From motivational experience to creative writing: A motivational AR-based learning approach to promoting Chinese writing performance and positive writing behaviours

Abstract

The ability to write is one of the key literacies required by students in relation to 21st century skills and is an emphasis of early education. Although the ability to write is a vital foundation for further education, due to the lack of authentic experience and limited instructional methods, cultivating writing ability in the early stage of education is still a significant challenge for students in elementary schools. Therefore, the majority of students are not able to actively engage in the process of learning to write. To address these problems, this study proposes a motivational AR-based (MAR) learning approach to support students in learning to write, which not only provides an authentic learning environment, but also aims to motivate students' active writing. Its effects were verified through a quasi-experiment. A total of 47 elementary school students from China were invited to participate and were assigned to either an experimental group (EG) which was exposed to the MAR approach or the control group (CG) which was exposed to the motivational learning approach in a conventional environment (MC). The results showed that the proposed MAR learning approach improved the students' writing performance in terms of feature descriptiveness and thinking innovation. It can be found that, compared with the CG, the achievement gaps between the low- and high-engagement students were much larger in the EG. In addition, the sequential pattern analysis results showed that students who learned with the MAR learning approach concentrated more on the process of observation than those who learned with the MC learning approach, and they tended to exhibit less distracted behaviours. To sum up, the proposed MAR learning approach was effective in terms of facilitating elementary school students' writing education. The main contribution of our study is that it provides evidence for the effectiveness of the proposed MAR learning approach and opens up opportunities for future studies which aim to further explore its impacts in different designs of writing learning activities.

Keywords: Augmented and virtual reality; Elementary education; Teaching/learning strategies; Improving classroom teaching

1. Introduction

The ability to write is one of the key literacies required by students in relation to 21st century skills (Alismail & McGuire, 2015); however, for most students, learning to write is a challenging and tedious process that needs a "tremendously complex problem-solving act involving memory, planning, text generation, and revision" (Bruning & Horn, 2000, p. 26). Moreover, due to the lack of authentic learning opportunities, the cultivation of writing skills has always been one of the dilemmas for learners, especially in the early stages of writing learning (Authors et al., 2021). Students may find it difficult to transmit their feelings or abstract ideas into specific writing scripts (Hsueh & Lai, 2008), or may not be able to activate their prior knowledge and be prompted to resonate with the writing context (Matsumura, Correnti & Wang, 2015). Correspondingly, students generally exhibit little engagement in the writing learning process, which hinders their development as active writers (Collie, Martin, & Curwood, 2016; Gardner, 2018; Graham et al., 2014; Hyland, 2002; Schunk & Zimmerman, 2007).

Augmented reality (AR) provides learners with an opportunity have an authentic experience related to the writing topic and facilitates the process of writing learning. It can provide authentic interactive learning opportunities by overlaying virtual objects in text, image, or video forms over the real world (Azuma, 1997), and causes the learner to experience less dizziness than using virtual reality and it does not hinder communication between users (Azuma, 1997). Researchers have revealed that the authentic and interactive capabilities of AR can help students to relate their previously learned knowledge/experience to the learning topic and stimulate their engagement in the writing learning process (Koç, Altun & Yüksel, 2022; Wang, 2017; Yılmaz & Batdı, 2016). Furthermore, the enriched immersion and experience provided by AR technology exhibit great potential for cultivating empathy as well as breaking through emotional barriers, and the vivid authentic inputs can motivate students to express their feelings in written language and trigger meaningful creative writing (Koç, Altun & Yüksel, 2022). Studies on the AR-based learning approach in different writing learning situations have shown to have beneficial effects in promoting students' writing skills (e.g., Koç, Altun & Yüksel, 2021; Lee & Park, 2020; Lin, Liu & Chen, 2020; Wang, 2017). However, there is still limited research on, and a major concern about this technological convergence, specifically whether the AR-based learning approach itself can help regulate the ups and downs of learners' engagement in writing. Researchers have already echoed the concern that the novelty of AR innovations can diminish rapidly when students become more familiar with the AR-based learning approach (Akçayır & Akçayır, 2017; Bursali & Yilmaz, 2019), or simply, students may not be motivated to learn unless they are exposed to complementary psychological dynamics to peak their interest (Lamb, 2017). In this respect,

researchers have pointed out that future AR-based research should no longer focus on "whether" the AR-based learning approach can promote learners' learning achievement (Wu, Lee, Chang & Liang, 2013), but on "what kinds" of AR-based designs can encourage students' engagement in the AR-supported materials or activities (Hao & Lee, 2021). That is, a pedagogical model to motivate and guide learners to use AR in writing is needed.

The motivational learning model (the ARCS model) proposed by Keller (1987) is a pedagogical model that provides practical strategies and methods for instructors to design the teaching processes and resources, which can motivate and guide learners to learn in an AR-enhanced environment (Chen, 2019; Hao & Lee, 2021; Lu et al., 2020). It provides a way of conducting a built-in design to ensure that AR-based courses maintain students' active engagement (Di Serio, Ibáñez & Kloos, 2013), which is also a theory to explain how AR technique can ensure the long-term engagement of students in writing learning (Mirzaei, Shafiee Rad & Rahimi, 2022).

Studies exploring the effectiveness of the fusion of AR and the ARCS model have been applied in many fields, for instance, mathematics education (Chen, 2019), science education (Lu et al., 2020), visual art education (Di Serio, Ibáñez & Kloos, 2013) and language learning (Ebrahimi, 2022). However, the potential of combining AR and the ARCS model in writing education is still unexplored, with only a limited number of studies investigating students' learning performance and learning behaviour in AR-based environments, and the effects of different engagement levels have not been fully examined. To bridge this gap, the present study proposed a motivational AR(MAR) approach (see details in Section 2.2) and aimed to extend prior research on the use of both AR and the ARCS model to provide evidence of the effectiveness of the proposed MAR learning approach. It also aimed to open up opportunities for future studies which aim to further explore its impacts in the different designs of writing learning activities.

1.1 The current state of writing learning

Writing is of great importance to primary school students as it enables them to acquire knowledge, communicate and demonstrate learning outcomes in various disciplines (Allen, Jacovina & McNamara, 2016; Rietdijk et al., 2018). However, it is a complex intended problem-solving activity requiring students to coordinate multiple cognitive skills and sources of knowledge through the process of goal setting, problem solving and the strategic management of memory resources (Allen, Jacovina & McNamara, 2016; Hayes & Flower, 1980). Many children struggle to learn how to write and they generally face substantial challenges in mastering writing in their native or second language (MacArthur, Graham & Fitzgerald, 2016; Rogers & Graham, 2020). National assessment studies have shown that writing proficiency problems are common in many countries (Graham & Rijlaarsdam,

2016). For example, one national assessment study from the United Kingdom showed that many elementary school students in their country performed below the expected level for writing (Rietdijk et al., 2018). Similarly, many elementary school students in Turkey were found to be poor writers (Graham, Tavsanli & Kaldirim, 2021). It is clear that the quality of writing learning in many countries is in dire need of improvement.

Researchers have noted that the main difficulties faced by writing learners emanate from three main sources: the first is that students lack the ability to transfer their feelings or abstract ideas into specific writing scripts; the second is their underachievement in rousing their relevant knowledge or experience from long-term memory to incorporate it into their writing; and the third is that they generally lack the engagement to participate in writing tasks (Berninger, 1999; Pressley & McCarmick, 1995). These difficulties are echoed in the study of Flower (1994) and Hayes (1996), in which they claimed that writing is a process of social cognition which needs to be situated in authentic contexts to provide purposes for writing, content, genre and audience as well as resources to support writing. With the contextual experience provided, students are able to establish internal connections between their prior knowledge and writing context, then they are engaged to describe their feelings in written language (Authors et al., 2022a). In this regard, many researchers have focused on finding effective methods or tools that provide an authentic context in which to empower young learners to learn to write (Authors et al., 2021; Graham, 2022). The present study, therefore, aimed to integrate authentic techniques to support the development of writing skills for elementary school students.

The enhancement of the ability to transfer ideas to the context of writing requires considerable effort and attention during the writing learning (Berninger, 1999). This in practice lends support to the argument that student engagement is one of the most critical factors contributing to the success of writing learning (Hu & Kuh, 2002; Richardson & Newby, 2006). As was suggested by Authors et al. (2021), students with higher engagement tended to exhibit a better writing performance. In turn, students who make positive achievements in the learning-to-write process generally exhibit positive learning behaviours (e.g., raising their hands to answer questions proactively, asking/answering questions proactively) (Authors et al., 2022a). Given the important role of student engagement in writing learning, we focus on different levels of student engagement to determine if it is affected by different learning approaches. Also, we explored whether different writing learning approaches would lead to different learning behavioural patterns.

According to Fredricks, Blumenfeld and Paris (2004), student engagement consists of three key elements, namely emotional engagement (physiological input, e.g., enjoyment, frustration.), behavioural engagement (behavioural effort, e.g., task participation), and cognitive engagement (mental effort, e.g., task attention). Although the three-dimensional framework of student engagement

is used in studies in writing education (e.g., Rahimi & Zhang, 2022; Zheng & Yu, 2018), researchers have mentioned that there is overlap in the definitions across different types of engagement (Fredricks, Blumenfeld Friedel & Paris, 2005). For example, it is likely to be blurred between efforts that demonstrate a mental investment in learning and efforts that simply reflect behavioural compliance with school requirements (Dotterer & Lowe, 2011; Henrie, Halverson & Graham, 2015). Furthermore, cognitive engagement (CE) is viewed as a higher-order engagement that includes metacognition and self-regulation, which to certain extent implies that the self-reported CE results from primary school students may be unreliable because they are too young to understand sufficiently the higher-order engagement (Li & Lerner, 2011; Madden, Green & Grant, 2020). Correspondingly, in the present study, we focus on behavioural and emotional engagement, which are more generally emphasized than cognitive engagement in studies of young learners (Dotterer & Lowe, 2011; Henrie, Halverson & Graham, 2015; Kaiser, Retelsdorf, Südkamp & Möller, 2013; Kim & Cappella, 2016; Li, Lerner & Lerner, 2010). In this study, 'student engagement' refers to behavioural and emotional engagement, unless stated otherwise.

1.2 Benefits of AR for writing learning

Augmented reality (AR) is a technology that has authentic functions, and it has been gradually employed to motivate and engage students in writing (Koç, Altun & Yüksel, 2021; Lee & Park, 2020; Lin, Liu & Chen, 2020; Wang, 2017). For example, Wang (2017) verified that the AR-based learning approach is able to support students' writing learning in high schools. The results of their study revealed that the AR approach is able to enhance content control, article structure, and the wording of students' writing performance. They further pointed out that students with low writing achievements tended to make extraordinary gains in the AR-based learning environment because they could start the first paragraph of writing more quickly than before. Lin, Liu, and Chen (2020) designed an AR-based context-aware ubiquitous writing application and conducted a quasi-experiment to verify whether the proposed application could enhance EFL students' writing instruction. Their results showed that AR is able to facilitate the construction of students' writing task schema in long-term memory and promote their writing engagement. Although studies have confirmed the effectiveness of integrating AR technology into writing activities (Koç, Altun & Yüksel, 2021; Lee & Park, 2020; Lin, Liu & Chen, 2020; Wang, 2017), it is yet to be determined whether it can promote students' writing learning in elementary schools. In particular, elementary school students are at the initial stage of developing their writing ability (Authors et al., 2021). Their minds are at the stage of concrete operation, and hence the development of their abstract thinking often relies on the support of concrete objects (Authors et al., 2022a). The way AR is used in elementary school writing education ought to be different from those

previous attempts of employing AR in writing activities for high school or tertiary level learners (Koç, Altun & Yüksel, 2022; Lee & Park, 2020). Therefore, the present study aimed to incorporate a suitable pedagogical model to motivate and guide younger learners in an AR-assisted writing learning context.

1.3 Benefits of the Motivational (ARCS) model for learning

Keller's ARCS model comprises four stages, namely, attention, relevance, confidence, and satisfaction (see Fig.1). It illustrates a motivational learning process in which the first stage is to capture and maintain the attention of students while also stimulating their curiosity to learn (Keller, 2008). The second step must ensure that the learning activity is in line with the individual goals and needs of the students, so as to be perceived as relevant (Keller, 2008). In these two steps, the learner should establish confidence by feeling in control and having expectations of success, since the extent of the achieved expectations will determine the amount of effort the learner puts into completing the activity (Di Serio, Ibáñez & Kloos, 2013). When the instruction succeeds in achieving the first three motivational dynamics, the learner subsequently feels motivated. Finally, the experience of learning satisfaction sustains their progressive desire to learn (Mirzaei, Shafiee Rad & Rahimi, 2022).

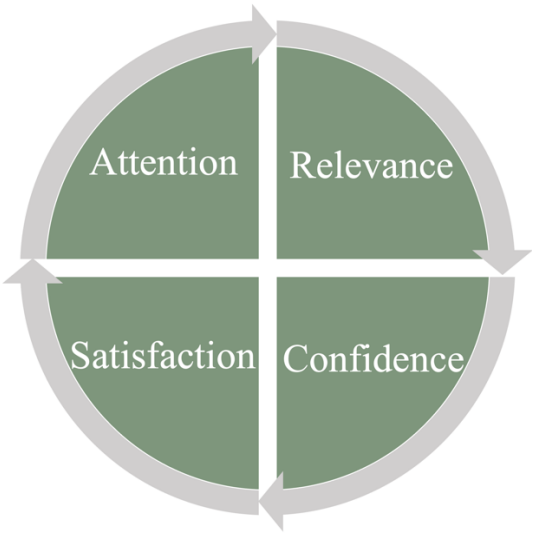

Fig. 1 The ARCS model (Keller, 1987)

The ARCS model has been utilized in multiple studies in different disciplines, such as mathematics (Turel & Sanal, 2018), language learning (Ebrahimi, 2022), and writing education (Mirzaei, Shafiee Rad & Rahimi, 2022). With the development of information and communication technologies, the need to incorporate motivational design into technology-assisted learning environments has become more pressing (Li & Keller, 2018). Song and Keller (2001) stated that the ARCS model can be utilized as a pedagogical model to guide technology-enhanced instructions. Annamalai (2016) stated that it was effective in designing a multimedia e-book approach based on the design of the ARCS model. Recently, there has been an emerging research effort to design AR-

assisted activities using the ARCS model, since the interaction patterns of AR applications during learning activities echo the first three phases of the ARCS model (Hao & Lee, 2021). Specifically, AR applications use videos or images to stimulate the attention of the learner, which helps them to establish a connection with the learning content, and then through an interactive learning process, the learner will develop confidence in their ability to perform the learning task (Ebrahimi, 2022). For example, Wei et al. (2015) examined the fusion of AR and the ARCS model and found it is effective for enhancing senior high school students' technical design ability. In addition to these studies, however, there is a paucity of research on the impact of combining AR and the ARCS model in writing education and on how well learning with a motivational learning (ARCS) procedure in an AR (MAR) learning environment triggers positive learning behaviour when compared to learning with an ARCS procedure in a conventional (MC) learning environment. It is also unclear whether different learning approaches lead to different writing performances of students with different levels of engagement.

1.4 The current study

To fill the gap in the literature, the current study proposed a MAR approach and examined its effects on students' writing performance and learning behaviours. Also, whether the proposed approach would lead to different writing performance between students with different levels of engagement was explored. To this end, we employed a quasi-experiment in an elementary school, involving two groups of elementary school students who participated in writing learning activities using either the MAR or MC approach. In addition, our study explored student learning perceptions under different learning approaches with a post-intervention qualitative inquiry. Previous studies (e.g., Authors et al., 2021; Lin, Liu & Chen, 2020) emphasized the need for researchers to conduct qualitative investigations into students' perceptions in different designs of writing learning environments to further explicate the quantitative findings and provide more convincing conclusions. The research questions are as follows:

(1) To what extent does the motivational AR-based learning (MAR) approach improve the students' Chinese writing learning performance in comparison with the motivational model-based conventional learning (MC) approach?

(H1). It is expected that students learning with the MAR approach will perform better than those learning with the MC approach since previous studies have reported that the incorporation of AR and the ARCS model can significantly improve students' learning achievement (Hao & Lee, 2021; Li & Keller, 2018).

(2) Are there differences between the writing achievements of students with lower and higher levels of behavioural engagement?

(3) Are there differences between the writing achievements of students with lower and higher levels of emotional engagement?

(H2 and H3). It is expected that the gap in the writing achievement between students with lower or and higher levels of engagement will be significantly wider in the group learning with MAR than in the group learning with MC. As suggested by Authors et al. (2021), authentic learning intervention is more effective for students with higher levels of student engagement.

(4) Are there differences in the learning behaviour patterns of students learning with different approaches?

(H4). Previous studies have claimed that the fusion of AR and the ARCS model may increase students' task attention, which would further reduce their distracting learning behaviours (Di Serio, Ibáñez & Kloos, 2013). It is expected that students learning with the MAR approach will be more focused and exhibit less distracting behaviours than those learning with the MC approach.

(5) What are the students' learning perceptions under the different learning approaches?

(H5). It is expected that different learning perceptions will be found between students learning with the MAR and MC approaches.

2. Motivational AR-based learning approach for Chinese article writing

2.1 System structure

Fig. 2 shows the structure of the AR system. In the teacher terminal, the teacher prepares the learning materials (e.g., scripts, learning sheets, 360-degree interactive AR) for students, and collects these learning materials into a learning portfolio database for further analysis. In the student terminal, the students are guided to observe and interact with the brachiosaurs through the AR system and discuss with their peers or the teacher to share ideas with each other.

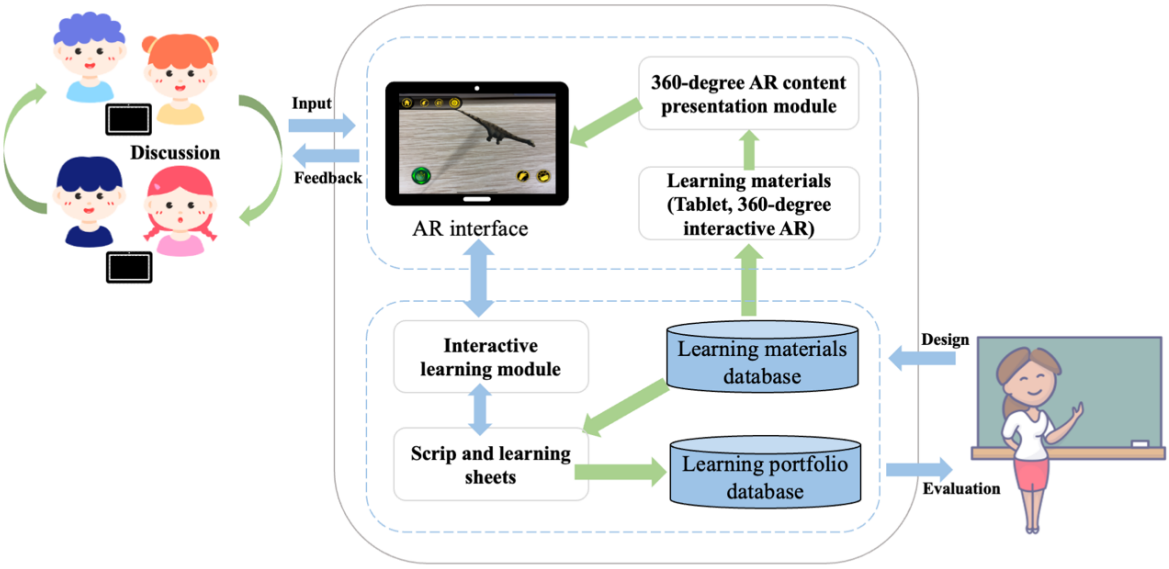

Fig. 2 Structure of the AR system

2.2 MAR learning approach

The MAR learning approach was utilized so students can experience an authentic learning process by engaging with AR scenarios in classroom learning activities. Our study was focused on writing activities in elementary school writing courses. To comply with the requirements of Chinese Curriculum Standards for Full-Time Compulsory Education in China, we chose "The birth of a brachiosaurus" as the theme of the writing activity. Since the brachiosaurus is an extinct dinosaur from the Jurassic period, it is impossible for students to see it in the real world. One of the main goals of teaching is to increase the depth of students' perceptions of scenes that are impossible or difficult to observe directly in the real world and to enhance their sense of presence to alleviate the feeling of alienation caused by the lack of physical experience.

The AR materials used were developed by Red Frog Digital Limited. As shown in Fig. 3, the AR system consists of one application (app) called "iDinosaur AR" and one iDinosaur book. This app was designed specifically to be used with the iDinosaur book. Using the "iDinosaur AR" app (see Fig. 4), students not only observed authentic 3D scenarios, but also interacted with the system, such as cracking the brachiosaur egg, controlling the brachiosaur's movement, and making the brachiosaurus cry. There are also several functions that students can choose, depending on their preferences, for example, they are able to take photos of the brachiosaurus through the screenshot function can increase students' experience and help them to conduct more detailed observations. They can also access the settings to adjust the screen size and brachiosaurus sound level.

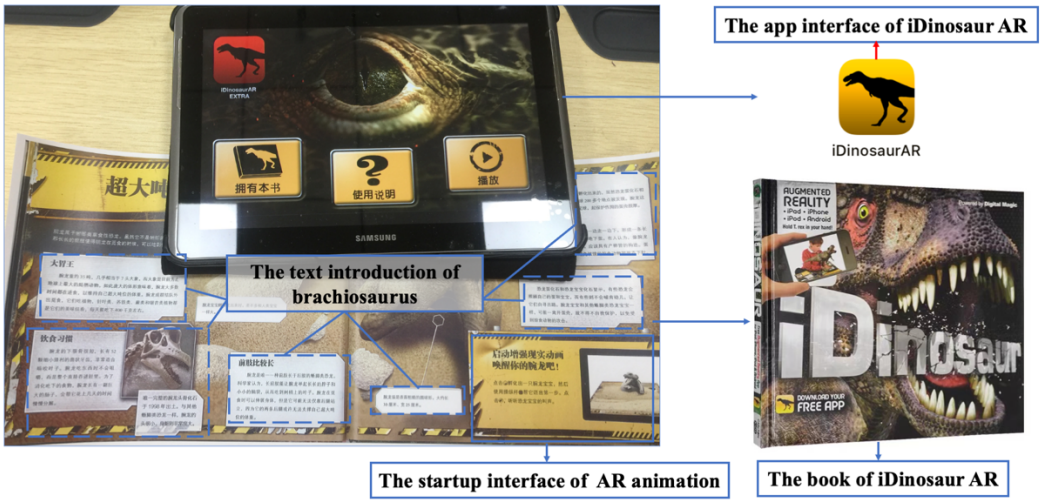

Fig. 3 Introduction of the AR materials

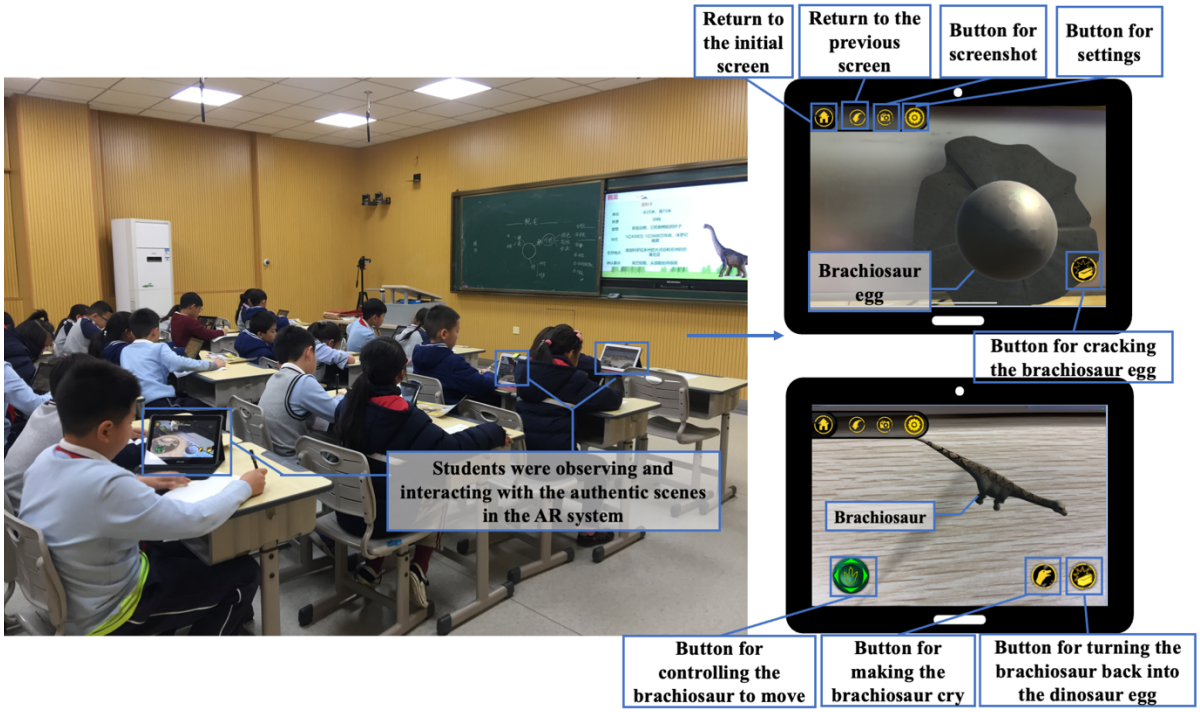

Fig. 4 In-class activity of students in the attention stage and the interface of observation and interaction in the app

In our study, a MAR learning approach was proposed based on the ARCS model from the motivation theory which was put forward by Keller (1987), as shown in Fig. 5. It has been verified to be an effective learning model to facilitate learners' writing performance in other studies (Annamalai, 2016; Mirzaei, Shafiee Rad & Rahimi, 2022). The approach comprises four stages, namely attention, relevance, confidence, and satisfaction. During the four stages of learning, students' learning motivation, engagement and confidence in writing activities will be enhanced to a certain extent. In the attention stage, students are guided to observe and interact with the brachiosaurus through the MAR

learning approach (see Fig. 4) and the process of interactive observation will stimulate and sustain the students' curiosity and interest. In the relevance stage, the teacher guides the students to relate to familiar knowledge/experience so they will not feel alienated from the learning context or become removed from their learning goals. In the confidence stage, the students are led to answer the questions posed by the teacher, and in the process of receiving feedback and/or recognition from the teacher, their confidence in expressing their ideas in writing will be built. If the students are successful in achieving these first three motivational goals (attention, relevance, and confidence), they are likely to be motivated to learn in the writing activities. Next, the stage of satisfaction ensures that the students will have a continuing desire to learn through discussion or interaction with their peers/the teacher and they should experience a sense of accomplishment.

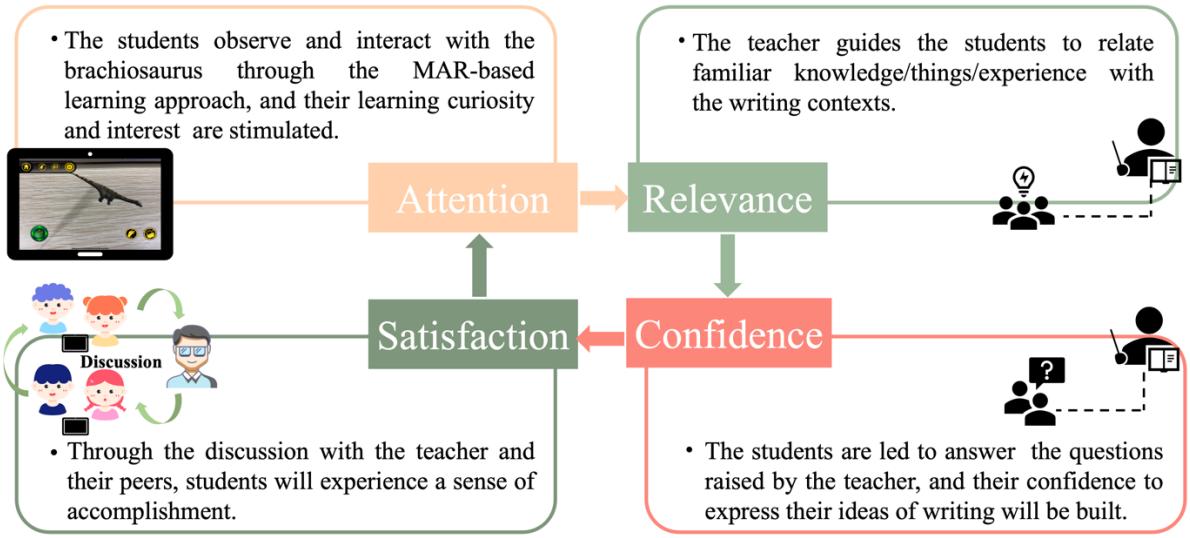

Fig. 5 The MAR learning approach

3. Methods

3.1 Participants

The inclusion criteria for the participants are: (1) the students must speak Chinese as their mother language; (2) the students must not have a severe cognitive or learning disability; (3) the students must not have a physical disability (e.g., visual impairment) which might decrease their AR-based learning experience. A total of 47 fourth graders (10- or 11-year-olds) from two classes at an elementary school in southeastern China were invited to participate. They were recruited through school administration contacts. Initially, a sample of 50 participants was recruited for this study. Three students (1 from the experimental class and 2 from the control class) were eliminated because their pre- or post- writing tests were not completed. To justify the sample size of this study, a post-hoc power analysis using

G*Power 3.1 (Faul, Erdfelder, Lang & Buchner, 2007) was performed. The result of the statistic power was 0.87, indicating that the sample size of our study was sufficient to reveal the main effects between the dependent variables of the control and experimental groups (Authors, 2022b; Chen & Chiu, 2016). The participants had no prior experience of using AR. Their background information is given in Table 1, showing the mean age of the participants was 10.4 years with a standard deviation of 0.496 years. Students from two classes participated in our empirical study, where one class was allocated to be the experiment group (EG) while the other class was the control group (CG): EG (N = 26, 15 males, 11 females; M_{age} = 10.35 years; SD = 0.485) and the CG (N = 21, 12 males, 9 females; M_{age} = 10.48 years; SD = 0.512). Most of the students (89.4%) were of middle socioeconomic status (SES), while a small percentage of were of high SES (4.2%) and low SES (6.4%).

Table 1 Participant background information

	Full sample	EG	CG
Average age	10.4 (*SD*=0.496)	10.35 (*SD*=0.485)	10.48 (*SD*=0.512)
Gender			
The number of males	27	15	12
The number of females	20	11	9
Socioeconomic status (SES)			
High	2 (4.2%)	1(3.85%)	1(4.76%)
Middle	42(89.4%)	23(88.5%)	19(90.48%)
Low	3(6.4%)	2(7.69%)	1(4.76%)
N	47	26	21

In the present study, convenience sampling was used, which allows researchers to quickly and easily access a sample (Sahin & Yilmaz, 2020). This sampling method was preferred because of the willingness of the selected school to participate in the study. We chose this school for two reasons. namely, one of the researchers has worked there as a Chinese teacher, and it was also easy to contact the students and it was close by in terms of distance. The principal and five teachers were asked to indicate their willingness to participate in the experiment by completing a consent form (two of them were the ones in charge of these two classes, two of them participated in grading the writing, and one of them acted as the writing instructor for our experiment), and all accepted. The participants were recruited during the first semester of the 2020-2021 academic year and we were allowed to conduct the intervention study during the non-instructional period. The data collection period lasted from 5th to 23rd October 2020. The experiment was conducted according to the principles in the Declaration of

Helsinki. Parental consent for each participant was provided and the parents were given documentation to explain the experiment. Furthermore, standard ethical institutional procedures were undertaken to ensure participant anonymity (e.g., name, class) and all the participants were told that their participation was voluntary and that they could leave the experiment at any time during the experiment process.

3.2 Experimental design and procedure

The current study employed a mixed-methods quasi-experimental design which included both quantitative (i.e., ANCOVA, *t*-test, ANOVA) and qualitative analysis (i.e., sequential analysis and interview). The learning approaches and different levels of student engagement were the independent variables, while the writing post-test, the learning behaviour and the learning perceptions were the dependent variables. Prior to the implementation of the experiment, all participants from the EG and CG were asked to complete a writing pre-test to determine whether the prior writing performance levels of the groups were equal.

A total of five analyses were performed to examine the research hypotheses proposed in this study. First, we analysed the differences in writing achievements of the students who learned with the MAR learning approach and those who learned with the MC learning approach. Then, we compared the writing outcomes of students with different levels of student engagement (behavioural and emotional engagement) in the two groups, after which we performed a sequential analysis to identify the learning behaviours of students who were exposed to the different approaches. Finally, a total of 16 students (8 from the EG and 8 from the CG) were randomly selected to participate in the interviews.

Fig. 6 shows the experimental procedure used in this study. The duration of our experiment was four weeks; in week 1, both groups of students completed the pre-tests to assess their writing performance. The independent sample *t*-test result showed no significant difference ($t = 1.399$, $p = 0.169 > 0.05$) between the pre-test writing scores of the EG ($M = 66.89$, $SD = 10.49$) and the CG ($M = 63.08$, $SD = 7.51$), which suggests that the previous writing performance of the two groups of students is equal. During the second week, the two groups were taught by the same instructor, who has more than seven years of experience in teaching Chinese writing, and the learning content in both groups was consistent. The classes for the two groups were held on different days. Both groups of students participated in over 90 minutes of writing activities following the ARCS model teaching procedure, but different learning tools were used for observation/interaction. That is, the EG students used AR-based material to interact with and observe the brachiosaurus, with each student sharing a tablet with their deskmate. In the CG, students observed a brachiosaurus using paper-based materials, and each student shared a booklet with their deskmate. They then completed a post-test to assess their writing

achievements and engagement. All written manuscripts and questionnaires were collected by the course instructor and were delivered to the second author of this paper. In addition, the classroom learning behaviours were video-recorded for further analysis. In week 3, a total of 16 students (8 from the EG and 8 from the CG) were randomly selected to participate in the group interviews to obtain their perceptions of the two different learning approaches.

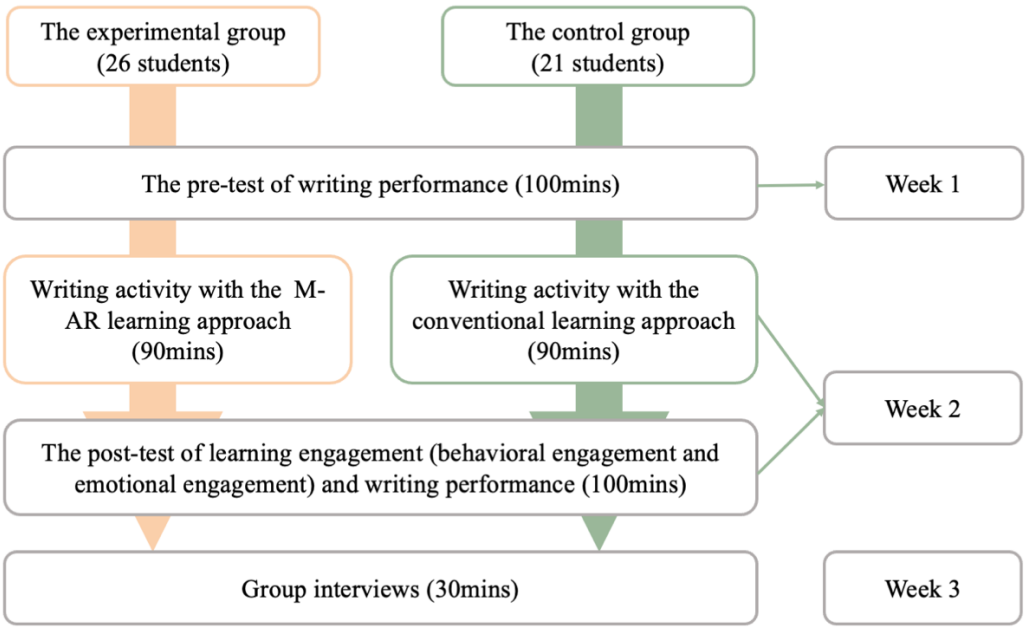

Fig. 6 Experiment procedure

3.3 Measuring tools

3.3.1. The rubric of Chinese writing outcomes

As shown in Table 2, there are four dimensions in the rubric of Chinese writing outcomes, namely linguistic accuracy, feature descriptiveness, rhetorical expressiveness, and thinking innovation. This was developed by referring to the writing evaluation scales proposed by Authors et al. (2019) and Authors et al. (2021), and all the dimensions were translated into Chinese and checked by three experienced instructors who had taught Chinese writing courses for more than 10 years. Linguistic accuracy refers to the correct usage of words, punctuation, and so on. Feature descriptiveness refers to the ability to grasp the main features of one concept, and the ability to highlight priorities when describing it. Rhetorical expressiveness refers to the ability to use rhetorical statements to express the feelings and details of the composition. Thinking innovation refers to the uniqueness and novelty of the subject idea, narrative perspective, and evidence description. The students' writing achievements were scored out of 100 points, with 35 points for linguistic accuracy, 30 points for feature descriptiveness, 25 points for rhetorical expressiveness, and 10 points for thinking innovation.

The students' writing pre-tests and post-tests were evaluated by two experienced Chinese teachers who have taught Chinese writing for more than 10 years. The writing grading teachers were required to use a back-to-back, double-blinded assessment method. The Cohen's kappa of their grading scores shows acceptable inter-coder reliability (k = 0.86) (Cohen, 1968), and the average scores of the two teachers were used as the final scores of the students' writing performance.

Table 2. Four-dimensional rubric for Chinese writing outcomes

Dimension	Index	85-95	75-85	65-75	65-55
Linguistic accuracy (35%)	Refers to the accuracy of the usage of words, punctuation etc.	The words used in the composition are accurate and very appropriate, and the writing is complete, with standard punctuation, correct sentences, and the paragraphing of the composition is reasonable.	The words in the composition are basically accurate and appropriate, the writing is basically complete, the punctuation is standard, and the paragraphing of the composition is reasonable. (Error 1-2)	The words in the composition are basically accurate but not necessarily appropriate, and the writing is not standard; the punctuation is basically standard and the paragraphing of the composition is basically reasonable. (3-4 errors)	There are many mistakes in the composition, and the writing is not standard. The punctuation is not standard and the paragraphing of the composition is not reasonable. (More than 5 errors)
Feature descriptive -ness (30%)	Refers to the ability to grasp the main features of one concept, and the ability to highlight priorities when describing it.	The composition describes the features of the objects in detail (more than 3-4 physical features or functions and uses) and highlights their unique features to distinguish the differences between things.	The composition describes 2-3 features of the objects. Although the uniqueness of the description is not outstanding, it highlights the differences between things.	The composition describes 1-2 features of the objects but fails to describe their uniqueness, making it difficult to distinguish the differences between things.	The composition fails to describe the features of the objects, the description was messy and varied, and the differences between things cannot be distinguished
Rhetorical expressive -ness (25%)	Refers to the ability to use rhetorical statements to express the feelings and details of the composition	The rhetoric is appropriate, vivid, reasonable and fluent.	The rhetoric is appropriate and vivid, there are 1-2 places where the sentence is not expressed well, but it is generally smooth.	The figure of speech is not appropriate, the image is not vivid enough, there are 3-4 incorrect sentences in the expression, and it is not very smooth.	There is no rhetorical device, the words fail to express the meaning, there are 5-6 problematic sentences, and

					overall, the article is not fluent.
Thinking innovation (10%)	Refers to the uniqueness and novelty of the subject idea, narrative perspective and evidence description.	The writing has a unique and profound conception, a unique narrative perspective, and uses association, imagination, analogy and quotation to describe evidence (more than 3)	The writing is profound in conception, but not unique. The narrative perspective is more conventional, and the evidence uses 2-3 associations, imaginations, analogies and citations.	The intention of the writing is not profound or unique, the narrative perspective is conventional, and only 1-2 points of association, imagination, analogy and quotation are used as evidence.	The purpose of the writing is unclear, the narrative perspective is confused, and the evidence fails to adopt any association, imagination, analogy or quotation.

3.3.2. Student engagement questionnaire

The student engagement questionnaire for Chinese writing uses the measurement scale proposed by Sun et al. (2021), and the original Cronbach's α coefficients were .82 for behavioural engagement and .86 for emotional engagement. It comprises two subscales with a total of 10 items (5 for behavioural engagement and 5 for emotional engagement). All the phrases were slightly modified based on the situation of the present study, for example, "I will listen carefully to the teacher when I am taking a writing class" for behavioural engagement, and "I think I am in a relaxed mood during the writing class" for emotional engagement. A 5-point Likert scale (from 1-*strongly disagree* to 5-*strongly agree*) was employed in the questionnaire. Each sub-scale has a minimum score of 5 and a maximum score of 25. For example, if a student strongly agrees on all five items of emotional engagement, the emotional engagement score is calculated as 25 points.

The reliability of the questionnaire was tested after all modifications and showed that the questionnaire (Cronbach's $\alpha = .928$; $\omega = 0.942$) and its two subscales of behavioural engagement (Cronbach's $\alpha = .852$; $\omega = 0.898$) and emotional engagement (Cronbach's $\alpha = .875$; $\omega = 0.912$) were reliable in terms of internal consistency. An exploratory factor analysis (EFA) using SPSS 25.0 was performed to ensure the validity of the questionnaire. The Kaiser-Meyer-Olkin (KMO) value was $0.899 > 0.8$ and the significance level for Bartlett's test was below 0.05, indicating that the items of the questionnaire were adequate for factor analysis (Field, 2009). The results of principal component

analysis (PCA) results suggest the presence of two significant components with eigenvalues greater than 1, which accounted for 71.537% of the total items. As shown in Table 3, the item loadings were high. Also, confirmatory factor analysis (CFA) was performed using MPLUS 8. The values of composite reliability (CR) for the two subscales of the questionnaire were acceptable with values greater than 0.7 (Fornel & Larcker, 1981), and the convergent validity (AVE) was acceptable with values greater than 0.5 (Peterson, 2000). The other indices for model-fit evaluation exhibited both a good fit and good psychometric properties ($\chi^2(45) = 333.328$, $p < .05$, CFI = 0.974, RMSEA = 0.085, SRMR = 0.035) (Hu & Bentler, 1999). The results show that the student engagement questionnaire had good internal reliability and validity.

The student engagement questionnaire was self-reported by the participants at the end of the writing course, and the questionnaire data were analyzed and the results were and entered into an Excel spreadsheet by the second author of this paper. According to Authors et al. (2021), we divided student engagement into different levels (e.g., high or low level) by calculating the mean scores of students' engagement in each group.

Table 3. Factor analysis results of EFA and CFA

Measures	Items	Loadings	Composite reliability (CR)	Average variance extracted (AVE)
Behavioural engagement	1	0.843	0.872	0.631
	2	0.801		
	3	0.649		
	4	0.829		
	5	0.862		
Emotional engagement	1	0.801	0.864	0.615
	2	0.825		
	3	0.835		
	4	0.794		
	5	0.846		

3.3.3. The coding scheme of students' learning behaviours

As shown in Table 4, a coding scheme was developed using the attention behaviour coding scheme proposed by Authors et al. (2018). To guarantee the effectiveness of the coding scheme in this study, three experts with experience in classroom behaviour observation coding were asked to confirm

the applicability of the codes and their definitions. Then a total of nine learning behaviours were identified and classified into three dimensions: behaviours related to the course, behaviours related to the activity, and distracted behaviours. Finally, a complete coding scheme of students' learning behaviours was developed and used to identify the differences in the learning behaviours of the students in the two groups.

Not all the participants' behaviours were recorded due to dead-angle photography. In each group, the learning behaviour of 19 students was video-recorded by the second author of this paper, and the recording began as soon as the students were allowed to observe using AR or paper-based learning materials. The entire video recording lasted for approximately 50 minutes and the participant's behaviours were encoded chronologically in 1-min time slots. The behavioural coding work was done by three second-year graduate students in educational technology with experience in encoding classroom learning behaviours. Before the coding work began, we explained the classification and the meaning of the three dimensions to the coders involved in the coding work. For example, C_M refers to actions focused on the task list and A_T refers to actions focused on the tool used for the observation, with the behaviour of A_T occurring only during the observation stage. One of the most obvious differences between the two actions is that the student is holding a pen while performing the action C_M. Moreover, the main distinction between course-related and activity-related behaviour is that activity-related behaviour occurs only during the observation phase, while course-related behaviour does not occur during the observation phase. The coding work was examined using Cohen's kappa with acceptable inter-coder reliability (k=0.92) (Cohen, 1968). For the inconsistent codes, the three coders discussed and negotiated with each other to reach a consensus.

Table 4. Coding scheme for students' learning behaviours (Authors et al., 2018)

Dimension	Code	Definition	Description
Behaviours related to the course	C_I	Behaviours that show attention to the instructor	Looking at the instructor, listening while the instructor is talking; Students took the initiative to raise their hands when the teacher asked questions; Students took the initiative to raise their hands to answer questions even though the teacher hadn't called on them.
	C_S	Behaviours that show attention to the students	Looking at the students who are answering the questions or sharing their opinions
	C_M	Behaviours that show attention to the learning materials	Students engaged in reading, marking, and completing task lists in class.
Behaviours related to the activity	A_T	Behaviours involving interaction with the learning tools (e.g., booklet, tablet)	Using the tablet/booklet to observe authentic learning materials.

	A_M	Behaviours involving interaction with group members	Talking and discussing with group members on the learning topic.
	A_E	Behaviours that show attention to the instructor's explanation of the answers	Listening to the instructor's explanation, checking the textbook, checking the learning materials, and looking at the presentation.
Distracted behaviours	D_T	Distracted behaviours involving learning tools	Using the tablet/book to do something irrelevant to the class activity.
	D_C	Distracted behaviours involving classmates	Chatting with classmates on irrelevant topics.
	D_O	Other distracted behaviours	Looking around the room (not at the textbook and learning material), staring blankly into space, searching for irrelevant items; Students' attention wandered off in class; Students were in a daze during the class; Students were sleeping in class; Students were scribbling or doodling in class.

3.3.4. Interview outline

The interview outline comprises six questions and was developed by referring to Lin et al. (2021). Each question was modified in line with the situation of this study, for example, "How is this writing class different from the other conventional writing classes you have previously experienced or how does it differ from what you expected from this writing class?". The interview outline was used to understand students' learning perceptions under the different writing learning approaches. Three third-year graduate students, all of whom majored in education technology and had experience in encoding interview results, participated in the encoding of the interview results, using a tape recorder to tape the interview content of the participants.

All the recorded files were transcribed to text using the IFlytek speech transcription tool before the coding work began. We then explained the meaning of each question to the coders who participated in the coding work. Following the analysis procedure proposed by Creswell (2008), the interview data were coded and categorized into several themes. The coding work was examined using Cohen's kappa with acceptable inter-coder reliability (k= 0.91) (Cohen, 1968). For inconsistent codes, the three researchers discussed and negotiated with each other to reach a consensus.

3.4 Data analysis

In this study, kurtosis and skewness statistics were controlled for each variable (see Table 5). We observed that the data were normally distributed, since the values of kurtosis are between -2 and +2, and the values of skewness are between -7 and +7 (West, Finch & Curran, 1995). The normality assumptions testing yielded acceptable results for performing parametric analysis methods (i.e., ANCOVA, *t*-test, ANOVA). Also, tests were performed to ensure that the assumptions regarding

linearity and homogeneity were not violated.

Quantitative data were analysed using IBM SPSS 25.0. The significance level was set at 0.05 for the present study. If there was a significant difference between the groups, the effect size was calculated. For RQ 1, a one-way factorial ANCOVA analysis was performed to examine the differences in writing performance between the two groups by taking the pre-test of student writing outcomes as a covariate and the post-test as a dependent variable. For RQ 2 and 3, we used the two-way factorial ANOVA tests to uncover the differences in the writing achievements of students with different levels of student engagement in the two groups by taking into consideration the different learning approaches and the different levels of student engagement as the independent variable, and the post-test of writing performance as the dependent variable.

Qualitative data were analysed using various software. For RQ 4, we performed a sequential analysis using the General Sequential Querier (GSEQ 5.1) software to identify differences in the learning behaviour of students in the two groups. For RQ 5, we analysed semi-structured interviews using NVivo 11.4 to understand the perceptions of the students who were exposed to different teaching approaches. Our empirical results and findings are detailed in the following section.

Table 5. Kurtosis and skewness statistics of dependent variables

Variables	Kurtosis	Skewness
Total score of writing performance	-0.915 (SE = 0.347)	1.127 (SE = 0.681)
Linguistic accuracy	-1.722 (SE = 0.347)	6.180 (SE = 0.681)
Feature descriptiveness	-1.323(SE = 0.347)	2.766 (SE = 0.681)
Rhetorical expressiveness	-0.660 (SE = 0.347)	0.084 (SE = 0.681)
Thinking innovation	-0.757(SE = 0.347)	0.783 (SE = 0.681)
Behavioural engagement	-1.021 (SE = 0.347)	1.703 (SE = 0.681)
Emotional engagement	-1.245 (SE = 0.347)	2.020 (SE = 0.681)

4. Results

4.1 RQ1: To what extent does the MAR approach improve the students' Chinese writing learning performance in comparison with the MC approach?

The results of Levene's homogeneity assumption were acceptable in terms of the total scores ($F = 0.607$, $p > .05$), and the four dimensions of writing ($F = 0.194$, $p > .05$; $F = 0.986$, $p > .05$; $F = 2.047$,

$p > .05$; $F = 1.012$, $p > .05$). The homogeneity regression test was as follows: overall scores ($F = 0.226$, $p > .05$), linguistic accuracy ($F = 0.049$, $p > .05$), feature descriptiveness ($F = 0.185$, $p > .05$), rhetorical expressiveness ($F = 1.343$, $p > .05$), and thinking innovation ($F = 0.001$, $p > .05$), implying that the assumptions were acceptable for writing performance. Therefore, we employed one-way factorial ANCOVA to examine the differences between the writing performance of the two groups.

Table 6 shows the descriptive data (means and standard deviations) for the students' pre- and post-test writing performance in the two groups. There were significant differences in the overall writing means ($F = 4.398$, $p < .05$, $\eta^2 = 0.091$), feature descriptiveness ($F = 6.337$, $p < .05$, $\eta^2 = 0.126$), and thinking innovation ($F = 22.399$, $p < .05$, $\eta^2 = 0.337$), indicating medium to large effect sizes (Cohen, 1988). In the dimensions of linguistic accuracy ($F = 2.634$, $p > .05$) and rhetorical expressiveness ($F = 2.980$, $p > .05$), no significant difference was found in the writing performance of the students in the two groups.

It is worth mentioning that our study found that the MAR approach had a positive effect on students' writing learning performance compared to the MC approach in terms of their overall writing scores, feature descriptiveness, and thinking innovation, whereas it failed to significantly improve students' writing performance in terms of linguistic accuracy and rhetorical expressiveness.

Table 6. ANCOVA results of writing performance

Variance	Groups	*N*	Pre-test		Post-test		Adjusted means	SE	*F*	η^2
			Mean	*SD*	Mean	*SD*				
Overall writing scores	EG	26	66.89	10.49	76.38	10.71	75.81	2. 11	4.398*	0.091
	CG	21	63.08	7.51	68.41	11.33	69.10	2. 36		
Linguistic accuracy	EG	26	75.33	12.17	80.23	10.05	80.30	1.59	2.634	—
	CG	21	75.75	6.02	76.54	7.04	76.45	1.76		
Feature descriptive-ness	EG	26	65.01	14.06	77.68	10.38	77.36	2.57	6.337*	0.126
	CG	21	55.71	10.52	66.94	14.94	67.33	2.88		
Rhetorical expressive-ness	EG	26	61.13	12.31	71.44	12.79	70.79	3.03	2.980	—
	CG	21	51.27	14.78	61.89	17.31	62.68	3.40		
Thinking innovation	EG	26	57.35	11.72	71.23	15.63	75.14	2.53	22.399***	0. 337
	CG	21	70.32	10.58	60.67	11.86	55.82	2.86		

**p< .05, ***p< .001*

4.2 RQ2: Are there differences between the writing achievements of the students with lower and higher levels of behavioural engagement?

As shown in Table 7, there were no significant differences in the overall means ($F = 0.774$, $p > .05$) or in the four dimensions of students' pre-test writing outcomes with different levels of

behavioural engagement ($F = 3.798$, $p > .05$; $F = 0.020$, $p > .05$; $F = 0.193$, $p > .05$; $F = 3.788$, $p > .05$), but we found significant differences in the post-test writing outcomes of students with different levels of behavioural engagement for all dimensions ($F = 10.927$, $p < .01$, $\eta^2 = 0.313$; $F = 10.067$, $p < .01$, $\eta^2 = 0.296$; $F = 7.377$, $p < .05$, $\eta^2 = 0.235$; $F = 9.060$, $p < .01$, $\eta^2 = 0.274$; $F = 11.589$, $p < .01$, $\eta^2 = 0.326$) with large effect sizes. The results show that of the students who were exposed to the MAR learning approach, those with high levels of behavioral engagement tended to perform better than those with low levels of behavioral engagement in terms of their overall writing scores and its four dimensions of linguistic accuracy, feature descriptiveness, rhetorical expressiveness, and thinking innovation in writing.

As shown in Table 8, except for the pre-test of the dimension of feature descriptiveness ($F = 4.514$, $p < .05$) with a large effect of 0.192, there was no significant difference in the overall means and its dimensions in the CG students' pre- ($F = 0.639$, $p > .05$; $F = 0.766$, $p > .05$; $F = 0.561$, $p > .05$; $F = 1.056$, $p > .05$) and post-test ($F = 0.031$, $p > .05$; $F = 0.001$, $p > .05$; $F = 0.076$, $p > .05$; $F = 0.121$, $p > .05$; $F = 0.336$, $p > .05$) writing outcomes with different levels of behavioural engagement. These results imply that there was no significant change in writing performance under MC learning for students with different levels of behavioural engagement in terms of their overall writing scores and its four dimensions.

Fig. 7 illustrates the impact of adopting different learning approaches and levels of behavioural engagement in terms of the students' overall writing performance. It is evident that the gap between the pre-test and post-test writing performance of students with different levels of behavioural engagement in the EG was larger than that in the CG. We also found that students with low behavioural engagement in the CG performed almost equally well to those in the EG. These results suggest that the MAR learning approach is more effective for students with high behavioural engagement, while this approach is not as effective for students with low behavioural engagement.

Table 7. Two-way ANOVA results of different behavioural engagement levels and (pre- and post-) writing scores in the EG

Group	Variance	Engage-ment	*N*	Pre-test				Post-test			
				Mean	*SD*	*F*	η^2	Mean	*SD*	*F*	η^2
EG	Overall writing scores	High	13	68.71	9.80	.774	—	82.24	4.95	10.927**	.313
		Low	13	65.07	11.22			70.50	11.82		
	Linguistic accuracy	High	13	79.74	5.65	3.798	—	85.59	3.60	10.067**	.296
		Low	13	70.92	15.31			74.87	11.64		
		High	13	65.41	15.74	.020	—	82.62	5.85	7.377*	.235

Feature descriptiveness	Low	13	64.62	12.80			72.74	11.73		
Rhetorical expressiveness	High	13	60.05	13.44	.193	—	78.00	7.29	9.060**	.274
	Low	13	62.21	11.51			64.87	13.94		
Thinking innovation	High	13	61.59	11.10	3.788	—	79.97	8.72	11.589**	.326
	Low	13	53.10	11.14			62.49	16.34		

*p< .05, **p< .01

Table 8 Two-way ANOVA results of different behavioural engagement levels and (pre- and post-) writing scores in the CG

Group	Variance	Engage-ment	*N*	Pre-test				Post-test			
				Mean	*SD*	*F*	η^2	Mean	*SD*	*F*	η^2
CG	Overall writing scores	High	11	61.82	7.98	.639	—	67.98	11.71	.031	—
		Low	10	64.46	7.11			68.88	11.49		
	Linguistic accuracy	High	11	76.85	6.42	.766	—	76.58	6.60	.001	—
		Low	10	74.53	5.63			76.50	7.87		
	Feature descriptiveness	High	11	51.42	8.40	4.514*	.192	66.06	16.92	.076	—
		Low	10	60.43	10.98			67.90	13.27		
	Rhetorical expressiveness	High	11	48.94	15.06	.561	—	60.61	17.41	.121	—
		Low	10	53.83	14.83			63.30	18.02		
	Thinking innovation	High	11	72.58	7.58	1.056	—	62.12	13.15	.336	—
		Low	10	67.83	13.10			59.07	10.73		

*p< .05

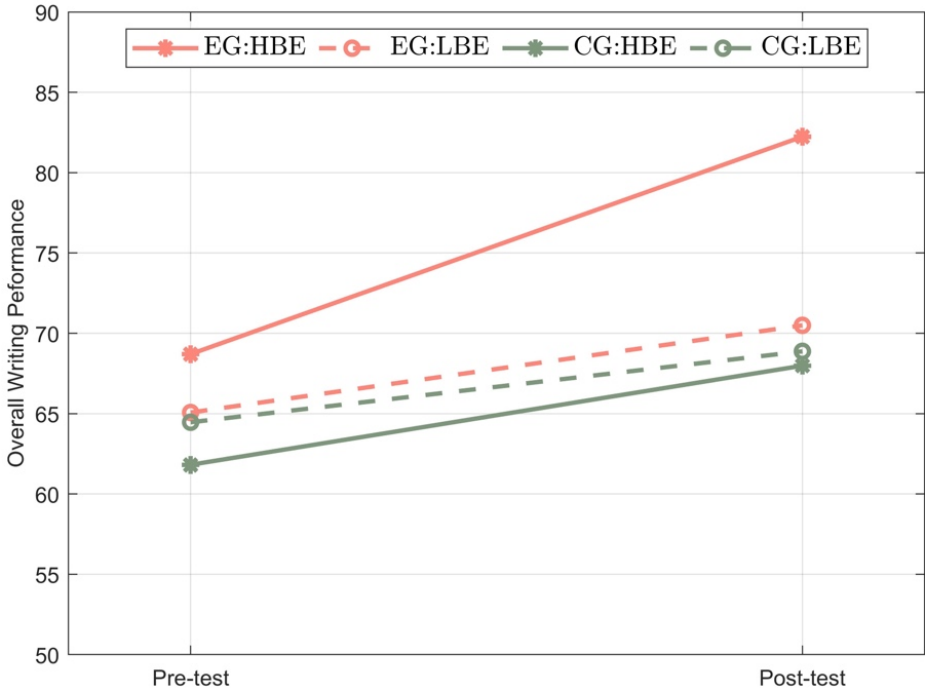

Fig. 7 The gap between the pre-test and post-test writing performance of students with different levels of behavioural engagement

*EG = Experimental group, CG = Control group, HBE = High behavioural engagement, LBE = Low behavioural engagement.

4.3 RQ3: Are there differences between the writing achievements of the students with lower and higher levels of emotional engagement?

As shown in Table 9, we only found a significant difference in the dimension of linguistic accuracy of the students' pre-test writing outcomes in the EG ($F = 5.546$, $p < .05$) with a large effect size of 0.188. No significant difference was found in the overall writing scores ($F = 0.074$, $p > .05$) and the other three dimensions of feature descriptiveness ($F = 0.032$, $p > .05$), rhetorical expressiveness ($F = 0.227$, $p > .05$) and thinking innovation ($F = 2.757$, $p > .05$). However, there were significant differences in the overall means ($F = 10.555$, $p < .01$, $\eta^2 = 0.305$) and four dimensions of the post-test of students' writing outcomes with different levels of emotional engagement ($F = 8.184$, $p < .01$, $\eta^2 = 0.254$; $F = 8.059$, $p < .01$, $\eta^2 = 0.251$; $F = 10.247$, $p < .01$, $\eta^2 = 0.229$; $F = 9.502$, $p < .01$, $\eta^2 = 0.284$) with large effect sizes. The results show that, with the help of the MAR learning approach, students with high levels of emotional engagement tended to perform better than those with low levels of behavioural engagement in terms of their overall writing scores and its four dimensions of linguistic accuracy, feature descriptiveness, rhetorical expressiveness, and thinking innovation in writing.

Table 10 shows that no statistical difference existed in the overall means and its dimensions of pre- ($F = 0.588$, $p > .05$; $F = 0.684$, $p > .05$; $F = 3.663$, $p > .05$; $F = 0.632$, $p > .05$; $F = 1.048$, $p > .05$) and post-test ($F = 0.588$, $p > .05$; $F = 1.711$, $p > .05$; $F = 0.376$, $p > .05$; $F = 0.294$, $p > .05$; $F = 0.123$,

$p > .05$) of students with different levels of emotional engagement in the CG. These results imply that there is no significant change in writing performance under MC learning for students with different levels of behavioural engagement in terms of their overall writing scores and its four dimensions.

Fig. 8 illustrates the impact of adopting different learning approaches and levels of emotional engagement in terms of students' writing performance. It is evident that the gap between the pre-test and post-test writing performance of students with different levels of emotional engagement in the EG is larger than that in the CG.

Table. 9 Two-way ANOVA results of different emotional engagement levels and (pre- and post-) writing scores in the EG

Group	Variance	Engage-ment	*N*	Pre-test				Post-test			
				Mean	*SD*	*F*	η^2	Mean	*SD*	*F*	η^2
EG	Overall writing scores	High	14	68.49	9.99	.704	—	81.74	4.79	10.555**	.305
		Low	12	65.01	11.17			70.10	12.40		
	Linguistic accuracy	High	14	80.12	5.90	5.546*	.188	84.83	3.85	8.184**	.254
		Low	12	69.75	15.24			74.86	12.40		
	Feature descriptiveness	High	14	64.55	15.46	.032	—	82.41	5.49	8.059**	.251
		Low	12	65.56	12.90			72.17	12.16		
	Rhetorical expressiveness	High	14	60.05	13.16	.227	—	77.79	7.29	10.247**	.229
		Low	12	62.39	11.69			64.03	14.06		
	Thinking innovation	High	14	60.76	12.13	2.757	—	78.79	8.74	9.502**	.284
		Low	12	53.36	10.30			62.42	17.53		

*$p < .05$, **$p < .01$*

Table 10 Two-way ANOVA results of different emotional engagement levels and (pre- and post-) writing scores in the CG

Group	Variance	Engage-ment	*N*	Pre-test				Post-test			
				Mean	*SD*	*F*	η^2	Mean	*SD*	*F*	η^2
CG	Overall writing scores	High	12	61.98	7.65	.588	—	70.07	12.36	.588	—
		Low	9	64.54	7.50			66.20	10.05		
	Linguistic accuracy	High	12	76.69	6.14	.684	—	78.25	6.92	1.711	—
		Low	9	74.48	5.97			74.26	6.92		
	Feature descriptiveness	High	12	52.14	8.38	3.663	—	68.69	17.22	.376	—
		Low	9	60.48	11.64			64.59	11.81		
		High	12	49.03	14.28	.632	—	63.69	18.35	.294	—

Rhetorical expressiveness	Low	9	54.26	15.77			59.48	16.58		
Thinking innovation	High	12	72.36	7.93	1.048	—	61.47	12.64	.123	—
	Low	9	67.59	13.36			59.59	11.39		

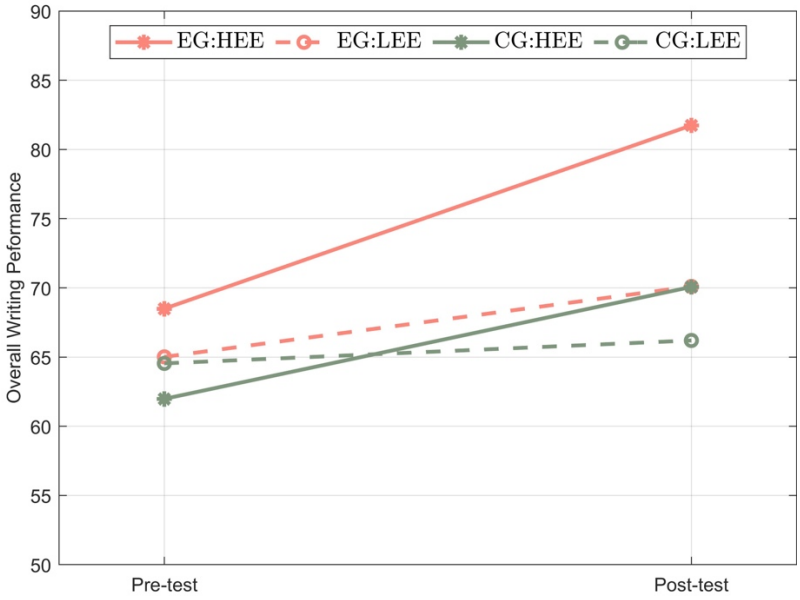

Fig. 8 The gap between the pre-test and the post-test writing performance of students with different levels of emotional engagement

*EG = Experimental group, CG = Control group, HEE = High emotional engagement, LEE = Low emotional engagement

4.4 RQ4: Are there differences in the learning behaviour patterns of students learning with different approaches?

As shown in Table 11, a total of 1,949 behaviours were recorded, including 961 codes for the EG, and 988 codes for the CG. In the EG, the top three most-frequent behaviours in the whole learning process were "behaviours involving interaction with the learning tools (e.g., book, tablet)" (A_T) (42.9%), "behaviours that show attention to the learning materials" (C_M) (23.9%), and "behaviours that show attention to the instructor's explanation of the answers" (A_E) (20.5%), whereas in the CG, the top three most-frequent behaviours in the whole learning process were "behaviours that show attention to the learning materials" (C_M) (34.2%), "behaviours that show attention to the instructor's explanation of the answers" (A_E) (28.7%), and "behaviours involving interaction with the learning tools (e.g., book, tablet)" (A_T) (22.0%). The results show that students in the CG paid more attention to the learning material and the instructor's explanation of the answers than those in the EG, while students in the EG paid more attention to interacting with the learning tools than those in the CG.

Table. 11 The frequency of coded learning behaviours of the students in both groups

Dimension	Category	EG		CG	
		N	Percentage	N	Percentage
Behaviour related to the course	C_I	52	5.4%	117	11.8%
	C_S	17	1.8%	9	0.9%
	C_M	230	23.9%	338	34.2%
Behaviour related to the activity	A_T	412	42.9%	121	22.0%
	A_M	33	3.4%	43	4.4%
	A_E	197	20.5%	284	28.7%
Distracted behaviour	D_T	5	0.5%	5	0.5%
	D_C	10	1.0%	23	2.3%
	D_O	5	0.5%	48	4.9%
Total		961		988	

Table 12 shows the sequential analysis of the classroom learning behaviours of the EG. There were 11 sequences of z-scores higher than 1.96, indicating that these sequences were statistically significant. The sequential analysis of classroom learning behaviours for the CG is shown in Table 13. It can be seen that 14 sequences of z-scores were higher than 1.96, demonstrating that these sequences were statistically meaningful. For instance, C_I → C_S indicates that students who showed attention behaviours to the instructor would turn their attention behaviours to their peers. C_M → C_M means that the learners repeatedly focused their attention on the learning materials. D_C → D_C indicates that the students repeatedly exhibited behaviours of chatting on irrelevant topics with their classmates.

Table. 12 Results of sequential analysis of classroom learning behaviours for the EG

Z	C_I	C_S	C_M	A_T	A_M	A_E	D_T	D_C	D_O
C_I	-0.51	3.33*	-2.33	-5.12	-1.4	8.95*	-0.54	-0.76	-0.54
C_S	-0.75	-0.56	-2.41	-3.19	-0.78	6.98*	-0.3	-0.43	3.1*
C_M	-0.51	-1.19	12.38*	-6.4	0.46	-5.46	0.84	1.2	-0.21
A_T	-4.45	-3.11	-5.52	11.96*	0.66	-6.21	0.78	-0.18	-0.13
A_M	-1.05	0.56	0.28	1.25	0.84	-1.65	-0.42	-0.6	-0.42
A_E	7.28*	3.34*	-5.45	-4.27	-0.34	7.45*	-1.14	-0.83	-0.03
D_T	-0.4	-0.3	0.77	-0.18	-0.42	-1.14	-0.16	4.19*	-0.16
D_C	-0.57	-0.43	4.01*	-1.53	-0.6	-1.61	-0.23	-0.33	-0.23
D_O	-0.4	-0.3	-0.27	0.73	-0.42	-0.03	-0.16	-0.23	-0.16

*p< .05

Table. 13 Results of sequential analysis of the classroom learning behaviours for the CG

Z	C_I	C_S	C_M	A_T	A_M	A_E	D_T	D_C	D_O
C_I	9.7*	-0.07	-7.88	-4.11	-1.97	6.61*	-0.82	-1.13	0.09
C_S	0.21	-0.29	0.51	-1.15	-0.64	0.31	-0.21	-0.47	0.85
C_M	0.52	-2.17	9.79*	-1.63	3.71*	-10.84	-1.62	1.39	-0.24
A_T	-3.04	-1.13	3.84*	5.11*	-1.55	-5.1	3.27*	-0.53	-0.45
A_M	-2.12	-0.64	0.12	1.64	9.27*	-4.26	1.72	0	-0.1
A_E	-3.63	4.01*	-8.51	1.01	-4.26	13.26*	-0.43	-3.08	-1

D_T	-0.71	-0.21	2.04*	-0.86	-0.48	-1.42	-0.16	2.63*	-0.51
D_C	-0.8	-0.47	-0.16	0.04	-1.04	-2.62	-0.35	6.25*	3.75*
D_O	-0.71	-0.68	1.4	-0.94	-1.52	0.07	-0.51	0.87	0.42

*p< .05

Fig. 9 shows the behaviour paths of the two groups of students, constructed from Tables 12 and 13. The black lines indicate the same behaviour transition of the students in the EG and the CG. The red lines indicate that the behaviour shifts only occur in a specific group. For example, the behaviour transition of A_E → C_S was evident in both groups, whereas the C_S → A_E transition was only evident in the EG.

It can be seen in Fig. 9 that the students in the EG who focused their attention on the instructor tended to transmit their attention to their peers who were answering the questions or sharing their ideas (C_I → C_S), then they focused their attention on the teacher's explanation of the peers' answers/ ideas (C_S → A_E), and after that, the students' attention switched back to the instructor (A_E → C_I). On the other hand, students in the EG displayed some distracted behaviours, for example, when the students were looking at their classmate who was answering questions or sharing opinions, they were likely to exhibit distracted behaviours, such as absent-mindedness or staring blankly into space (C_S → D_O). Additionally, we also found that those who exhibited the distracted behaviour of playing with the learning tools were inclined to communicate with their classmates (D_T → D_C), but eventually, most of them would turn their attention back to the learning materials (D_C → C_M).

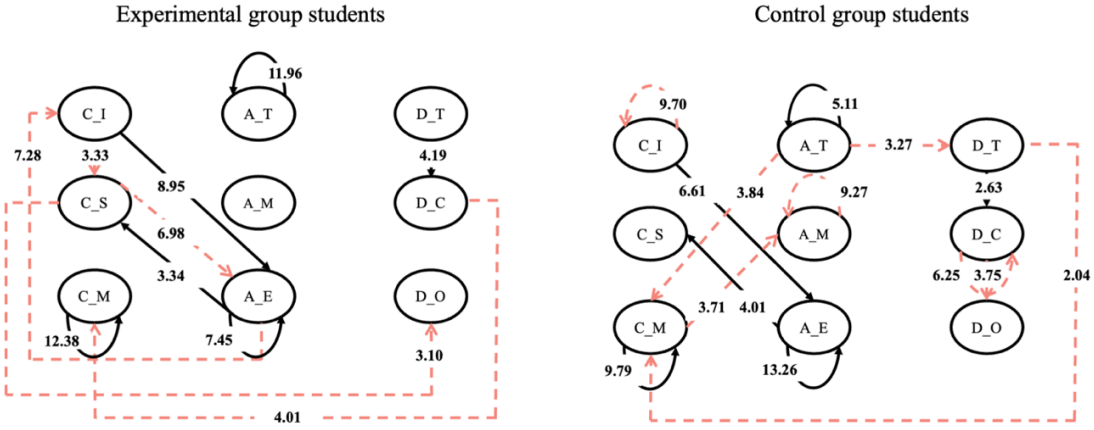

Fig. 9 The learning behaviour patterns of the two groups

Fig. 9 shows the learning behaviour patterns of the CG. We found that the students in the CG tended to focus their attention on the instructor when she was teaching (C_I → C_I) or providing explanations of students' answers (C_I → A_E). However, the students who used the learning tools to observe were more likely to shift their attention to the learning materials (A_T → C_M), then they tended to switch their attention to discuss the learning topics with their group members (C_M→ A_M;

A_M→ A_M). In addition, we noticed that when the students used the learning tools to observe, they were inclined to show some disengaging behaviours with the tools (A_T→ D_T), and some of them would switch their behaviours back to the learning materials (D_T→ C_M), whereas some of them would change their behaviours to chat with their peers (D_T→ D_C; D_C→ D_C) or become absent-minded during class time (D_C→ D_O).

According to the analysis of students' learning behaviour frequency in the two groups, it was not difficult to see that the students in the EG exhibited less distracted behaviours than the students in the CG. The results of students' learning behaviour patterns of the two groups imply that the students in the EG focused their attention more on interacting with the learning tools rather than transmitting their behaviours to other forms, whereas the students in the CG tended to exhibit other behaviours (e.g., distracted behaviour with learning tools, showing attention to the learning materials) when they were using the learning tools to observe.

4.5 RQ5: What are the students' learning perceptions under the different learning approaches?

Table 14 shows the analysis results of the interviews, including the themes, coding description, and the number of occurrences. The top three benefits that were mentioned the most by students in the EG were "promoting learning motivation" (n = 60), "improving writing performance" (n = 48), and "promoting reflection" (n = 42), whereas the top three benefits that were mentioned the most by students in the CG were "promoting reflection" (n = 43), "providing students with individualized opportunities for authentic learning" (n = 31), and "improving writing performance" (n = 23). The results provide preliminary evidence that students who were exposed to the MAR learning approach were inclined to exhibit higher learning motivation than those who were exposed to the MC learning approach, and it can be inferred that the reason why students in the EG achieved better performance in writing may be due to the mediation impact of learning motivation with the help of AR technology.

In terms of "promoting reflection," the two groups (n = 42, n = 43) reported an almost equal number of occurrences, with both groups of students agreeing that during the process of discussing and interacting with others (e.g., peers, teacher), their reflective thinking on what they observed as well as the questions raised by the teacher was enhanced.

> *During the discussion with my classmates, they would always tell me some details that they thought were interesting but I didn't notice, which would make me reflect on whether these details were really interesting and why I didn't notice them when I was observing them*. (E02)

> *I would exchange my observations with my desk mate, and I found that we often had different views on one thing. For example, I thought that the egg-breaking process of the brachiosaurus*

was just like that of a chicken, in that it needed to be incubated, but he thought that the brachiosaurus egg did not need to be incubated. I will reflect on this disagreement and solve the problem by consulting the teacher, other peers or referring to relevant materials. (C05)

As for "promoting learning motivation," the EG (n = 60) reported many more occurrences than the CG (n = 16). The interview results showed that the students in the EG were inclined to report the immersion and interaction of observational learning, whereas nobody in the CG reported this.

I really enjoyed the process of interactivity with the AR learning tools. The sense of immersion was really wonderful, and I felt the brachiosaur was really in the classroom. I also wanted to ask the brachiosaur a lot of questions. (E05)

With regard to "providing students with individualized opportunities for authentic learning," the EG (n = 31) reported a much larger number of occurrences than the CG (n = 10). Although both groups were given individualized learning opportunities, the students in the EG were more likely to mention it.

Compared with the conventional learning approach, the AR-based method allowed me to review and learn according to my preferences, and I also preferred to observe the authentic scenery repeatedly, so that I could form an impression of the brachiosaurus. (E02)

I found the study material provided by the teacher in the writing class so unattractive and not vivid that I didn't want to watch it again. (C04)

In terms of "improving writing performance," the students in the EG (n = 56) reported almost double the occurrences in relation to their abilities of "linguistic accuracy" (n = 8), "feature descriptiveness" (n = 17), "rhetorical expressiveness" (n = 15), and "thinking innovation" (n = 16) than the CG (n = 30).

I was inspired to think creatively; for example, I imagined whether the brachiosaurus would move when it was inside the egg. (E01)

I took the text description in the learning materials into my writing to enrich its content. (C03)

Regarding "enhancing the knowledge and content transferred in the process of interactive observation," an interesting phenomenon shown in Table 13 is that both groups (n = 14, n = 15) reported almost the same number of occurrences, whereas in relation to previous knowledge, the number of the occurrences reported by the EG (n = 15) was significantly higher than that of the CG (n

= 6). These results show that both approaches support the development of students' knowledge transferring abilities; however, the MAR learning approach may be more effective in terms of encouraging students to make connections between the new and old knowledge, and to some extent refresh their relevant knowledge.

> *The AR learning approach reminded me of one game I played before, and I want to integrate the current experience with the previous experience as one of the materials to enrich the writing content.* (E06)

> *I used the sentences and vocabulary from the model essays which I previously learned in this writing task.* (C04)

Table. 14 Themes, coding items, and the number of occurrences of the interview results.

Theme	Code	Description	The number of times mentioned	
			EG	CG
Promoting learning motivation	PM_1	Increase the immersion of observational learning.	20	0
	PM_2	Increase the interaction of observational learning.	18	0
	PM_3	Stimulate students' learning interest in further study.	22	16
Providing students with individualized opportunities for authentic learning	PL_1	Allowed to watch the authentic learning materials repeatedly.	12	4
	PL_2	Allowed to review and learn according to their preference.	19	6
Promoting reflection	PR_1	Reflect on their understanding of observational learning through discussions with others.	20	23
	PR_2	Increase the interactions between peers, teachers, and students to facilitate their reflection.	22	21
Improving writing performance	IP_1	Promote the abilities of linguistic accuracy.	8	7
	IP_2	Promote the abilities of feature descriptiveness.	17	10
	IP_3	Enhance the abilities of rhetorical expressiveness.	15	7
	IP_4	Promote the abilities of thinking innovation.	16	6
Enhancing the knowledge and content transferred in the process of	EO_1	Encourage students to relate the knowledge/experience they have previously learned with the learning topic.	15	6

interactive observation	EO_2	Promote the transfer of knowledge (e.g., words, rhetorical expressiveness, sentence patterns).	14	15

5. Discussion and conclusion

5.1 Discussion

In recent years, the writing abilities of elementary school students have been studied in many countries (Graham & Rijlaarsdam, 2016). This is because the early development of the writing ability is a vital foundation for further education (Graham, Tavsanli & Kaldirim, 2021). However, due to the lack of authentic experience and limited instructional methods, cultivating the writing ability at an early stage is a significant challenge for students in elementary schools (Authors et al., 2021). The application of AR, one of the authentic technologies, has great potential for elementary Chinese writing education (Wang, 2017). This study explored a motivational AR-based design within a quasi-experiment and its effects on writing learning in elementary school students. The research questions can be answered as follows.

5.1.1. RQ1: To what extent does the MAR approach improve the students' Chinese writing learning performance in comparison with the MC approach?

Research question 1 was to identify whether the MAR learning approach would improve students' writing performance. The findings revealed that students exposed to the MAR learning approach exhibited better writing performance in terms of their overall scores, feature descriptiveness, and thinking innovation than those exposed to the MC learning approach. The findings of our study confirm Lin, Liu and Chen's (2020) study which found that the authentic and interactive environment created by AR can stimulate learners' creative thinking and Wang's (2017) study which reported that AR can improve students' writing performance. Our results also echoed Hao and Lee (2021) who suggested that the AR learning materials cater for the "attention" and "relevance" elements of the ARCS model, since they not only present the learning content but also motivate students to focus their attention on the classroom learning and help them connect the learning content to real cases. Meanwhile, students were able to raise their relevant knowledge or experience from long-term memory and then transfer their feelings or abstract ideas into specific writing scripts, which further promote their writing performance (Authors et al., 2021).

We found no significant difference in the dimensions of linguistic accuracy and rhetorical expressiveness in the writing performance of the two groups. The result echoes the results of Authors et al. (2020) whose revealed that the authentic and immersive nature of technology does not play an

active role in enhancing learners' ability of vocabulary use in Chinese writing. Possible explanations for this finding could be due to the vivid and authentic learning environment provided by the MAR learning approach, which captured the attention of the students and motivated them to describe in detail what they had seen; thus, they may have neglected linguistic accuracy when they were writing (Wang, 2017). On the other hand, the findings are not consistent with Lin, Liu and Chen (2020) who noted that AR applications can help learners use more rhetorical expressions in their writing. However, their comparison was between different types of concept map-based learning (AR-based vs no-AR-based) for English as a Foreign Language writing in college, while this study compared different types of ARCS model-based learning (AR-based vs. no-AR-based) for primary school students' Chinese writing, which may explain the discrepancy. Furthermore, rhetorical expressiveness in writing education is closely connected to students' abilities of analogy and dialectical emphasis (Connor & Lauer, 1985; Lu, 1998), which is not easily cultivated by simply providing a motivational AR-based learning environment (Wang, 2017; Wen, 2021). Therefore, future studies will investigate the integration of other teaching methods (e.g., concept map, peer assessment, argumentative teaching) that emphasize the development of learners' analogy and dialectical emphasis abilities, which may be more beneficial for the cultivation of students' rhetorical skills.

5.1.2. RQ2 and RQ 3: Are there differences between the writing achievements of the students with lower and higher levels of behavioural and emotional engagement?

Questions 2 and 3 analyze the differences in the writing achievement of students with lower and higher levels of behavioural and emotional engagement. After the intervention, there was a significant difference between the overall writing scores and the four dimensions for low and high engagement students in EG, while there was no significant difference for students in CG. It was also found that the achievement gap between low- and high-engagement students was much larger in EG compared to CG. These results imply that high-engagement students exposed to the MAR learning approach tend to exhibit better writing performance and its four dimensions than students exposed to the MC learning approach. These findings are similar to the study of Authors et al. (2021), in which the researchers found that students in the middle years of elementary school who had higher student engagement and were exposed to an immersive learning environment would achieve better writing performance than students who were exposed to conventional learning environments. It has been verified that the multi-channel perceptual learning opportunities provided by AR technology may reduce the cognitive load of students in the process of writing learning (Pozharina, 2019), so their learning efficiency is enhanced, especially for students with higher engagement (Bujak et al., 2013). As discussed by Di Serio, Ibáñez and Kloos (2013), within the AR-based learning environment, students who show high levels of

engagement generally succeed in achieving the first three motivational dynamics (attention, relevance and confidence) of the ARCS model, so they are more likely to be motivated to learn and receive satisfactory learning performance.

However, for those students with low-behavioural engagement, almost equally good performance was found in the two groups. This result indicates that the MAR learning approach failed to promote the overall writing performance of students with low-behavioural engagement. The finding echoes Authors et al.'s (2021) study, in which they found that immersive technology-enhanced learning did not play an active role in increasing the writing performance of students with low-behavioural engagement. The possible reason for this may be due to the fact that less engaged students do not fully embrace AR techniques or do not use complementary mental dynamics to motivate themselves to engage in writing activities (Akçayır & Akçayır, 2017; Lamb, 2017; Wang, 2017). That is, for the majority of students with low behavioural engagement, the use of the proposed MAR approach in the current study may not play a role in assisting their process of learning to write. Therefore, future research may consider designing more appropriate AR-based learning materials (e.g., add some learning scaffoldings) for students with low behavioural engagement.

5.1.3. RQ4: Are there differences in the learning behaviour patterns of students learning with different approaches?

To answer research question 4, the differences in the learning behaviours of the students in the two groups were analysed. It was found that compared with the CG (34.2% + 22% = 56.2%), the behavioural frequencies of A_T and C_M in the whole learning process of the students in the EG (42.9% + 23.9% = 66.8%) were higher. Furthermore, there were significant behaviour sequences in terms of A_T → A_T, C_M → C_M and A_E → A_E in both groups; the Z scores of A_T and C_M in the EG were much higher than those of the CG (11.96 > 5.11), whereas the Z score of A_ E in the EG was much lower than that of the CG (7.45 < 13.26). According to Authors et al. (2018), the behaviour of A_T and C_M shows more attention to the student's self-learning process, while the behaviour of A_E shows more attention to the teacher's instructions. These results imply that the MAR learning approach helps students to focus more attention on their self-learning, and these findings are further supported by previous research which indicates that AR technology constructs a learning-by-doing environment that sustains students' self-learning process (Bujak et al., 2013; Wojciechowski & Cellary, 2013; Yilmaz, 2018). As suggested by Chang (2021), the combination design of AR and the ARCS model can effectively enhance the application efficacy of AR technology by stimulating learners to have more confidence in their self-learning abilities. Another direction for future research is to explore whether the proposed approach promotes self-regulated learning by learners.

As for the distracted behaviours, we found that students in the CG were inclined to manifest more of these than the students in the EG. In particular, once the students in the CG exhibited the behaviour of D_C, they were more likely to repeat the behaviour of D_C as their next behaviour, while those in the EG were likely to convert their next behaviour to C_M even if they had exhibited behaviours of D_C. These results further support the conclusion drawn by Ab Aziz et al. (2012) that AR technology increases students' attention rather than distracting them. The findings can also be explained by Ebrahimi's (2022) study, in which they suggested that AR can optimize the teaching efficacy of the ARCS model by increasing learners' attention and relevance to prior knowledge. Future studies can further examine whether the MAR approach influences learners' attention using emerging fields of learning analytics and AI in education (e.g., facial emotion detection, EEG).

5.1.4. RQ5: What are the students' learning perceptions under the different learning approaches?

To answer research question 5, we conducted semi-structured interviews with the students in the two groups. It was found that there were more students in the EG who reported that they were motivated by the immersion and interaction provided by the MAR learning approach than those in the CG. This means the MAR learning approach may be able to stimulate students' learning motivation by enhancing the immersion and interaction of the learning environment; these results echo those of Al Hakim et al. (2022). Approximately half the number of students in the CG reported that they had been given individualized opportunities for authentic learning compared to the EG, even when both groups were given the same observable materials (the material was presented differently). One possible interpretation of this finding is that the MAR learning approach creates a more motivationally authentic learning environment than the MC learning approach; this impressed the students in the EG which is why they mentioned it during the interview. This conclusion provides further support for the study of Cai (2018) which found that the authentic AR environment is an attractive and innovative learning mode that eliminates isolated feelings in the learning environment. We also found that approximately half the number of students in the CG reported an improvement in their writing performance compared to the EG, and this result is in line with the statistical results analysed in Section 5.1, which indicates that the MAR learning approach is better than the MC learning approach in terms of promoting students' writing performance. Furthermore, more students in the EG reported that they were able to relate their previous knowledge/experience with the learning topic with the help of the MAR learning approach than the CG. This result is in line with that presented in Wang (2017). Approximately the same number of students in both groups reported knowledge transfer, and these results could further explain the statistical results in Section 5.1 which showed there was no significant difference in the students' rhetorical expressiveness in terms of their writing between the two groups. One possible explanation

for this may be because the control condition involved the same well-planned motivational learning approach which might be equally valuable for certain dimensions of writing learning (e.g., rhetorical expressiveness). Therefore, except for the improvement and optimization of AR-based designs, other appropriate instructional interventions (e.g., problem-based learning) are required in the future that can be integrated into AR-based activities to fully exploit to the advantages of AR technology.

5.2 Limitations and suggestions

Although our findings offer some insights into the writing education of elementary school students using different learning approaches, there are still some drawbacks. First, although research has shown that experiments with a medium sample size ($25 < n < 49$) were considered reasonable and acceptable (Burston, 2015), the sample size of our study is not large enough to possibly generalize our conclusions to other circumstances (e.g., other subjects, secondary or high school students). Second, the duration of our study might be considered short, so different conclusions may have been drawn if the students' writing ability had been examined in a longer-term study (one semester or a school year). Furthermore, due to the limitation of the experimental period, students' learning behaviours in different learning phases were not reported. Third, existing AR resources were used in our study, but we could not modify them (e.g., adding voice scaffolds or text scaffolds). Finally, we did not assess the prior knowledge of the participants on writing, which could be a potential reason to account for dimensions of writing that were not significant.

Therefore, it is suggested that, in the future, studies with larger sample sizes and longer period duration should be adopted; meanwhile, the MAR learning approach can be employed in other circumstances to verify its effectiveness. Some AR resource construct platforms (e.g., the Metaverse) with simple operational functions could be considered. Future studies can explore the integration of other appropriate pedagogical strategies (e.g., peer assessment, problem/project-based learning) with AR-based writing activities. Meanwhile, other potential factors (e.g., attention, prior knowledge, gender) that may influence the writing learning effect of AR-based activities and other potential analysis methods (e.g., social network analysis (SNA) and epistemic network analysis (ENA) can be employed in future studies to conduct an in-depth analysis. Additionally, multimodal data sources, such as physiological (e.g., GSR, EEG, fMRI, NIR) and physical (e.g., facial expressions, gestures, eye tracking) signals can be considered to draw more accurate and objective conclusions.

5.3 Implications and conclusions

The practical implications of the present study include the importance of incorporating the ARCS

model as a guiding part of the curriculum design in AR-based writing learning activities. The ARCS model seemed to enable students to avoid some of the negative effects of AR novelty and engage them in learning to write with a continuous learning motivation. The study also points to the advantages of the proposed MAR learning approach to motivate students with higher levels of engagement to perform better in writing and exhibit more focused rather than distracting behaviours. The main contribution of this study is that it sheds light on the potential application value of combining AR and the ARCS model in writing learning for elementary students, and it opens up opportunities for future research aimed at further exploring its impact in different designs of writing learning activities.

To sum up, our study proposed a MAR learning approach to support elementary school students' writing learning, and it verified that the incorporation of the proposed approach is effective in terms of promoting students' writing performance (especially for students with high engagement) and positive learning behaviours. The interview results revealed that, compared with the MC learning approach, students were motivated to increase their immersion and interaction in the process of writing learning. With the MAR learning approach, students could perceive the authenticity of learning, so they were motivated to watch the learning materials repeatedly. Moreover, through the interaction with the virtual objects, students' learning experience was internalized and their previously learned knowledge could be connected; hence, they were inclined to engage in creative writing. In other words, the proposed MAR learning approach is effective for student writing learning. It shows the benefits for learners in cultivating their writing abilities or skills in a motivational AR-based learning environment.

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