristics of AR interaction are that it is real-time interactive, includes static and dynamic contents, blends real and virtual environments, and provides three-dimensional graphics (Rice, 2007; Specht, Ternier, & Greller, 2011). With the rapid increase in learning technology, the applications of AR could be extended and could work with various learning devices such as tablet PCs and mobile phones. Some studies have focused on how AR application designs could support learning, how students acquire knowledge through AR interaction, and what teachers or schools have learned from using AR applications to achieve instructional goals (Ivanova, Aliev, & Ivanov, 2014; Cifuentes et al., 2016; Bacca et al., 2015; Ibáñez et al., 2016; Mitsuhara et al., 2016; Tobar-Muñoz, Baldiris, & Fabregat, 2016). A summary of the various categorizations of AR applications and the related study results is presented in Table 1.

The early AR applications were conducted through wearable devices (Table 1-a). For example, Liarokapis et al. (2002) adopted wearable devices: Head Mounted Displays (HMD) with AR techniques to develop a system that integrates images, animations, text, and sound information for supporting interactive engineering education, and Cerqueira and Kirner (2012) used HMD devices with a behavioral authoring system for augmented reality (basAR) to assist students in learning polygon extrusion and revolution mathematics concepts. As well as the AR applications on wearable devices, applications of computer-based AR and marker-based AR have also been explored (Table 1-b). These

systems used trained markers as triggers, and the learning information was overlaid on it when learners scanned the markers with a computer camera. For example, Matcha and Awang Rambli (2011) presented an experiment of using a computer-based AR system for learning the concept of light dispersion and combination. The learners were grouped into pairs to conduct the learning tasks using the AR system, and the findings revealed that AR is a learning medium that might enhance collaboration and learning interaction between peers. Ivanova, Aliev, and Ivanov (2014) used marker-based AR to produce an experimental AR textbook for mechanical engineering students in Russia. The researchers used a 3D model to present a combined measuring tool and an animated movie to show the dynamic measuring process of a broach using calipers, a micrometer and a protractor. Another study revealed that among Asperger's syndrome students, learners with a marker-based AR system for courses on the Human Skeletal System and the Water Cycle produced better results in terms of their learning motivation and engagement than those who did not use the system (Cifuentes et al., 2016). More recently, with the increasing pervasiveness of the applications utilized through mobile devices, mobile-based AR apps have matured and expanded rapidly to a level such that they are available for educational purposes (Bitter & Corral, 2014; Table 1-c). For example, Chen, Huang and Hsu (2013) adopted mobile-based AR interaction for an outdoor geography course and revealed that mobile-based AR with the situated learning strategy facilitated learners' learning retention of the targeted learning contents. Bacca et al. (2015) introduced a marker-based mobile-based AR application to support the learning process of repairing paint on a car for a vocational education program on car maintenance. The findings revealed that learners could take advantage of the design of the AR application. Mitsuhara et al. (2016) adopted both HMD devices and tablets to develop an AR system which simulated the situational and audio-visual realities and scenario-based interactivity to assist students in experiencing disaster situations for evacuation drills. Chang et al. (2016) developed a mobile-based AR system to assist senior high school students in investigating a socio-scientific issue on radiation energy and pollution, and revealed that the mobile-based AR interactive game was helpful for enhancing students' knowledge acquisition.

To date, AR in education has been implemented in the fields of astronomy (Fleck & Simon, 2013), engineering (Liarokapis et al., 2002), history (Martin et al., 2011), physics (Coffin et al., 2008), and in the contexts of elementary (Fleck & Simon, 2013), middle-school (Di Serio et al., 2012) and college education (Liu & Tsai, 2013). The above applications of AR for educational purposes have been proven to have positive effects on learning, and the advanced development of learning technology and the mature AR techniques bring about more flexible interaction and applications. However, several issues should be carefully considered when adopting AR in learning such that there are still barriers to the integration of AR into education such as the practical limitations of the use of AR apps, teacher interest, and administrative support (Rajaan et al., 2014) and inexperience of AR system operation and large amounts of information displayed on the AR screen might result in negative learning effects (Di Serio, Ibanez, & Kloos, 2013). Besides, the AR learning tools should also fulfill the key learning purpose for the targeted learning subject. Otherwise, AR applications may lack learning effectiveness for high-level students (Bitter & Corral, 2014; Paivio, 1986).

Table 1 Summary of various categorizations of AR applications

Summary of the literature

Many studies have investigated the practice of writing through the assistance of learning technology, while the use of AR techniques has rarely been examined. Researchers have suggested that teachers should evaluate students' writing cognition ability and provide them with suitable learning scaffolding to transform their inner thinking into specific words, and to assist them in recalling their experiences related to the writing topics. Since the characteristics of AR such as being real-time interactive, inclusion of static and dynamic contents, and blending real and virtual environments have been proved to be beneficial to learning, AR techniques were adopted in this study to construct writing internal and operational factors as scaffolding, and to provide learners with opportunities to plan and write articles on their own for self-practice purposes.

The co-design stage and pilot study

Researchers (Bacca et al., 2015; Cober et al., 2015) have indicated the importance and need for research teams to invite teachers to be participatory designers as they have contextual knowledge and thus can help to achieve a good design of AR educational applications, thus reducing the gap between system designers and practitioner teachers (Tobar-Muñoz, Baldiris, & Fabregat, 2016). Hence, in this study, instructors were invited to participate in the co-design stage to understand and elaborate what

kinds of AR supports learners might need, and how the designed AR contents could be implemented to assist students' writing. The co-design stage included three phases (Figure 1); firstly, questionnaires were used to collect the Chinese teachers' ideas and needs of using AR techniques for assisting Chinese writing. The survey results were then used to develop the preliminary prototype of the AR-based writing support system. Then, a focus group discussion was held to revise the prototype. Lastly, one teacher was invited to participate in the third stage in which the teacher and system developer worked together to produce the learning contents and final version of the AR-based writing support system.

Figure 1 The three phases of the co-design stage

In the first phase, questionnaires were used to collect 21 Chinese teachers' ideas and expectations regarding using AR to support students' writing processes. Most teachers had 2 to 5 years of teaching experience and were aged from 26 to 40 years old (Table 2). These questionnaires included five-point Likert scale items, multiple choice questions, and open-ended questions, and the items in the questionnaires included three parts, namely personal information, a video demonstration of AR interaction, and collection of teachers' feedback. According to the results of the questionnaires, the teachers had high expectations and attitudes towards using AR techniques to support Chinese writing, especially regarding using the AR support for low-learning achievement learners. Besides, the teachers also gave positive feedback on the question items of using AR to support after-class Chinese writing practice, using AR to enhance learners' writing motivation, and using AR in learning to provide learners with scenarios (The average score of these three items were all over 4.2 points). Moreover, they reflected that AR-based writing supports may be suitable for writing topics related to the outdoors (85.70%), journeys (76.20%), and everyday life experiences (71.40%). The teachers also suggested integrating multimedia into the AR presentations so as to connect learners' previous life experience with the writing topics. The contents could include related sentences and inspirational quotes to assist learners in step by step article imitation. For example, the teachers gave students a topic and a paragraph to describe the topic, then the students were encouraged to write similar paragraphs to describe the same topic or to fill in the blanks in the given paragraph using other descriptive terms.

The prototype of the AR-based writing support system was then conducted based on the findings of the pilot results of phase one.

Table 2 Participants of Phase 1

Considering the students' existing writing learning experience, the preliminary prototype of the AR-based writing support system was designed on paper-based learning sheets (printed handouts). The supported writing materials were embedded on these learning sheets using AR techniques so that when the learners used the learning devices such as smart phones or tablets with a camera to scan the triggers on the learning sheets, the writing materials (including video, audio, animation and referable sentences) and writing guidance were presented accordingly. Then, in the second phase, two Chinese teachers were invited to participate in the focus group discussion and to test the system. The teachers had 15 minutes to test the AR system and 30 minutes for the focus group discussion. The teachers' suggestions for the improvement of the system were organized into three aspects including content design, way of writing guidance, and integration of AR into writing instruction (Table 3). The findings of the second phase informed the system and instructional design of the final version of the AR-based writing support system. The details of the final version of the system are described in the next section.

Table 3 The teachers' suggestions for improvements to the AR-based writing system from Phase 2

The AR-based writing support system

The AR-based writing support system was developed based on the results of the pilot study, and the reviewed research (Hayes & Flower, 1980; Hayes, 1996; Hayes, 2012) which suggested providing learners with writing supports in terms of environmental, internal, and operational factors during the process of writing, assisting learners in recalling their experiences from working memory related to the writing topics, and then making writing plans to achieve the writing goals. Moreover, studies have also revealed that teachers could prepare various forms of writing instruction through giving organized writing procedural knowledge including sample rhetoric and syntax as references to assist learners in

transforming oral language into textual writing (Zhao, 2006; Hayes & Flower, 1980; Chuang, 2004; Cole, 2004). Thus, two modes of AR writing support materials were designed accordingly, Mode 1: authentic scenes support, and Mode 2: paper-based learning sheet support (Figure 2).

Figure 2 The framework of the system: Mode 1 and Mode 2

In Mode 1, the AR contents were developed based on authentic scenes. This mode was developed for outdoor topic writing. For example, in the topic "My School," the learners had to write an article about the impressive places or scenes that have special meaning for them in school, and thus they could first take a tour around the campus and use the learning devices (tablet PCs) with the AR app (Aurasma) to scan the authentic scene on campus to read the pre-embedded AR contents in specific locations as writing scaffolding. The information of the AR contents included a brief introduction to the scenes (animation), related referable sentences including sample rhetoric and syntax (textual information), and video or audio materials to provide the learners with writing stimulation and guidance. Take one specific spot on the campus, the Melia azedarach (China tree), as an example; when the learners used the learning device to scan the tree, they were first presented with introductory information about the tree and learned the special meanings of the tree to the school. They then read the rhetoric and syntax for learning how to use the wording to describe the tree. They were also encouraged to use the provided words and sentence lists to describe their emotions or special memories related to the tree (Table 4-A).

In Mode 2, the AR contents were embedded in the paper-based learning sheets. This mode was developed for in-class writing scenarios and to help learners without related writing experience who had to write articles in the limited class time. For example, for the topic of "The power of love," the learners sat in the classroom and used the learning devices with the AR app to scan the paper-based learning sheets. The related materials were shown on the screen, with the contents provided through multimedia presentations including video and animation to assist the learners in recalling the feeling of love, their experience of love, or to reflect on scenarios of positive and negative examples of love. Take one part in the paper-based learning sheets, negative examples of love, as an example; when the learners used the learning device to scan the pictures on the paper, a video that demonstrated a loveless scenario in daily life was shown. Then the rhetoric and syntax related to how to describe the feelings of this situation and textual guidance for further self-reflection on this situation was provided (see Table 4-B).

Table 4 Demonstration of Mode 1 and Mode 2

Methodology

In this study, a comparative test was adopted to report on the performance of Chinese writing in the two learning scenarios, with and without the AR-based writing support system, and both qualitative and quantitative approaches were employed. The duration of the experiment was four weeks and the learners had to complete four writing topics. The topics were The Mailbox (Topic 1), The Power of Love (Topic 2), My Campus (Topic 3), and A Rainy Day (Topic 4). These topics were designed based on the topics from the college entrance examination. The learners wrote their articles using their original approach for Topics 1 and 4 in which only a brief explanation of the topics was given, while the writing scaffoldings were provided for Topics 2 and 3. All of the learners received paper-based learning sheets as writing scaffolding, but the sheets for the experimental group (E.G.) were embedded with AR triggers and the learners could use their learning devices (tablet PCs) with the AR app (Aurasma) to read the AR-based contents via the paper-based learning sheets or the authentic scene. Meanwhile, the control group (C.G.) only used paper-based learning sheets in which all the writing scaffolding was presented in textual format. The researchers used questionnaires and interviews to collect the learners' and the teacher's feedback and attitudes towards using the scaffolding tools (both the AR content and the paper-based learning sheets) to assist their writing. The structure of the experiment is presented in Figure 3.

Participants

A total of 30 female twelfth graders (aged from 16 to 17) from a girls' senior high school in Taiwan participated in this study. The students were divided into two groups according to their writing grades for Topic 1 so as to ensure that the learners in the two groups were at the same writing level. Besides, the learners in each group were divided into three subgroups for further qualitative analysis. The high-achievement learners were those students whose grades for Topic 1 were in the top one third

of the class. The grades of the low-achievement learners were in the bottom third of the class, and the rest of the students were categorized as medium-achievement learners. Hence, the E.G. consisted of 15 learners with 5 students in each learning achievement level, and vice versa in the C.G. One Chinese teacher was invited to participate in the whole study and also rated the students' writing performance. Another Chinese teacher was invited after the experiment to rate 40% of the students' writing performance again in order to understand the reliability of the scores evaluated by the first teacher. Moreover, two co-researchers were involved with the field observation and videotaping. They were also trained before the experiment to categorize the students' feedback into forms for qualitative data analysis.

The process of integrating the AR system into writing practice

The study adopted writing scaffolding to assist the students' writing for Topics 2 and 3; the learners in the E.G. used both AR-based contents and paper-based learning sheets as scaffolding when writing, while those in the C.G. only had paper-based learning sheets as their learning supports. The paper-based learning sheets were co-designed by the Chinese teacher and a learning technology expert. The Chinese teacher designed the script of the process and scaffolding steps, and then the learning technology expert designed the AR-based materials accordingly and embedded the contents into the learning sheets using AR techniques.

In the experiment, the learners in both groups received paper-based learning sheets and had to follow the writing guidelines on the sheets step by step in order to complete the writing tasks. Meanwhile, each student in the E.G. was provided with a tablet PC for viewing the AR contents during the writing activity. For Topic 2, the learners in both the E.G. and C.G. sat in the classroom and followed the instructions to conduct the writing with the paper-based learning sheets as scaffolding, but the learners in the E.G. followed both the AR-based and the paper-based instruction. For Topic 3, the learners in the C.G. remained sitting in the classroom, but the learners in the E.G. first walked around the campus with their tablet PCs to explore the special spots in the school and then went back to the classroom to finish the writing. The process of integrating the AR system into writing practice is presented in Figure 4, and the AR-supported contents were provided to the students through both authentic scenes (Mode 1 for Topic 3) (Figure 5-b) and paper-based learning sheets (Mode 2 for Topic 2) (Figure 5-a).

Figure 3 The structure of the experiment
Figure 4 The process of integrating the AR-based writing support system into the writing practice
Figure 5 The learning scenario of the E.G. with the AR-based writing support system

Writing evaluation and questionnaires

In order to understand the students' writing performance before and after the experiment and to ensure a reliable evaluation, one qualified Chinese instructor was invited to rate the students' writing performance. In this study, the categories and criteria of the College Entrance Examination Center (CEEC) in Taiwan were referred to for defining four scales, Subject (40%), Content control (20%), Article structure (20%) and Wording (20%), for rating the students' writing performance. The total score of each topic was 100 points, and each scale for each student was collected for further analysis. The researcher further invited a second Chinese teacher to double-score 40% of the students' writing performance to ensure a reliable evaluation. The Spearman's rank correlation coefficient was used to access the relationship between the two raters' scores. Spearman's rank correlation coefficient is a measure of statistical dependence between two variables and is often denoted by r_s. A perfect Spearman correlation of +1 or −1 occurs when each of the variables is a perfect monotone function of the other. The result of the Spearman rank correlation test showed a significant correlation between the two raters. It was found that the Spearman's correlation coefficients, r_s , were 0.67, 0.75, 0.60 and 0.73 for the four writing topics, and that they were statistically significant ($p = 0.04$; 0.02; 0.04; 0.01) which means that the scores determined by the two raters were highly reliable.

Three questionnaires were administered in this study. Questionnaires 1 and 2 were conducted before and after the writing activity, both of which had similar items. Questionnaire 3 was administered to the E.G. only to collect their feedback on the use of the system. Questionnaires 1 and 2 consisted of items on a five point Likert scale (from 5 to 1: strongly agree, agree, neutral, disagree, strongly disagree) and multiple response questions to investigate how the learners perceived using scaffolding materials when writing, while Questionnaire 3 consisted of items to investigate the design of the AR-based writing support system. A Cronbach's α test was used to measure the reliability of the questionnaires, where an α value of above 0.7 is usually considered to

indicate good reliability. The coefficient α of the measures of Questionnaires 1 and 2 for E.G. and C.G. were 0.87 and 0.77, and for Questionnaire 3 for E.G. was 0.88. Besides, in order to understand the instructor's perceptions, opinions and experience of using the AR-based writing support system that could not be observed by the researcher, the cooperating Chinese teacher was invited to take part in an individual interview, during which questions were posed regarding how the teacher perceived the experience of using the AR-based writing support system in the writing class. The interview questions were: 1) How do you perceive the use of the AR system for assisting students' writing? Do you think it could enhance students' writing ability? Why? 2) Do you think that the use of the AR system restricts students' creativity when writing? 3) Do you think the AR system could benefit all levels of learners? Or do you have any suggestions for how to use the AR system to support learners at various levels? 4) Do you have any other feedback or suggestions after the experiment?

Data Analysis

The data were analyzed according to the research questions and the data from the four scores of the writing performance, as well as the responses to the questionnaires and interviews. SPSS for Windows 12 was used as the major software for statistical analysis. Descriptive statistics were calculated to describe the means and standard deviations, a mixed ANOVA method, and one-way ANOVA were adopted to compare the final learning results and questionnaire results of the two groups. For the qualitative data from the instructor, the researcher translated the feedback from the interview questions into raw data files for each participant, and re-coded the raw data according to different themes. The final qualitative data were organized and displayed as reduced data from which the findings for each question could be highlighted.

Writing performance

The four writing scores were analyzed to answer the first research question. The results of the Levene's test confirmed that the data met the equality of variance assumption, and the learners in the two groups did not show a significant difference in the four aspects of their writing performance according to the analysis of the mixed ANOVA method with one within-subject factor (writing performance which had four levels: Subject, Content control, Article structure and Wording) and one between-subjects factor (group). According to the results of Tests of Between-Subjects Effects (Table 5a), it was noticed that there was a significant main effect of group on the writing performance in Article structure ($p=0.007 < .001$), and the descriptive statistics showed that the average scores of Topic 2 for the C.G. were a little higher than those of the E.G., but this finding was inverted for Topic 3 which was an outdoor writing topic. Meanwhile, when analyzing the learners' writing scores in more detail (one-way ANOVA), it was found that the learners in the E.G. with the AR-based writing support system performed better in the scales of article structure for Topic 3 and content control and article structure for Topic 4, with the scores achieving a significant difference (Tables 5-b and 5-c).

Table 5a Tests of Between-Subjects Effects
Table 5b Descriptive statistics
Table 5c ANOVA analysis

Besides, considering the possible influence of the students' learning achievements, the mixed ANOVA method was also adopted to further analyze the students' performance according to their learning achievements. It was found that the high- and low-achievement learners in the E.G. and C.G. did not differ in their performance in the four writing activities; however, it was noted that, according to the results of Tests of Between-Subjects Effects (Table 6), there was a significant main effect of group on the writing performance, and the descriptive statistics showed that the medium-achievement learners in the E.G. performed significantly better than the learners in the C.G. in terms of their scores for Topic 4, especially in the scales of content control, article structure, and wording. This indicates that after the writing scaffolding was removed, the medium-achievement learners in the E.G. showed better writing performance than that of the learners in the C.G. (Table 6-a &6-b).

Table 6-a Descriptive statistics
Table 6-b ANOVA analysis

Students' perceptions of using the AR-based writing system

The data from the questionnaires regarding the learners' feedback on using the AR-based writing support system were analyzed to answer the second question. A one-way ANOVA was conducted to analyze the two groups' feedback before and after the experiment. The overall questionnaire results indicated that the learners in the two groups did not differ in their feedback, with both groups giving positive feedback on using the learning supports during the writing activity. However, it was noted that the learners in the E.G. seemed to find it easier to start writing the first paragraph compared to their experience of writing without the system (Table 7: I5).

The descriptive statistics were calculated to describe the means and standard deviations of the results of Questionnaire 3 from the E.G. which was conducted after the experiment. The results revealed that the students were positive about using the system to assist them with their writing, and most students reflected that they could operate the AR system quite well. The feedback was further analyzed according to the students' learning achievements (Table 8), and the data showed that the medium- and low-achievement level students gave more positive system evaluation feedback compared to that of the high-achievement students. It was noted that the low-achievement students gave very positive feedback regarding the uses of the AR system, and they reflected that with the support of the system they were able to start the first paragraph more quickly (Table 8:I6). Furthermore, they also expressed that the AR system was a useful tool for assisting writing through enriching their ideas for writing (Table 8:I7 and I11).

Moreover, according to the open-ended questions, the students reflected that they were given more writing directions and materials so that they could more easily organize their ideas for writing the articles. Besides, the students mentioned that writing was not so boring when integrating the AR-supported writing system into the writing activity. Meanwhile, it was noted that one high learning-achievement student reflected that using the AR-supported system might restrict her creativity in writing, and thus she revealed a preference for the paper-based learning support. Some students also provided suggestions for improving the system such as the AR information being fixed while learners are reading the contents, and information remaining on the screen after the device has been removed from the triggers.

Table 7 The one-way RM ANOVA of the two groups for Questionnaires 1 and 2
(a) Description analysis
(b) ANOVA analysis

Table 8 The descriptive data results for Questionnaire 3 of various achievement learners in the E.G.

Instructor's perceptions of adopting AR techniques to assist writing teaching and learning

The Chinese instructor's interview feedback regarding adopting the AR techniques in the writing activity was coded and organized in order to answer the second question. According to the interview data, the instructor gave quite positive feedback after the experiment, commenting that the first try to adopt the new technology into writing practice might be a good start in writing instruction. However, whether it could facilitate students' writing ability may need more long-term evaluation since the improvement in students' writing ability is a long-term process. The instructor explained that the twelfth graders were facing the pressure of taking the college entrance examination, and so had limited time to do writing practice with the AR technology since it might need more time than normal writing practice activities. However, the adoption of AR technology was a good method for triggering middle- and low-achievement learners to start writing from the aspect of organizing their writing thoughts and connecting their experience with the topic. Meanwhile, the teacher also stated that it might be less helpful for the high-achievement learners since they already had all the writing materials and ideas in mind. The instructor also reflected that despite some learners using the AR-based writing support system possibly presenting similar content in their writing, through redesigning and enriching the system content, the problem of limiting writing creativity could be avoided. Besides, the instructor also gave suggestions about the kinds of writing topics that could benefit from the writing support of the AR system such as those topics involving writing reflections based on abstract thinking or topics on art appreciation for describing art objects or buildings.

Discussion

Using AR technology to support middle- and low-achievement learners' writing

According to the students' writing performance and questionnaire feedback, it was found that the intermediate-level learners in the E.G. performed significantly better than those of the same level in the C.G. on the fourth writing task for the scales of content control, article structure and wording once the scaffolding was removed. This finding seems to echo Hayes and Flower's (1980) and Zhao's (2006) studies in which the researchers suggested that providing learners with writing assistance helped them transform their inner thinking into specific words. In answer to research questions one and two, it was found that using AR techniques as writing scaffolding was beneficial in terms of providing the learners with the internal and operational factors that helped them organize the wording and sentences, and then to produce a complete piece of writing; this was especially the case for the intermediate-level learners. Hence, it could be concluded that adopting the characteristics of AR for giving learners various forms of writing instruction helped the learners to achieve better writing performance than those who learned with the paper-based learning instruction. Besides, the questionnaire results also indicated that the low-achievement students were more positive about using the system for assisting self-writing practice than the learners in the other levels. Meanwhile, the instructor had positive feedback of using AR tool in assisting writing instruction, and indicated that the AR-based writing support system might be more useful for intermediate- or lower-level students to bring out their thoughts and turn them into writing texts since high-achievement students already have the writing structure and article draft in mind, and so have less need for additional writing scaffolding. These findings were similar to the research results of previous studies (Bitter & Corral, 2014; Paivio, 1986).

Possible modes for integrating AR techniques into writing courses

The writing performance of the two groups did not show significant difference in the current study results because the acquisition of writing ability may need long-term practice to achieve improvements. Nevertheless, it was found that the learners who used the AR-based writing support system performed better in the skills of article structure and content control, especially for the outdoor writing topic. Besides, it was noted that various kinds of writing scaffolding could be provided for different writing topics; for example, AR techniques could be used to support the writing of expository essays such as introducing a place and expressing one's feelings about the targeted building or environment. Meanwhile, paper-based writing scaffolding might be more suitable for descriptive essays. Hence, to answer the third research question, it is concluded that a blended mode could be adopted when integrating learning technology to assist with writing courses. The course teacher and traditional paper-based guiding materials with sample rhetoric and syntax as a reference could be used for general topics, while AR-based learning materials could be used for making connections with experience, transforming inner thinking into specific words, and achieving the writing goals accordingly. The blended mode of integrating AR techniques into writing courses is proposed as shown in Figure 6.

Figure 6 A blended mode of integrating AR techniques into assisted certain environments

It was noted that some students mentioned that the information on the AR screen would disappear when they moved the camera away from the trigger, and this might be a nuisance when they were learning. This echoes the findings of Di, Ibanez, and Kloos (2013) who found that inexperience of operating the AR system might result in negative learning effects. Besides, if the purpose of the AR-based system was to act as writing scaffolding, then the supported materials should be continually presented so that the learners could reference the scaffolding when they needed it. According to these findings, an optional function of the AR system could be designed to give learners opportunities to choose when the writing support could be shown.

Limitations

The limitations of the study were the small number of students in each group and the period of time spent conducting the experiment. Besides, considering the diversity of participants and teaching contexts, the findings probably cannot be generalized to other subjects.

Conclusion

This research aimed to explore whether using AR-based learning materials could benefit high school students in the process of Chinese writing, and further identify the pros and cons of using the state-of-the-art AR for acquiring Chinese writing skills. In this study, instructors' opinions regarding using AR techniques for assisting writing were firstly collected, and then teachers were invited to participate in the co-design stage of developing the AR-based writing support system. Evaluation was conducted to investigate the learners' writing performance after using the paper-based and AR-based

writing support system, and to discover the reasons why there were differences in the effectiveness of writing performance by analyzing the writing performance and feedback of learners with different levels of achievement.

The findings of this study demonstrate that the use of AR techniques helped the intermediate-level learners the most in their writing performance in the scales of writing content control, article structure and wording, and the students reflected that the functions of the AR system supported them to start writing the first paragraph more quickly, and enriched their ideas because the AR materials gave them more writing stimulation; this was especially true for the low-achievement students. Meanwhile, the teacher revealed that AR technology was a good method for triggering middle- and low-achievement learners to start writing from the aspect of organizing their writing thoughts or making connections with their experience. However, whether this kind of new learning technology could really improve students' writing ability needs more long-term evaluation. Moreover, possibly because of the target learners' learning level, it was also found that the AR tools are useful for intermediate-level learners, but might not be sufficient for high-level students. The instructor also noted that some of the high-achievement students felt that the paper-based learning materials were more suitable for them.

It can be concluded from the current research findings that a blended mode of using AR to assist writing could be adopted by teachers; that is, the AR support materials could be provided according to various writing topics. The writing topics related to outdoor discovery activities are more suitable for using AR materials, while paper-based writing scaffolding that provides learners with rhetoric and syntax as a reference might be better for descriptive essays. This paper could be a reference for educators and learning technology researchers who want to design AR-guided writing learning materials or courses the goal of which is to encourage learners to experience the writing process in a variety of settings.

Future Work

Further studies could focus more on investigating using an AR-supported writing system for various writing topics to confirm and categorize the topics that are most suited to using AR techniques support. This would ensure that technology is not being used for its own sake, but that the advantages of learning technology are really being used for learning. Secondly, it is suggested that the next study focus on how the AR system can support intermediate-level learners in their writing. Thirdly, there could be an optional button on the AR screen to help learners decide the presentation mode of the AR information during the writing activity. Lastly, it is suggested that future studies recruit more participants of different genders and spend longer implementing the system so as to confirm the research findings.

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Tables

Table 1 Summary of various categorizations of AR applications

AR categorization	Study	Descriptions
a. AR applications on wearable devices	Cerqueira & Kirner (2012); Liarokapis et al. (2002)	Liarokapis et al. (2002) used AR techniques with wearable devices to support engineering education. Cerqueira and Kirner (2012) adopted AR techniques with wearable devices for learning polygon extrusion and revolution math concepts.
b. Computer-based AR or marker-based AR applications	Matcha & Awang Rambli (2011); Ivanova, Aliev, & Ivanov (2014); Bacca et al. (2015); Cifuentes et al. (2016)	Matcha and Awang Rambli (2011) used a computer-based AR system for learning the concept of light dispersion and combination. Ivanova, Aliev, and Ivanov (2014) used marker-based AR for learning the dynamic measuring process of a broach. Cifuentes et al. (2016) used a marker-based AR system for learning the Human Skeletal System and the Water Cycle.
c. Mobile-based AR applications	Chen, Huang & Hsu (2013); Bacca et al. (2015); Mitsuhara et al. (2016); Chang et al. (2016)	Chen, Huang and Hsu (2013) adopted mobile-based AR interaction for an outdoor geography course. Bacca et al. (2015) adopted a marker-based mobile AR application for learning the process of repairing paint on a car for a vocational education program. Mitsuhara et al. (2016) adopted both HMD devices and tablet computers to assist students in experiencing disaster situations. Chang et al. (2016) used a mobile-based AR system for learning about radiation energy and pollution

Table 2 Participants of Phase 1

Age	**22-25**	**26-30**	**31-40**	**41-50**	**above 50**	
%	9.50%	33.3%	42.9%	9.50%	4.80%	
Teaching experience	**Under 1 year**	**2-3 years**	**3-5 years**	**5-10 years**	**11-19 years**	**Over 20 years**
%	9.50%	33.30%	28.60%	9.50%	9.50%	9.50%

Table 3 The teachers' suggestions for improvements to the AR-based writing system from Phase 2

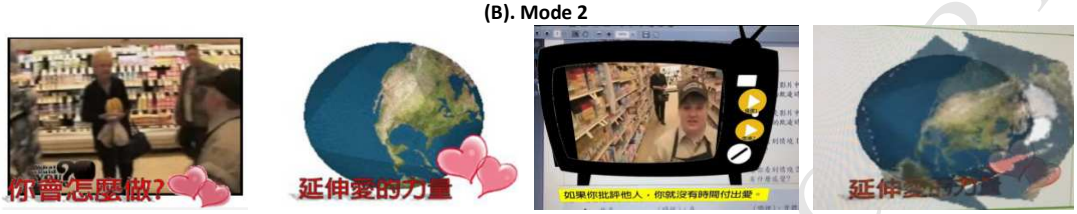
(1) Contents design	(2) Way of writing guidance	(3) Integration of AR into writing instruction
· Using writing topics in college entrance exam for practice. · Providing more positive and negative learning cases for learners as references. · Redesign the presentation of good sentences, the current AR mode was not good for reading.	· Using guiding questions to trigger students' thinking. · Designing two stages of guidance, describing the meaning of the topic in the first part and presenting related materials to arouse learners' related experience and prepare for writing in the second part.	· The AR system could be used for in-class writing practice with the assistance of instructors to produce the writing step by step. · For example, the AR contents could support the practice of three sessions of article writing. The teacher guides the learners to write in the first session and then the learners could use the supporting AR contents to finish the following sessions. · Using the AR system for outdoor writing might be suitable for small groups so that the instructor could control the learning schedule and manage the class well.

Table 4 Demonstration of Mode 1 and Mode 2

(A). Mode 1

(a)The scene on campus (b)The content lists (c) Information about the scene (d) Writing guide: using the scene as writing material

(B). Mode 2



(a)The pictures on the learning sheets (b) The AR information and animation

Table 5a Tests of Between-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	Subject	37985.208	1	37985.208	1069.325	.000
	Content control	12140.408	1	12140.408	1843.113	.000
	Article structure	11880.300	1	11880.300	3628.892	.000
	Wording	13589.408	1	13589.408	2083.428	.000
Group	Subject	15.408	1	15.408	.434	.516
	Content control	15.408	1	15.408	2.339	.137
	Article structure	28.033	1	28.033	8.563	.007
	Wording	10.208	1	10.208	1.565	.221
Error	Subject	994.633	28	35.523		
	Content control	184.433	28	6.587		
	Article structure	91.667	28	3.274		
	Wording	182.633	28	6.523		

Table 5b Descriptive statistics

						95% confidence Interval	
		N	Average	S.D.	S.E.	lower bound	upper bound
		30	10.1333	1.79527	.32777	9.4630	10.8037
Topic 3	C.G.	15	10.6000	1.54919	.40000	9.7421	11.4579
Article structure	E.G.	15	12.0667	2.34419	.60527	10.7685	13.3648
	Total	30	11.3333	2.08993	.38157	10.5529	12.1137
Topic 4	C.G.	15	8.0000	3.35942	.86740	6.1396	9.8604
Content control	E.G.	15	10.5333	2.58752	.66809	9.1004	11.9663
	Total	30	9.2667	3.21562	.58709	8.0659	10.4674
Topic 4	C.G.	15	7.7333	3.08143	.79562	6.0269	9.4398
Article structure	E.G.	15	10.1333	2.26358	.58445	8.8798	11.3869
	Total	30	8.9333	2.92355	.53376	7.8417	10.0250

Table 5c ANOVA analysis

		Sum of Squares	df	Mean Square	F	Sig.
Topic 3	Between group	**16.133**	**1**	**16.133**	**4.087**	.053
Article structure	Within group	110.533	28	3.948		
	Total	126.667	29			
Topic 4	Between group	48.133	1	48.133	5.354	.028
Content control	Within group	251.733	28	8.990		
	Total	299.867	29			
Topic 4	Between group	43.200	1	43.200	5.910	.022
Article structure	Within group	204.667	28	7.310		
	Total	247.867	29			

Table 6-a Descriptive statistics

						95% confidence Interval	
		N	Average	S.D.	S.E.	lower bound	Upper bound
Topic 4	C.G.	5	7.0000	1.87083	.83666	4.6771	9.3229
Content control	E.G.	5	11.0000	2.23607	1.00000	8.2236	13.7764
	Total	10	9.0000	2.86744	.90676	6.9488	11.0512
Topic 4	C.G.	5	6.0000	1.22474	.54772	4.4793	7.5207
Article structure	E.G.	5	10.8000	2.38747	1.06771	7.8356	13.7644
	Total	10	8.4000	3.09839	.97980	6.1835	10.6165
Topic 4	C.G.	5	7.2000	1.48324	.66332	5.3583	9.0417
Wording	E.G.	5	11.0000	3.39116	1.51658	6.7893	15.2107
	Total	10	9.1000	3.17805	1.00499	6.8266	11.3734

Table 6-b ANOVA analysis

		Sum of Squares	df	Mean Square	F	Sig.
Topic 4	Between group	40.000	1	40.000	9.412	.015
Content control	Within group	34.000	8	4.250		
	Total	74.000	9			
Topic 4	Between group	57.600	1	57.600	16.00	.004
Article structure	Within group	28.800	8	3.600		
	Total	86.400	9			
Topic 4	Between group	36.100	1	36.100	5.270	.051
Wording	Within group	54.800	8	6.850		
	Total	90.900	9			

Table 7 The one-way RM ANOVA of the two groups for Questionnaires 1 and 2

(a) Description analysis

	C.G.	Avg.	S.D.	E.G.	Avg.	S.D.
I1. I enjoyed practicing writing	Q1	3.00	1.13	Q1	3.50	0.65
	Q2	3.40	.83	Q2	3.78	0.43
I2. I was nervous when practicing writing	Q1	2.80	.78	Q1	2.78	1.12
	Q2	2.53	.64	Q2	2.21	0.58
I3. I looked forward to have writing class	Q1	2.80	.94	Q1	3.07	0.27
	Q2	3.07	.70	Q2	3.29	0.47
I4. I did not know how to start writing in the writing activity	Q1	3.33	.82	Q1	3.43	1.22
	Q2	2.73	.80	Q2	3.07	0.92
I5 The writing supports in the activity were helpful	**Q1**	**2.67**	**.488**	**Q1**	**2.50**	**1.02**
	Q2	**3.27**	**.961**	**Q2**	**3.93**	**0.83**
I6. I think it is difficult to write an outline before writing	Q1	3.20	.86	Q1	3.14	1.57
	Q2	3.27	.70	Q2	3.36	0.63
I7. I need writing supporting materials to help me write	**Q1**	**4.07**	**.85**	**Q1**	**4.64**	**0.63**
	Q2	**3.27**	**.80**	**Q2**	**4.00**	**0.68**
I8. I am confident in my writing performance	Q1	3.40	.51	Q1	3.07	0.83
	Q2	3.47	.63	Q2	3.43	0.65
I10. I am satisfied with today's writing work	Q1	3.13	.83	Q1	3.07	0.92
	Q2	3.20	.86	Q2	3.14	0.95

(b) ANOVA analysis

	C.G.			E.G.		
	Type III Sum of Squares	F	Sig.	Type III Sum of Squares	F	Sig.
I1	7.500	11.667	.004	.571	2.167	.165
I2	1.200	4.421	.054	2.286	2.773	.120
I3	.533	2.154	.164	.321	3.545	.082
I4	2.700	3.500	.082	.893	.744	.404
I5	**2.700**	**4.846**	**.045**	**14.286**	**17.33**	**.001**
I6	.033	.062	.806	.321	.218	.648
I7	**4.800**	**7.304**	**.017**	**2.893**	**8.163**	**.013**
I8	.033	.189	.670	.893	3.218	.096
10	.033	.072	.792	.036	.062	.807

Table 8 The descriptive data results for Questionnaire 3 of various achievement learners in the E.G.

	Avg -All	S.D.	Avg -H.L.	S.D.	Avg- L.L.	S.D.	Avg- M.L.	S.D.
I1. I am pleased to use the AR system for writing	3.83	.718	4.00	1.00	4.20	.45	3.50	.58
I2. I could use the AR system well	**4.08**	**.515**	4.00	1.00	4.20	.45	**4.00**	**.00**
I3. The AR system is helpful in guiding me to write	3.58	.669	3.33	.58	3.80	.84	3.50	.58
I4. I like to use the AR system for outdoor writing	3.50	.905	3.67	1.16	3.80	.84	3.00	.82
I5. I like to use the AR system for indoor writing	3.83	.718	4.00	1.00	**4.00**	**.71**	3.50	.58
I6. The use of the AR system helped me to start writing more quickly	3.92	.793	4.00	.00	**4.20**	**.84**	3.50	1.00
I7. The AR system enriched my ideas for writing	3.92	.515	3.67	.58	**4.20**	**.45**	3.75	.50
I8. Using the AR system enhances my writing motivation	**3.67**	**0.49**	3.67	.58	3.67	.58	**4.00**	**.00**
I9. Using the AR system enhances my writing creativity	3.42	.900	4.00	.00	4.00	00	2.50	.58
I10. I like to use the AR system for writing in general	3.75	.754	3.00	1.00	**4.20**	.45	3.75	.50
I11. I think using the AR system is useful to assist writing	3.75	.622	3.33	.58	**4.00**	.71	3.75	.50

*H.L.: high-achievement learners; M.L.: medium-achievement; L.L.: low-achievement

Figures

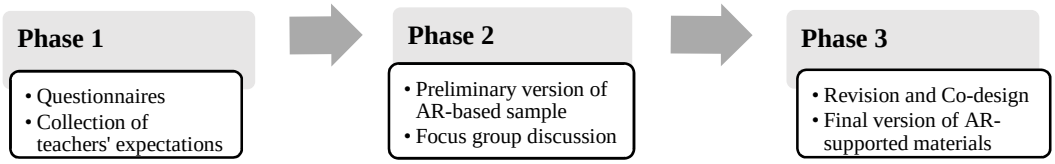


Figure 1 The three phases of the co-design stage

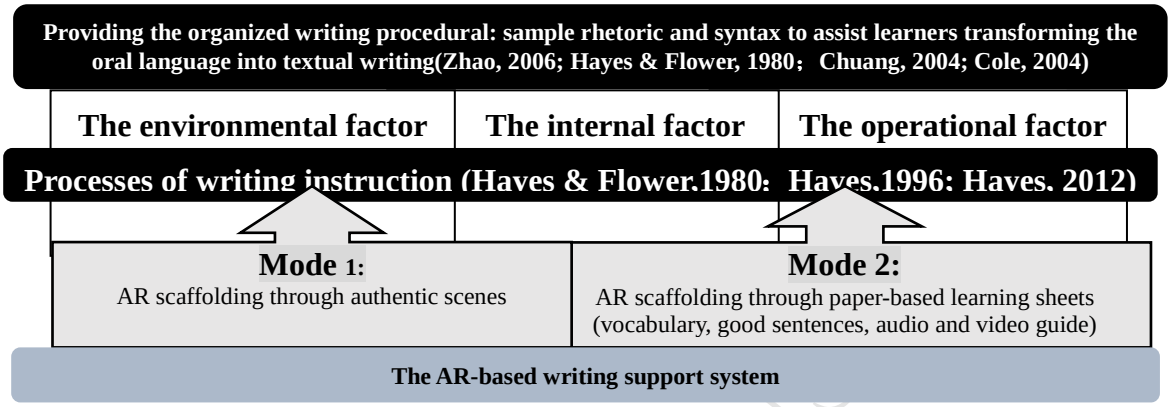


Figure 2 The framework of the system: Mode 1 and Mode 2

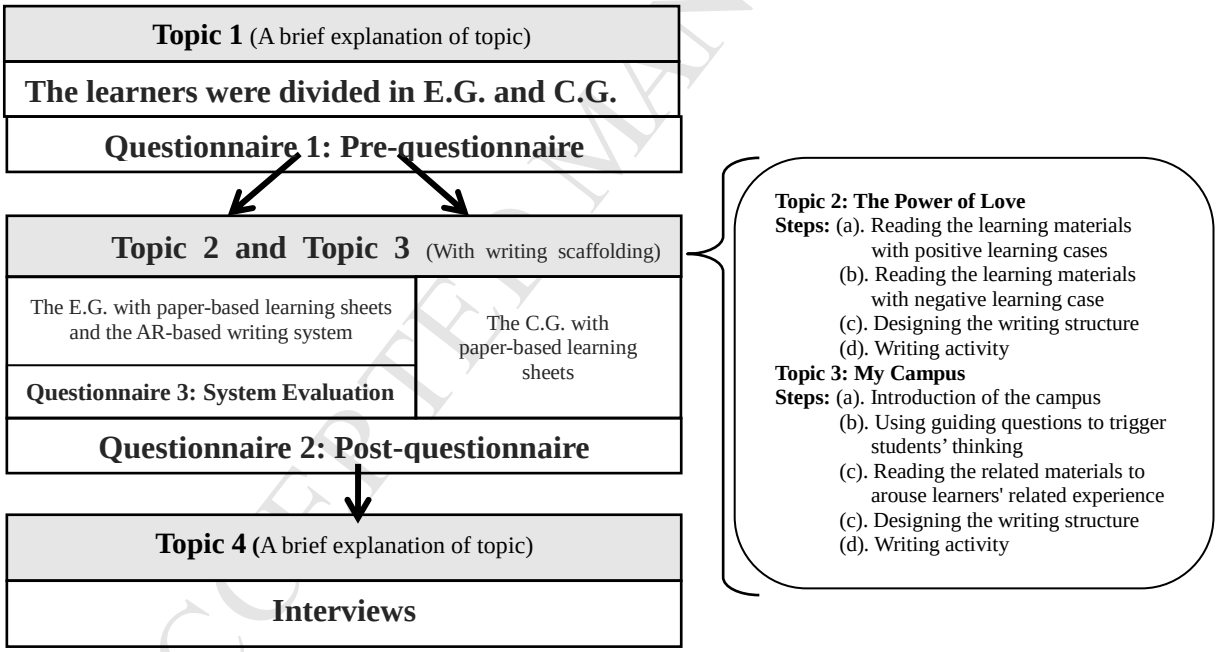


Figure 3 The structure of the experiment

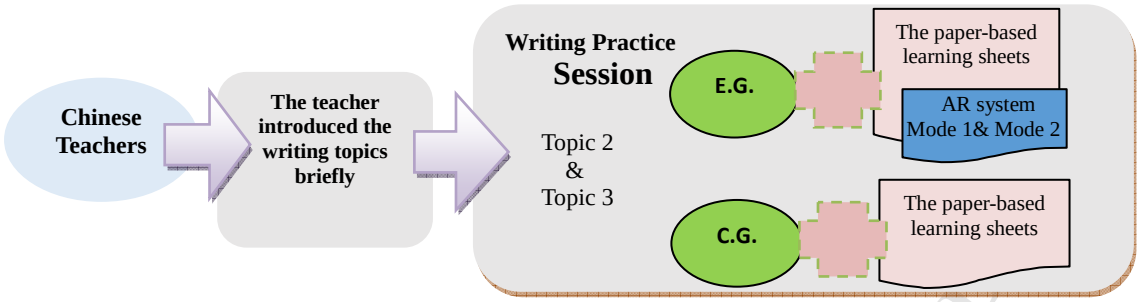


Figure 4 The process of integrating the AR-based writing support system into the writing practice

(a) The learners with the AR-supported system: Mode 1

(b) The learners in the E.G. with the AR-supported system: Mode 2

Figure 5 The learning scenario of the E.G. with the AR-based writing support system

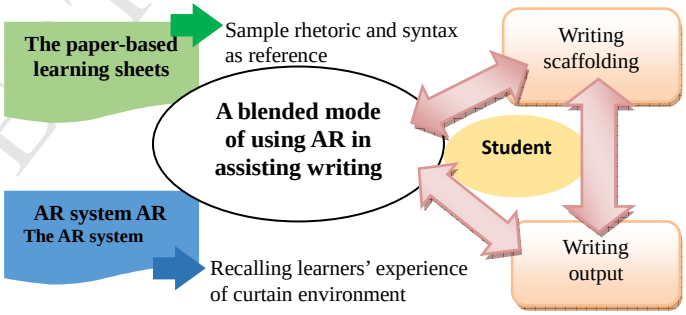


Figure 6 A blended mode of integrating AR techniques into assisted certain environments

Highlights

- The co-design study explored the effects of using AR technology to assist writing.
- Using AR-based materials benefit intermediate-level students' writing performance.
- The AR-based materials help learners to organize thoughts and ideas for writing.
- A blended mode of integrating AR techniques in writing courses is proposed.