Unleashing imagination: An effective pedagogical approach to integrate into spherical video-based virtual reality to improve students' creative writing

Abstract

Creative writing is a valuable skill that enables learners to become proficient writers. One reason students often struggle with creative writing is their lack of contextual experiences. Spherical video-based virtual reality (SVVR) has been argued to support students' writing through immersive virtual experiences. However, what specific pedagogical practices can be developed and integrated with emerging technologies like SVVR to improve their effectiveness to support elementary school students' creative writing needs further work. This study proposes an innovative approach that integrated the generative learning strategy (GLS) of imagining with SVVR to enhance elementary school students' creative writing performance. To test the effectiveness of the proposed approach, a quasi-experiment was conducted in an elementary school writing class. The experimental group (N=56) used the generative learning-based SVVR approach (GSVVR), while the control group (N=55) used the generative learning-based conventional approach (GC). The results showed that the GSVVR group outperformed the GC group in terms of creative writing (F = 10.953, p < 0.01) with a medium effect size. Furthermore, we found a significant impact on students' behavioural and emotional engagement as well as their learning persistence, particularly if they had engagement values below 4.3 before the intervention. These findings indicate that the approach may have limited benefits for students who are already highly engaged (engagement values exceeding 4.3) with SVVR. It can also notably enhance the performance of relatively less engaged (engagement values below 4.3) students. There was a positive correlation between learning persistence and creative writing in the GSVVR group, with learning persistence being one of the significant predictors of student creative writing performance. The study is concluded with a discussion on the pedagogical and theoretical implications of the findings to support elementary school students' creative writing.

Keywords: Spherical video-based virtual reality; Generative learning; Creative writing; Learning persistence; Learning engagement

1 Introduction

Writing is a critical component of language education, serving as a powerful tool for expressing emotions, thoughts, and desires throughout life. Developing proficiency in writing requires an essential

skill set, including creativity, which facilitates the generation of ideas (Lin, 1998; Hayes & Flower, 1980). The symbiotic relationship between creativity and writing has spawned a distinct form of writing, known as creative writing. Scholars have underscored the importance of cultivating students' creative writing skills and transforming their writing development from a "knowledge telling" phase to a more advanced "knowledge transformation" phase (Barbot et al., 2012). However, creative writing is a challenging task for many young learners because it necessitates organization, planning, idea exploration, and a willingness to reject narrow-minded thinking (Temizkan, 2011). Additionally, its inherent nature is a source of consternation for elementary school students as they struggle to translate their imaginative ideas into written expression. This is because they often lack sufficient contextual knowledge to recall relevant experiences and knowledge from long-term memory and integrate them into their writing (Berninger, 1999). This issue is particularly prevalent among elementary school students (Eckhoff & Urbach, 2008; Yang et al., 2021).

In recent years, spherical video-based virtual reality (SVVR) has emerged as a technology that can provide students with contextual backgrounds (Chen et al., 2022). SVVR utilizes cost-effective immersive 360-degree videos and images that transport users to a virtual world, immersing them in the experience (Jong et al., 2020). The immersion, imagination, and interactivity that SVVR provides create an environment that has the potential to drive creative writing in students. Thus, scholars have proposed the view that SVVR can expand the students' level of thinking abstractness and relevancy, diminish the separation between the subject and the situation in writing, and ultimately enhance their creative writing excellence (Chen et al., 2022). Further research supports the notion that SVVR is superior in terms of providing an authentic learning experience, which in turn enhances the students' motivation to learn (Yang et al., 2021) and self-efficacy (Lin et al., 2021) when compared to the traditional media-driven learning paradigm that involves the use of PowerPoint or 2D video. It has also been reported that SVVR-based writing instructions are highly effective in promoting critical thinking abilities (Abdelrahim, 2023), facilitating in-depth learning (Chen et al., 2022) and eliciting positive learning behaviours (Chen et al., 2022). Despite these advantages, it should be noted that SVVR still has limitations when it comes to creative writing education. Although it can provide learners with rich, engaging materials to stimulate creativity, it may not be amenable to enhancing learners' generative processing ability (Yang et al., 2021). Generative processing is a crucial aspect, as it involves fundamental cognitive processes that form the foundation for learners to generate creative ideas (Moma et al., 2013). Therefore, to fully leverage the potential of SVVR, pedagogies that promote generative processing for learners should be incorporated into written instructions.

Generative learning is a promising pedagogy based on constructivism that encourages students to actively make sense of the material by reorganizing it and integrating it with their existing knowledge (Fiorella & Mayer, 2015). It involves the crucial process of taking incoming information and transforming it into usable information by selecting, organizing, and integrating it appropriately

(Parong& Mayer, 2018). Researchers have confirmed its potential to foster students' creative thinking abilities as it encourages learners to explain the main idea from what they have learned in their own words (Yang & Wang, 2021), enables learners to construct knowledge in their minds (Moma et al., 2013), and helps them to conceptualize abstract concepts (Gunawan et al., 2019). In particular, generative learning strategies (GLS) such as summarizing, answering and enacting have been found to improve learning outcomes when incorporated into immersive VR environments (Mayer, Makransky & Parong, 2022). Parong and Mayer's (2018) study revealed that students who used the summarizing strategy after each section of an immersive VR experience performed significantly better in science learning performance than those who did not summarize. Similarly, Klingenberg et al. (2020) found that applying a GLS in teaching could significantly improve the transfer, retention and self-efficacy of biochemistry students when learning via immersive VR. While the literature suggests the potential of generative learning in enhancing creativity and VR-based learning, little is known about the impact of incorporating these strategies into SVVR-based writing learning to promote creative writing among students. As such, the present study aims to explore whether the integration of GLSs and SVVR-based learning can stimulate elementary school students' creative writing performance.

2 Literature review

2.1 Creative writing

Creative writing is an open-ended design process that fosters creativity and plays a crucial role in children's cognitive and communicative skill development (Chen & Zhou, 2010; Essex, 1996). According to researchers, creative writing is an individual creative process that is based on establishing a diverse and fluid relationship between many thoughts and dreams, which can lead to successful writing for young writers (Flower & Hayes, 1981; Temizkan, 2010; Torrance & Galbraith, 2006). It helps children understand and explore the value and functions of writing, thus contributing to the development of their reading and writing skills (Shanahan, 2006). Furthermore, creative writing is seen as a way for individuals to express their ideas or feelings on paper by using their imagination (Oral, 2003). This point of view regards creative writing as the recreation of sentimental experiences in the mind (Sharples, 1996). Imagery is considered a crucial element in the development of creative writing (Engle, 1970). The learner must store images and sensory experiences in their mind and then encode these thoughts into an output verbal form (Plum, 1982). Creativity heavily relies on imagination, as well as the ability to visualize and observe within a learning environment that is contextualized (Barbot et al., 2012). One effective approach to enhancing elementary school students' creative writing skills is providing them with an authentic learning environment (Chen et al., 2022). By doing so, students can build their psychological confidence,

take pleasure in sharing their ideas with others, and concentrate on creative writing (Barbot et al., 2012; Gunning, 2005). Moreover, as education progresses and changes, so do the profiles of students over time. Dewey (2004) once noted that "If we teach today's students as we taught yesterday's, we rob them of tomorrow." Therefore, it is important to consider the integration of modern information technology and appropriate media into traditional writing instruction situations, providing an authentic learning environment that can support students' creative writing and meet the educational needs of different age groups.

Experts in creative writing from different fields, including psychologists, writers, and linguists agree that developing persistence is a crucial factor for successful creative writing (Barbot et al., 2012). This is because persistence ensures that students not only put in the necessary effort and practice to hone their writing skills, but they also apply the required mental effort to produce a creative piece (Taylor, Kaufman & Barbot, 2021). Through persistent practice, students can develop the necessary skills and mindset to continue learning and growing as creative writers (Taylor, Kaufman & Barbot, 2021). Research by Lucas and Nordgren (2015) found that persistence is a critical determinant of creative performance, and adjusting people's beliefs about the value of persistence may enhance creativity by preventing them from quitting early and leaving their best ideas uncovered. Additionally, according to the dual pathway model, persistence can lead to creativity through a narrow attentional scope, systematic processing and cognitive persistence, which directs focused cognitive effort toward a task. For instance, Taylor and Barbot's (2021) work indicated that learning persistence is closely related to creative writing performance by regulating the process of assessing fluid reasoning, comprehension knowledge, and long-term storage and retrieval. Furthermore, the learning engagement of students is also a critical factor that contributes to the success of creative writing (Hu & Kuh, 2002; Richardson & Newby, 2006), as it can encourage students to develop high-quality learning (Pino-James et al., 2019). Learning engagement is a multidimensional and multifaceted construct that comprises interrelated and mutually supportive dimensions of students' behaviour, emotion, and cognition (Fredricks et al., 2004). Specifically, cognitive engagement involves personal investment in academic tasks, self-regulation, and the value of the learning process; emotional engagement involves students' learning affect, sense of connectedness, and sense of belonging to school; behavioural engagement pertains to students' participation and involvement in academic, social, and extracurricular activities, including positive conduct such as attending class, and following class rules, involvement in learning such as displaying effort, being persistent, finishing homework, and participating in school-related activities such as taking part in extracurricular activities (Fredricks et al., 2004). Previous research has indicated a positive association between learning engagement and the creative writing performance of elementary school students (Yang et al., 2021). In particular, elementary school students who exhibit higher levels of learning engagement are more likely to achieve better outcomes in their writing abilities (Chen et al., 2022). Inspired by the literature reviewed here, we include student learning persistence and engagement as two of our dependent variables. Analyzing these two elements

may aid in understanding the findings revealed in this study.

2.2 SVVR

SVVR has gained increasing attention in education in recent years due to its low technical barriers and development costs (Yang et al., 2021; Chen et al., 2022; Liu et al., 2023; Zhao et al., 2023). It is one of the immersive VRs that only requires the use of 360-degree videos or photos, which could be obtained from open resources (e.g., YouTube) or using a 360-degree camera (Wu et al., 2021). More recently, SVVR has been applied to facilitate the learning-to-writing process of students in schools (e.g., Chen et al., 2022; Huang et al., 2020; Yang et al., 2021), as it can create a more authentic learning environment with immersive experience which makes the learner feel like they are encompassed in the virtual world with an authentic "field trip" experience (Huang et al., 2022). For example, Lan and Tam (2022)'s work investigated the effects of using 360-degree videos (one of the definitions of SVVR) in Chinese as a second language (CSL) writing learning. They assert that SVVR is a meaningful technology that can be incorporated into CSL writing to help students construct meaning from virtual and immersive experiences and help them perform better in writing. Chen et al. (2021)'s study used SVVR to support secondary school students' Chinese writing in Hong Kong. At the end of the study, they found that the virtual learning environment helped students to recognize different aspects of community life, broadened their horizons and inspired them to gain a deeper understanding of the cultural significance of local landscapes. It has been also justified by researchers that SVVR is conducive to the implementation of a learning-by-doing environment, which is not only essential in promoting students' learning engagement (Chen et al., 2022; Yang et al., 2021), but also helps them to build confidence in learning to write (Chen et al., 2021). As learning confidence builds, students are able to lavish attention on the learning-to-writing process.

However, there is no consensus in the literature on whether SVVR can support the development of student creative writing. On the one hand, researchers indicated that SVVR can stimulate the ability of students to perceive and imagine things in creative ways that do not exist in the real world (Barrett et al., 2021; Chen et al., 2022; Lan et al., 2019). For example, a study conducted by Chen et al.'s (2022) demonstrated that elementary school students who learned with the SVVR-based approach performed better than those who learned with a traditional 2D video-based approach in terms of their creative writing performance. Lan et al.'s (2019) research indicated that integrating 3D virtual worlds in CSL classes is a potential approach to freeing the minds and imaginations of students. On the other hand, Patera et al. (2008) highlighted that a VR environment provides abundant imaginative stimuli for elementary school students. However, this plethora of stimuli also presents a challenge for students as they face the difficulty of selecting a starting point and determining what to include or exclude in their writing. A quasi-experiment conducted by Yang et al. (2021) also found SVVR does not significantly

enhance elementary school students' creative thinking achievements. The literature contains varying findings on the effectiveness of VR or SVVR-based approaches in education due to differences in design. Limitations such as time-consuming activities, physical discomfort, and distracted attention need to be addressed with appropriate pedagogical designs (Mayer et al., 2022). Previous research by Mayer et al. (2022) has shown that incorporating GLSs could enhance immersive VR-based learning outcomes. Building on this idea, we aim to integrate GLSs into the design of VR-based writing activities to unlock the full potential of SVVR.

2.3 Generative learning

Generative learning is the process of actively making sense of information that needs to be learned by mentally reorganizing and integrating it with one's previous knowledge, which enables learners to apply what they have learned in new situations (Fiorella & Mayer, 2016). This approach emphasizes the active participation of students in the learning process (Wittrock, 1974), their deep understanding of the learning content, and their ability to transfer knowledge already known in other contexts (Fiorella & Mayer, 2016). There are two kinds of GLSs (Fiorella & Mayer, 2016): 1) verbal GLSs, such as summarizing, self-testing, self-explaining and teaching, are most effective when the materials are not complex or spatial in nature, when the learner can internalize spatial relationships on their own, or when the external spatial representations are already available. 2) Spatial GLSs, including mapping, drawing, imaging and enacting, are most effective when the materials are highly intricate or spatial in nature when the learner cannot internalize the relevant spatial relationships on their own, or when external spatial representation is not available. GLSs have been suggested to be effective for learning in an immersive virtual environment, as they can either enhance the unique features of immersive technology (e.g., SVVR) or overcome its limitations (Makransky & Mayer, 2022). For example, Makransky et al. (2021) found that the presence and enjoyment of taking a science class in a VR-based environment were significantly higher than experiencing a similar video course. However, there was no difference between the two media in terms of declarative knowledge, procedural knowledge, or transfer outcomes. In a follow-up experiment, the researchers added the GLS of enactment, which involves implementing the learned procedure with specific operations after the lesson (Fiorella & Mayer, 2016). They found that interaction with the GLS of enacting led to significantly better program knowledge and transfer outcomes in the VR condition compared to the video condition. The authors suggest that the GLS of enacting is particularly helpful when learning in immersive VRs because highly engaging learning experiences may result in students not allocating enough resources to reflect on what they have learned without integrated or follow-up GLS activities.

Of the eight GLSs, the GLS of imaging appears to be particularly well-suited to the research context of the present study, as we aim to explore whether the use of GLS+SVVR facilitates the students' creative

writing performance. The rationale behind the GLS of imagining refers to the process of translating the text into mental images, which prompts learners to select relevant information from the text, display its spatial organization in their mental images, and use their prior knowledge to clarify the text's meaning and its relationship with images (Fiorella & Mayer, 2016). The nature of learning by imagining is qualified with the requirements of creative writing, which entails writers retrieving related knowledge from long-term memory, and then integrating it comprehensively with newly formed ideas to generate creative writing output (Taylor & Barbot, 2021). Building on the existing literature, we have identified potential opportunities for integrating the GLS of imagining into SVVR-based activities in facilitating students' creative writing. However, to the best of our knowledge, no previous study has investigated the combined effects of these factors. Therefore, our study aims to fill this gap by proposing a generative learning-based SVVR (GSVVR) approach to writing instruction in elementary courses. We expect that this approach will not only enhance elementary school students' creative writing performance but also improve their learning persistence and engagement in the writing process. Specifically, our study seeks to answer the following questions:

RQ1: How does the effect of the generative learning-based SVVR (GSVVR) approach on creative writing performance differ from that of the generative learning-based conventional (GC) approach?

RQ2: How does the effect of the GSVVR approach on student engagement differ from that of the GC approach?

RQ3: How does the effect of the GSVVR approach on learning persistence differ from that of the GC approach?

RQ4: Can learning persistence be used to predict students' creative writing performance in different learning conditions (GSVVR vs. GC)?

3 Generative learning-based SVVR approach for creative writing

3.1 System structure

The system structure of the present study is illustrated in Figure 1, comprising a teacher terminal, a student terminal and a database containing learning materials and learning portfolios. Through the teacher terminal, educators design SVVR content as learning materials for students, and all the outputs generated by students (such as essays and questionnaires) are collected into a learning portfolio database for subsequent analysis. The student terminal is designed to enable students to engage with the SVVR content via VR headsets, providing an immersive and interactive learning experience.

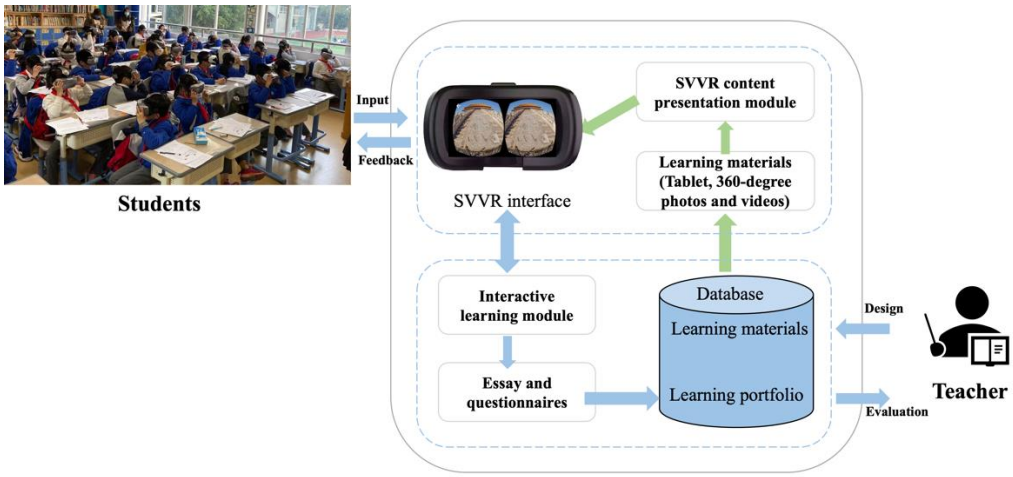

Figure 1 System structure

3.2 The learning content in GSVVR-based learning

The learning content for this study aligns with the requirements of the Chinese Curriculum Standards for Full-Time Compulsory Education. To enhance students' perception of writing context and mitigate their feelings of alienation from an authentic experience, we selected four writing themes centered on describing landscapes that are not easily accessible in a traditional classroom (see Figure 2 for details).

To develop the SVVR content (Figure 2a, 2b 2c), we utilized EduVenture VR (http://vr.ev-cuhk.net), a low-cost and user-friendly platform for designing spherical learning materials. For more information about this platform, please refer to Jong et al. (2018). The 360-degree spherical video in Figure 2d was sourced from NEWSCCTV (www. newscctv.net) and was carefully selected for its compatibility with the experimental setup. All materials were carefully curated and adopted by the researcher and a Chinese teacher to fit the context of the present study.

Figure 2 The writing themes

3.3 GSVVR learning approach

The current study introduced a generative learning-based SVVR (GSVVR) approach that drew on the GLS of imaging proposed by Fiorella and Mayer (2016). As illustrated in Figure 3, this approach emphasizes four key phases: selecting, organizing, integrating, and summarizing. The GSVVR approach is well suited to SVVR-based writing learning, as it enables students to process spatial material while engaging in a specific writing task and stimulates their creativity in writing. During the "selecting" stage, students were guided by the teacher to connect their prior knowledge and experience with specific writing contexts. They were then encouraged to focus on relevant information presented in spherical videos, which helped prevent distractions and kept them on task. In the "organizing" stage, students observed spherical videos using VR headsets and they mentally arranged the information in the videos into a coherent writing structure. This procedure was beneficial in promoting the development of coherent essays. In the "integrating" stage, students shared their observations with peers and related verbal and pictorial representations to one another. This procedure enabled students to activate relevant prior knowledge from long-term memory and improved their creativity. In the "imagining" stage, the students were encouraged to write down their imaginative thoughts. This process proved to be effective in generating creative ideas among students. They were then prompted to select, organize, and integrate these creative ideas with their existing knowledge structures to improve their creative writing. This procedure helped students recall what they had done during the previous three procedures, clarify their learning objectives, and lay the groundwork for full essay writing. The GSVVR approach not only provided an immersive learning experience but also engaged students in the cognitive process of learning, resulting in the improved quality of their creative writing.

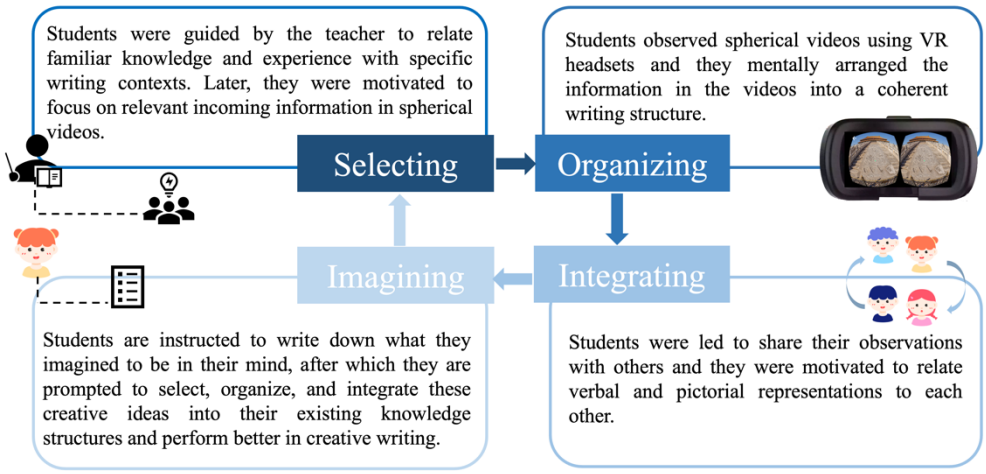

Figure 3. The GSVVR learning procedure

4 Methods

4.1 Participants

To quickly and easily access a sample, we used the convenience sampling method, selecting a school that expressed a willingness to participate in the study (Sahin & Yilmaz, 2020). A total of 111 students from two classes of an elementary school located in southern China were recruited during the second semester of the 2021-2022 academic year, and we were allowed to conduct the intervention study during the regular instructional period. The two classes of participants were randomly assigned to either the experimental group (EG) (N=56, 26 males, 30 females; M_{age} = 10.42 years; SD = 0.356) or the control group (CG) (N=55, 27 males, 28 females; M_{age} = 10.43 years; SD = 0.361) group. Both groups were taught by the same Chinese teacher who has 5 years of teaching experience, using different approaches (i.e., GSVVR approach for EG and GC approach for CG). All participants were volunteers who had agreed to participate in the experiment and were told they could withdraw from the experiment at any time.

4.2 Experiment design and procedure

A quasi-experiment was conducted to explore whether the proposed approach was effective in promoting students' creative writing. As shown in Figure 4, the study structure defined the learning approaches as independent variables: the GSVVR approach, which utilizes spherical video-based virtual reality during a motivating learning procedure, and the GC approach, which employs regular video during a motivating learning procedure. The dependent variables were defined as post-tests for creative writing performance, learning engagement and learning persistence, with pre-tests serving as covariates. To answer research questions 1 to 3, variance analysis (i.e., ANCOVA) or Johnson-Neyman was utilized, while research question 4 was addressed through correlation and regression analysis.

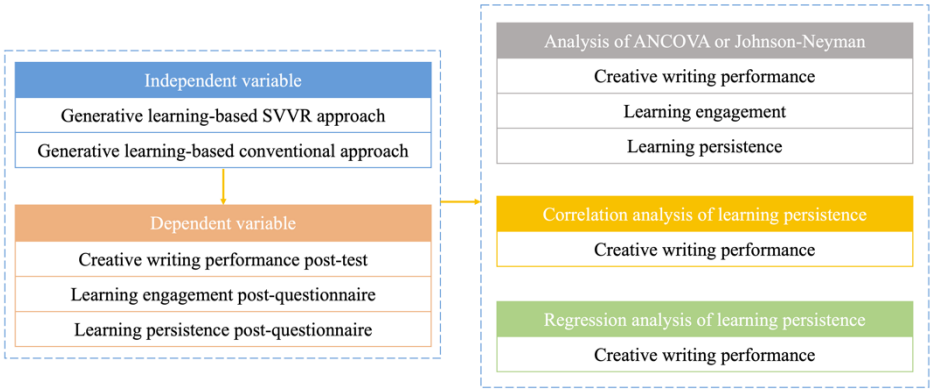

Figure 4 The research structure

The experimental procedure of this study is illustrated in Figure 5. The experiment lasted for five weeks, during which the participants underwent various assessments and interventions. In the first week, all participants took pre-tests to evaluate their creative writing performance with the theme of "Beautiful Jiangxin Island". Additionally, students completed pre-questionnaires on learning engagement and learning persistence. Subsequently, from weeks 2-5, students in the EG group were guided by a teacher using the GSVVR method, while those in the CG were guided by a teacher using the GC method. The GC approach follows the procedures of the GSVVR approach, with the only difference being that the students in the GSVVR group observed spherical videos using VR headsets, whereas the students in the GC group observed 2D videos. Prior to the start of class, the EG students were taught how to use VR headsets. Due to school schedule constraints, classes for the two groups were held on different days, with the EG students meeting every Tuesday and the CG students meeting every Thursday. In the final week, all participants took post-tests on creative writing performance with the requirement to write an essay to describe a place they had experienced during the last four weeks. Students were also guided to take post-questionnaires on learning engagement and learning persistence.

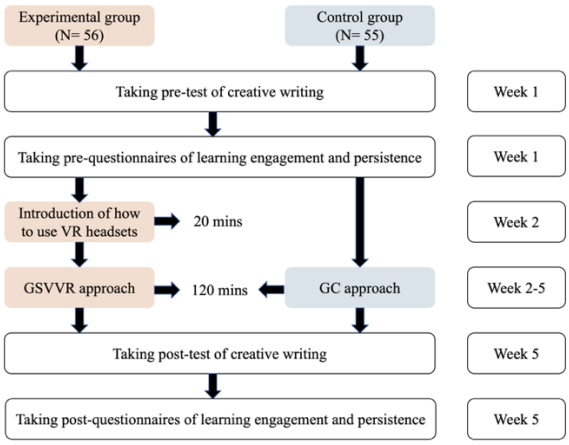

Figure 5 The experiment procedure

4.3 Measuring instrument

The rubric of creative writing

The creative writing rubric was developed with reference to the verbal creativity assessment from Torrance's (1974) creative thinking tests, in which he posits that creativity can be evaluated in four aspects: fluency, flexibility, originality and elaboration. Fluency measures the ability to generate a sequence of ideas; flexibility measures the ability to switch one's opinions or ideas; originality measures the ability to generate new ideas; elaboration measures the ability to expand ideas and add more details (Treffinger, 2002). The total score for both the pre- and post-test is 100, with 25 points allocated to each dimension. All writing was evaluated by two Chinese teachers with over 10 years of teaching experience, who were required to use a back-to-back double-blind evaluation method to ensure fairness. The grading

scores were found to have an acceptable reliability of 0.746 (Cohen, 1968), and the final scores were calculated by averaging the scores given by the two teachers.

Learning engagement

The learning engagement questionnaire was adapted and slightly modified by Sun et al. (2021) and consists of 12 items, with 4 items each for cognitive engagement, emotional engagement, and behavioural engagement. An example of a cognitive engagement item is, "I am able to use the words and sentences I learned from reading during ordinary times in my writing." An example of an emotional engagement item is, "I feel relaxed during the writing class." An example of a behavioural engagement item is, "I am able to concentrate when taking a writing course." The questionnaire utilized a 5-point Likert scale from 1 (lowest score) to 5 (highest score) and demonstrated acceptable reliability, with Cronbach's α of 0.918 for the overall scale and 0.748, 0.854, 0.830 for the three sub-scales (Cohen 1968).

Learning persistence

The learning persistence questionnaire used in this study was adapted and slightly modified from Duckworth and Quinn (2009) and consists of 3 items. For example, one of the items was, "I am determined to overcome the obstacles to achieve my learning goal in writing." The questionnaire utilized a 5-point Likert scale, where the lowest score was 1, and the highest score was 5, and showed acceptable reliability with a Cronbach's α of 0.749 (Cohen 1968).

4.4 Data analysis

In this study, quantitative analysis was carried out to examine the effectiveness of the GSVVR approach in creative writing. As shown in Table 1, the kurtosis and skewness statistics analysis of each variable show that the data are normally distributed, with kurtosis values ranging from -2 to +2 and skewness values ranging from -5 to +5 (West et al., 1995). The normality assumptions testing resulted in acceptable outcomes for conducting parametric analysis methods (i.e., t-test, Pearson's correlation analysis, regression analysis).

All quantitative data were analyzed using IBM SPSS 25.0 with a significance level set at 0.05. The effect size was calculated when there was a significant difference between the groups. For research questions 1, 2 and 3, tests were performed to check for linearity and homogeneity of covariates and independent variables. If both assumptions were satisfied, a one-way factorial ANCOVA analysis is performed to uncover differences between the two groups in certain dependent variables. If either assumption was violated, alternative methods such as non-parametric analysis or Johnson-Neyman analysis were employed. For research question 4, we first used Pearson's correlation analysis to explore whether a correlation exists between student learning persistence and creative writing performance. Then, we employed regression analysis to identify the degree to which learning persistence affects student creative writing performance.

Table 1 Kurtosis and skewness statistics of dependent variables

Variables	Skewness	Kurtosis
Creativity writing performance	-0.526 (SE = 0.228)	0.371 (SE = 0.453)
Learning persistence	-1.902 (SE = 0.229)	4.743 (SE = 0.455)
Cognitive engagement	-1.107 (SE = 0.229)	2.922 (SE = 0.455)
Behavioural engagement	-1.159 (SE = 0.229)	1.026 (SE = 0.455)
Emotional engagement	-1.556 (SE = 0.229)	3.279 (SE = 0.455)

5 Results

5.1 RQ1: How does the effect of the generative learning-based SVVR (GSVVR) approach on creative writing performance differ from that of the generative learning-based conventional (GC) approach?

The results of Levene's homogeneity assumption (F = 0.150, p > 0.05) and the homogeneity regression test (F = 3.016, p > 0.05) were found to be acceptable for student creative writing performance, indicating that a covariate analysis (i.e., one-way ANCOVA) could be performed to examine the statistical difference in creative writing performance between the two groups. As shown in Table 2, there was a significant difference in creative writing performance (F = 10.953, p < 0.01) between the two groups with a medium effect size. The results show that the GSVVR approach is more effective than the GC approach in facilitating students' creative writing.

Table 2 Analysis of ANCOVA results of creative writing performance for the two groups

Variance	*Groups*	*N*	*Mean*	*SD*	*Adjusted mean*	*SE*	*F*	*p*	η^2
Creative writing	CG	55	75.465	8.523	75.439	1.157	10.953**	0.001	0.092
performance	EG	56	80.803	8.721	80.829	1.146			

***p < .01*

5.2 RQ2: How does the effect of the GSVVR approach on student engagement differ from that of the GC approach?

The results of regression slope assumptions and Levene's tests show that the cognitive engagement measures met both assumptions (regression slope test: F = 1.987, p > 0.05; Levene's test: F = 3.578, p > 0.05), whereas behavioural engagement (F = 14.198, p < 0.001) and emotional engagement (F = 19.716, p < 0.001) violated the regression slope assumptions. This indicates that there was a significant interaction effect between the covariate variable (pre-test of behavioural or emotional engagement) and

the independent variable (learning approach). Therefore, a one-way ANCOVA analysis could be performed to examine the difference in cognitive engagement between the two groups, but it cannot be used to examine the differences in behavioural and emotional engagement between the two groups. Hence, as suggested in D'Alonzo (2004), the Johnson-Neumann (J-N) technique was used as an alternative to ANCOVA. The J-N technique provides additional information to researchers regarding non-significant regions with different interventions. Thus, we employed the J-N technique to examine the differences in behavioural and emotional engagement between the two groups.

Table 3 shows no significant difference in cognitive engagement ($F = 1.153$, $p > 0.05$) between the two groups. Figure 6 shows the behavioural engagement results for both groups, where the red and blue lines represent the regression slopes for the GSVVR and GC groups, respectively. The significance point of the two groups' difference in the pre-test of behavioural engagement is 4.397, implying that only students in the GSVVR condition whose pre-test score of behavioural engagement was below 4.397 ($t = 1.99$, $p < 0.05$) outperformed others in the GC approach significantly in behavioural engagement. On the other hand, there was no significant difference in behavioural engagement between the two groups when the pre-test score was above 4.397. Along the same line, as shown in Figure 7, the significance point of the two groups' difference in the pre-test of emotional engagement is 4.3325, suggesting that when the pre-test score of emotional engagement is below 4.3325, the students who learned with the GSVVR approach outperformed significantly in emotional engagement than those who learned with the GC approach ($t = 1.99$, $p < 0.05$). However, there was no significant difference in emotional engagement between the two groups when the pre-test score was above 4.3325. All the above results demonstrate that the GSVVR approach is more effective in promoting students' behavioural and emotional engagement that the GC approach when they have a lower pre-test score of behavioural (below 4.397) and emotional engagement (below 4.3325). However, the GSVVR approach does not seem to have an impact on promoting students' cognitive engagement.

Table 3 Analysis of ANCOVA results of cognitive engagement for the two groups

Variance	*Groups*	*N*	*Mean*	*SD*	*Adjusted mean*	*SE*	*F*	*p*	η^2
Cognitive	CG	55	4.083	0.707	4.129	.065	1.153	0.285	__
engagement	EG	56	4.272	0.546	4.228	.065			

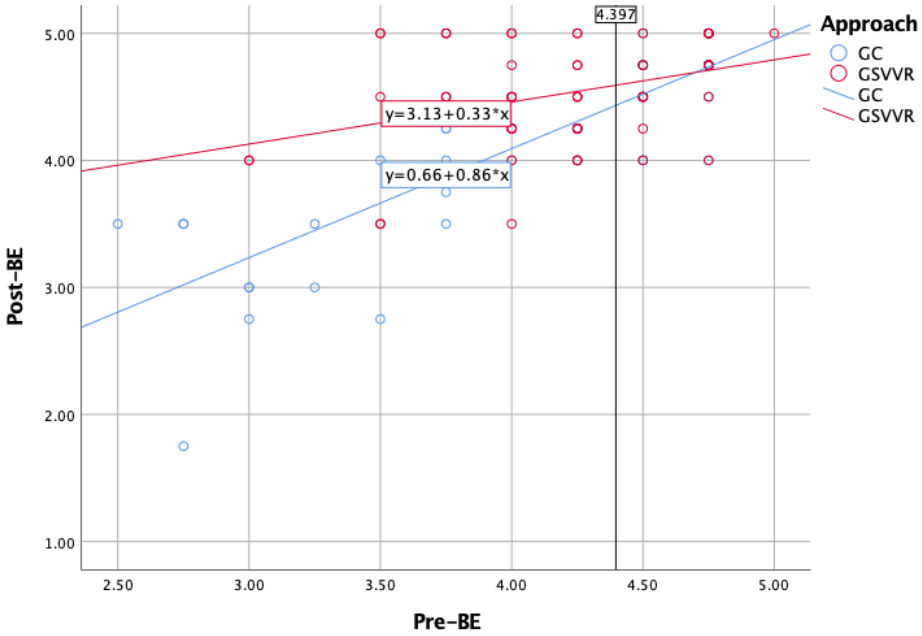

Figure 6 Illustration of the significant difference in the behavioural engagement of the two groups

*(Pre-BE means pre-test of behavioural engagement; Post-BE means post-test of behavioural engagement)

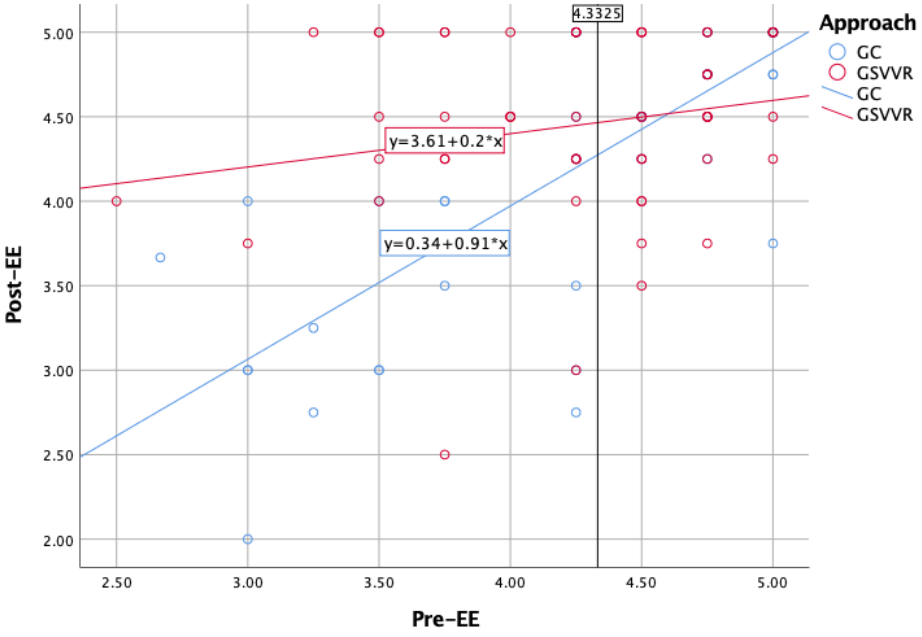

Figure 7 Illustration of the significant difference in the emotional engagement of the two groups

*(Pre-EE means pre-test of emotional engagement; Post-EE means post-test of emotional engagement)

5.3 RQ3: How does the effect of the GSVVR approach on learning persistence differ from that of the GC approach?

First, we examined the results of regression slope assumptions and Levene's tests of student learning persistence. However, the homogeneity of regression coefficients was violated, suggesting that there was

a significant interaction effect between the covariate variable (pre-test of learning persistence) and independent variable (learning approach). To address this issue, we employed the J-N technique to examine the difference in learning persistence between the two groups. As shown in Figure 8, the red and blue lines show the regression slopes for the GSVVR and GC groups, respectively. The point of significance of the two groups' difference in the pre-test of learning persistence is 4.4953, implying that the students who learned with the GSVVR approach outperformed significantly in learning persistence than those who learned with the GC approach when their pre-test score of learning persistence was below 4.4953 ($t = 1.99$, $p < 0.05$). On the other hand, when the pre-test score was above 4.4953, there was no significant difference in learning persistence between the two groups. These findings suggest that the GSVVR approach is more effective in promoting students' learning persistence than the GC approach, particularly for those with a lower pre-test score of learning persistence (4.4953).

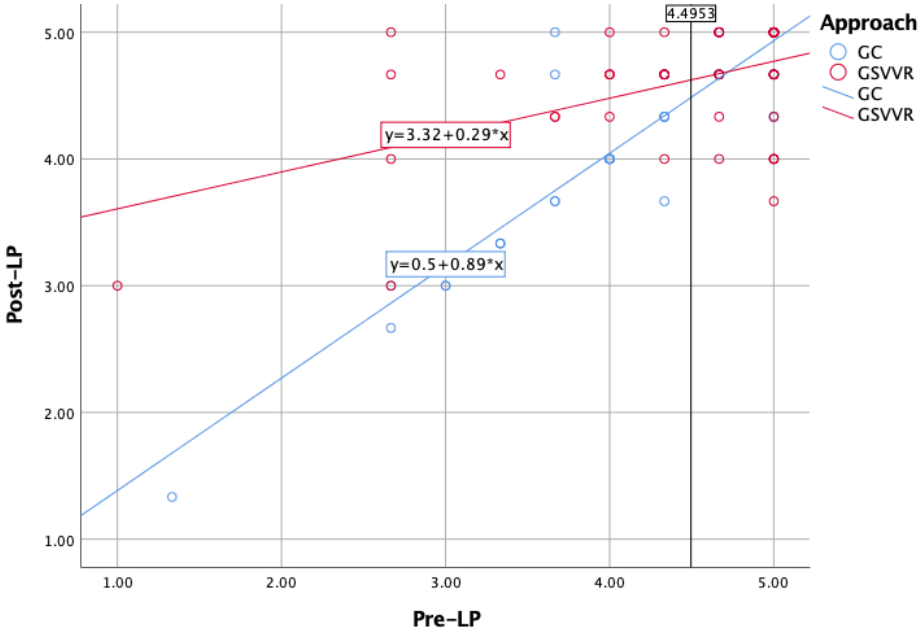

Figure 8 Illustration of the significant difference in the learning persistence of the two groups

*(Pre-LP means pre-test of learning persistence; Post-LP means post-test of learning persistence)

5.4 RQ4: Can learning persistence be used to predict students' creative writing performance in different learning conditions (GSVVR vs. GC)?

To better elucidate the mechanism behind the effectiveness of the GSVVR approach in promoting students' creative writing, we performed a correlation analysis of creative writing performance and learning persistence. More specifically, we were interested in identifying the extent to which learning persistence relates to creative writing performance in our study context. As shown in Table 4, we observed a positive correlation between student creative writing and learning persistence in the EG, whereas no significant correlation was found in the CG. These findings suggest that in the EG, students with higher levels of learning persistence were more likely to exhibit better creative writing performance.

Table 4 Pearson's correlation analysis results

Group	*Variance*	*N*	*Mean*	*SD*	*r*	*p*
CG	Creative writing	55	75.465	8.523		
	Learning persistence	55	4.358	0.769	0.196	0.151
EG	Creative writing	56	80.803	8.721		
	Learning persistence	56	4.613	0.479	0.337*	0.011

To further investigate whether learning persistence is a significant predictor of the enhancement of creative writing performance, we conducted a regression analysis. The results, shown in Table 5, indicate that 11.4% of the variance in creative writing performance was explained by learning persistence. The results of the ANOVA test (F = 6.923; p = 0.011) show that the model was statistically significant, indicating that the development of student learning persistence affected their creative writing performance. The B value for learning persistence was 6.138 and the B value for creative writing was 52.488. This leads to the formula of the regression model (see Figure 9):

Predicted creative writing performance = 52.488 + (6.138) learning persistence

This suggests that an increase of one point in learning persistence is associated with a 6.138-point improvement in creative writing performance. Overall, the results of this section suggest that in the context of GSVVR learning, students' learning persistence could be a predictor of their creative writing performance.

Table 5 Coefficients of regression model

Groups	Dependent Variables	Predictor Variables	Unstandardized Coefficients	Standardized Coefficients		t	Sig.	Model Summary		ANOVA	
			B	Std. Error	Beta			R Square	Adjusted R Square	*F*	*Sig.*
CG	Creative Writing	(Constant)	65.966	6.601		9.998	.000	0.038	0.020	2.121	0.151
		Learning persistence	2.173	1.492	.196	1.456	.151				
EG	Creative Writing	(Constant)	52.488	10.819		4.852	.000	0.114	0.097	6.923*	0.011
		Learning persistence	6.138	2.333	.337	2.631	.011				

*$p < .05$

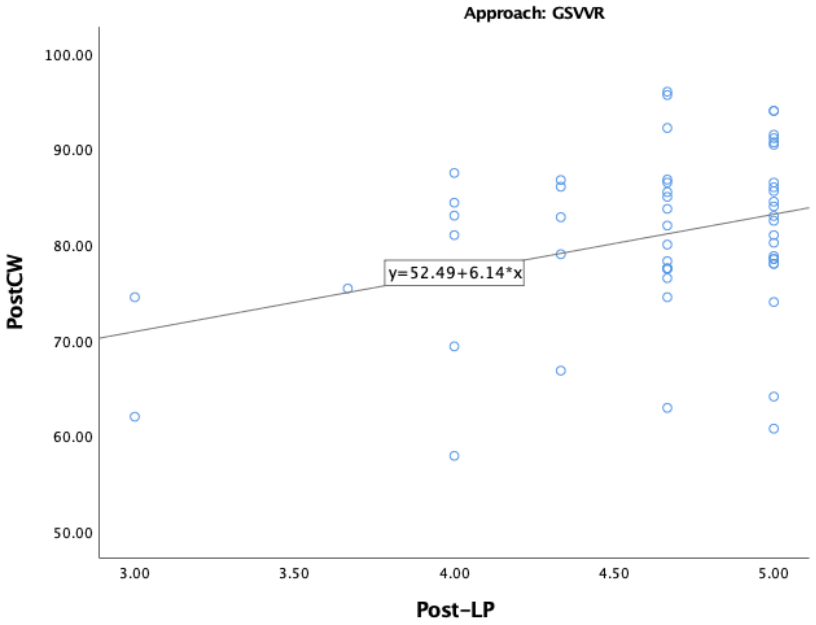

Figure 9 Regression square correlation

*(Post-LP means post-test of learning persistence; PostCW means post-test of creative writing performance)

6 Discussions

The potential positive effects of SVVR in creative writing have been studied in prior research. The results indicate that studies without guidance on appropriate pedagogical approaches have limited the impact of SVVR in facilitating student creative writing (Yang et al., 2021). Hence, the present study proposed a pedagogical approach to be integrated into SVVR-based contexts and studied its effects on improving students' creative writing performance in a quasi-experiment. The four research questions were posed and answered as follows:

In response to research question 1, students in the GSVVR group outperformed the GC group in terms of creative writing performance. This finding contrasts with previous research by Yang et al. (2021), who found no significant enhancement in students' creative writing performance using an SVVR-based approach. A possible reason for this is that the pedagogical approach proposed in this study may facilitate the specific features of SVVR better (Makransky & Mayer, 2022), and enable SVVR affordances to be more impactful on students' creative writing performance (Klingenberg et al., 2020). Our results are aligned with the theoretical propositions of Makransky et al. (2021) and Mayer et al. (2022), that using immersive VR in combination with a GLS may be beneficial in sustaining and improving learning outcomes. GLSs can help learners reduce the extraneous processing caused by VR-based learning, which is detrimental to learning outcomes, and increase generative processing which is linked to student comprehension of the learning materials. This increased generative processing may motivate students to

devote more engagement and persistence to focusing on a specific task, enabling them to perform better in creative writing.

With regard to research question 2, it was found that students in the GSVVR group, who initially had lower levels of behavioural and emotional engagement (i.e., engagement values below 4.3), demonstrated significantly higher engagement in the post-test compared to the control group. These results indicate that the GLS intervention is likely to help students with engagement values below 4.3. More specifically, it can improve the value of SVVR for their learning, sustain their engagement with the task, and improve their creative writing performance. It is important to note that the intervention did not yield significant effects on students who were already highly engaged (i.e., engagement values exceeding 4.3). It is important to note that the intervention did not yield significant effects on students who were already highly engaged (i.e., engagement values exceeding 4.3). These findings are aligned with previous studies, such as Chen et al. (2022), which found that SVVR contributes to enhancing student behavioural engagement in learning to write by transforming their level of behavioural engagement from medium to high. Similar support is provided by the results of Wang and Sun (2021), who found that students learning in a virtual environment experienced significant increases in emotional engagement. The increased agency and presence provided by SVVR may promote students' perceived enjoyment and positive learning behaviours in the learning context (Chen et al., 2022; Makransky et al., 2021), leading to increased behavioural and emotional engagement. Such engagement can encourage students to focus more on their writing tasks, which can improve their performance in creative writing. One interesting result that comes out of our engagement investigations was that the pedagogical approach integrated had no statistically significant effect on those students who were already highly engaged with the SVVR (i.e., engagement values exceeding 4.3). These results further support the previous research evidence (Nelson et al., 2012) that low-engagement students might benefit even more from effective pedagogical strategies in SVVR on their engagement behaviours.

We did not find significant differences in the cognitive engagement of the students between the two groups. This result indicates that the VR-based approach does not appear to have a significant impact on student cognitive engagement, which might be due to the limited intervention times and unfamiliarity with the tool used (e.g. Wang & Sun, 2021). Cognitive engagement involves higher-order indicators, such as metacognitive and self-regulation, which require a long-term process of continuous practice and reflection in learning. These skills are difficult to be influenced by short-term interventions such as the four-week intervention used in the current study. In addition, compared to behavioural and emotional engagement measures, the validity and reliability of cognitive engagement measures are lower, particularly in contexts of emerging technology interventions (Martins et al., 2022). Therefore, it is worth noting that, at least to a certain extent these results from our study, and previous research in the field, might be associated with challenges in measuring the cognitive engagement of students.

As for research question 3, students who learned with the GSVVR approach and had lower pre-test

values for learning persistence tended to outperform those who learned with the GC approach as reflected in their post-test scores for learning persistence. This result sheds light on the effectiveness of the proposed approach in facilitating the learning persistence of students' learning to write. The finding supports the hypotheses generated and tested in previous work (i.e. Chen et al., 2022), that the use of the SVVR technique can facilitate students' learning persistence. One potential reason for the increase in learning persistence in VR-based learning may be linked to the enhancement of interest in the process of learning (Makransky et al., 2021). This viewpoint is supported by the findings of Endres et al. (2020), who discovered that situational interest acts as a mediator of increased learning persistence. It implies that students put in more effort when they have a genuine interest in the subject matter or when the lesson sparks situational interest within them. Immersive virtual learning experiences can elicit episodic interest because students perceive them as more enjoyable than conventional media lessons (e.g., Parong & Mayer, 2018).

In terms of research question 4, we found that the students in the GSVVR group tended to perform better in creative writing when they had a higher level of learning persistence; while there was no positive correlation between the two elements in the GC group. These results encourage the idea that SVVR may serve as a mediator in regulating the relationship between learning persistence and creative writing. Furthermore, learning persistence plays a facilitating role in the effects of SVVR and contributes to the improvement of student creative writing performance, as we found learning persistence was a significant predictor of student creative writing development. Leroy and Romero (2022) proposed that persistence in the face of obstacles is an important aspect of development in creative pursuits. Our study suggests that creative writing performance can be improved through students' persistent engagement with learning via SVVR. These findings are supported by previous research (e.g., Taylor & Barbot, 2021) that highlights the indirect influence of learning persistence on creative writing performance.

These findings have several pedagogical implications for the research and educational practice of SVVR. First, the GLS of imaging appears to be an effective intervention to be integrated into SVVR to improve students' creative writing performance. The mixed findings from previous research on SVVR interventions and their impact on students' learning outcomes may be attributed to the degree to which pedagogical approaches incorporated in SVVR interventions are truly conducive to learning. GLS of imagining as designed, implemented, and evaluated in this study appears to facilitate primary school students' creative writing process and might mitigate some of the potential detrimental impacts of SVVR (e.g., extraneous cognitive load), hence leading to an increase in their creative writing performance. Second, the study highlights the potential of the proposed GSVVR approach to foster higher levels of learning engagement and persistence among students, particularly for those students whose initial engagement levels are low. Therefore, the suggested intervention can be particularly helpful in contexts where there is limited initial engagement among students. Furthermore, our findings indicate that SVVR plays a crucial role in moderating the connection between learning persistence and creative writing

among students. Notably, learning persistence emerged as a key predictor of creative writing advancement when utilizing the GSVVR approach. Educators should highlight the value of perseverance and encourage students to persist in their learning endeavors in SVVR interventions with appropriate pedagogical implementations. It is also essential for educators to establish a supportive learning atmosphere that would encourage and allow space for students' persistence. One effective strategy is to assist students in developing their utility values, which pertain to recognizing the usefulness of a task or a specific domain related to their current and future goals, such as career aspirations (Loh, 2019). By helping students understand how their learning connects to their aspirations and the practical value it holds, educators can foster a sense of purpose and motivation that contributes to their learning persistence in technology-enhanced instructions.

7 Limitations and future research

There are some limitations of this study that need to be taken into account in the interpretations of its findings. First, the study sample size was relatively small for an experimental design, consisting of only 111 fourth-graders. Although this is larger than most studies of previous SVVR implementations in primary classrooms, for experimental study designs this size may be considered limited. Future studies should consider a larger sample size that includes participants from other grade levels to extend and generalize the findings. Second, the study duration was only four-week, which is a relatively short period considering that creative writing development is a long and cumulative process (Yang et al., 2021). Therefore, it is suggested that the duration of future experiments should be increased to provide more reliable data and reduce the novelty effect of SVVR. Third, we only adopted one of the generative learning strategies (i.e., imaging) in this research, but there are other promising GLS (e.g., summarizing, enacting) that could be further integrated into SVVR-based writing instructions to enhance the effects of SVVR on writing learning outcomes. Fourth, it is possible that students with already high pre-test engagement scores may have experienced a ceiling effect of engagement impact. Therefore, it is necessary to further investigate in detail the reasons behind the absence of significant differences in students' engagement. This could be accomplished by conducting interviews with students, allowing for a more comprehensive understanding of their experiences and perspectives. Finally, only quantitative data with certain relevant variables have been collected and analyzed in the current study. Additional variables (i.e., self-efficacy) can be used to extend the research findings of the current study. Qualitative data (i.e., student and teacher interviews; students' writings' content analysis, observations etc.) should be included in future studies to be able to provide more insights into reasons behind the observed positive impact of the GSVVR approach. Data from these various qualitative sources can be used to investigate different aspects of the observed impact (e.g., students' meta-cognitive ability); through its analysis with

recent innovative methods such as epistemic network analysis and social network analysis.

8 Conclusions

The general learning strategy of imagining can be effectively integrated into SVVR to promote students' creative writing as well as the behavioural and emotional engagement and learning persistence of students in primary school contexts. These results contribute to the broader research on effective pedagogical interventions of SVVR and their impact on various learning outcomes. It is particularly significant that the evaluated intervention is impactful for students who are initially low-engaged in the learning activity, whilst it is not negatively impacting students with high engagement. However, further investigations on the longevity of the impact, as well as its cross-subject and cross-age-group validity, should be undertaken.

Statements and Declarations

Ethical approval All participants were volunteers who had agreed to participate in the experiment. They were told they could withdraw from the experiment at any time. There are no ethical issues or conflicts of interest emanating from this study.

Informed consent Informed consent was obtained from all individual participants included in the study.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

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