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REVIEW

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# Enhancing college students' creativity through virtual reality technology: a systematic literature review

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Cultivating learners' creativity has been a matter of great concern for numerous researchers in higher education since the millennium, as it involves not only artistic expression but also critical thinking and innovation. With the continuous innovation and iteration of educational technology, virtual reality (VR) technology is increasingly becoming a transformative tool for higher education. At present, VR has been well demonstrated in some disciplines by providing various sensory experiences and allowing students to complete highly interactive learning experiences in a virtual environment. This study systematically reviewed articles published between 2014 and 2023, aiming to examine trends in the past ten years in using VR to enhance learners' creativity, the types of learning materials developed, the types of existing research, and the methods of collecting data. A total of 16 articles were included after a screening process by searching the literature in five databases: Springer Link, ScienceDirect, Web of Science, ProQuest, and Google Scholar. The results showed that the use of VR to develop learning materials for college students is relatively limited and quantitative research is the majority. In addition, the existing cases are mainly concentrated in art design, engineering, and education related courses. These findings may provide actionable insights for researchers interested in this field and also suggest the possibility of further empirical research in other fields.

## Introduction

Since the turn of the millennium, technology has been seamlessly integrated into the fabric of human life, spawning countless innovations, iterations, and subtly changing people's daily lives (Jwo et al., 2021). According to Fitria (2023), the rapid development of immersive technologies represented by augmented reality (AR) and virtual reality (VR) has attracted many researchers from different fields to try to introduce simulated or completely artificial environments to bring learners a new learning experience. These cutting-edge technologies have proven to be very effective in higher education environments, often surpassing the effectiveness of traditional classrooms (Al-Ansi et al., 2023; AlGerafi et al., 2023; Ibañez-Etxeberria et al., 2020). As a result, immersive technologies are gradually reshaping traditional

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education by allowing learners to engage with emerging tools and materials that enrich their educational journeys.

While AR and game-based learning (GBL) have also received a lot of attention from educators in recent years, VR offers distinct benefits when it comes to encouraging creative thinking. VR creates an entirely immersive experience, as opposed to AR, which only superimposes digital elements onto the real world. This allows students to explore and interact with virtual settings in ways that would be impossible in the real world. Vega et al. (2020) and Samala et al. (2024a, 2024b) found that students' ability to conceptualize complicated ideas, try out ideas in a safe setting, and work together to solve problems was enhanced by this immersive VR environment. Moreover, VR also provides a more personalized and immersive learning experience than traditional GBL, which often relies on predefined outcomes and rules (Lyu et al., 2023). Integrating VR into educational methodologies enables educators to establish transformational learning environments that foster diverse thinking, creativity, and creative expression. Some researchers have also raised some possible and practical considerations based on the role of VR technology in educational development. These concerns are mainly focused on the fact that VR may reduce students' opportunities for face-to-face communication, the negative impact of VR on users' physical condition (motion sickness, nausea, spatial orientation disorder, etc.), the high equipment cost and adaptability of VR equipment (Ardiny and Khanmirza, 2018; Baniasadi et al., 2020; Vehteva et al., 2021).

Presently, educators predominantly employ three forms of VR in educational settings: non-immersive, semi-immersive, and fully immersive (Żammit, 2023). Non-immersive VR, commonly known as desktop VR, involves interacting with a virtual environment using a computer monitor, keyboard, and mouse. Semi-immersive VR offers a more engaging experience by using larger displays, such as projection systems, large screens, or multiple monitors, to create a more encompassing visual environment. Fully immersive VR, the most advanced form, utilizes head-mounted displays (HMDs) or VR headsets along with motion tracking to provide users with a highly immersive experience, allowing them to interact with virtual environments almost as if they were real.

Creativity, characterized as the ability to generate novel ideas, innovate, and discover (Khalid et al., 2020; Ismayilova and Laksov, 2022; Xu, 2024), thrives in environments that promote various perspectives, autonomous reasoning, and collaboration. According to Vygotsky's sociocultural theory (Vygotsky, 1978), a famous theory of cognitive development, adolescents in higher education are in a critical stage of creative development. During this period, students may engage in abstract thinking, resolve complicated issues, and synthesize diverse areas of knowledge, which are essential to creativity (Daneshfar and Moharami, 2018). The university environment prioritizes interdisciplinary education and engagement with developing technologies, creating an optimal environment for fostering students' creativity. While universities provide such environments, many still rely on traditional teaching methods like lectures and slides (Kaur et al., 2022), which can limit creative exploration. However, recent studies highlight how emerging technologies like VR present unique opportunities to nurture creativity (Xing and Qi, 2022; Samala et al., 2024a, 2024b). VR's immersive and interactive experiences, combined with advanced tools and collaborative platforms, equip students with the skills and mindset necessary for innovation. This suggests that VR has transformative potential in education, offering hands-on, creative learning opportunities beyond what traditional classrooms can provide.

It is worth noting that several studies have explored the use of VR in education over the past few years, but few studies have specifically focused on its role in enhancing creativity among college students. Asad et al. (2021) performed a thorough evaluation of VR as an educational instrument, although they did not explicitly address creativity. Likewise, Li et al. (2022) examined developing technologies in education, although did not concentrate on higher education or creativity. This study employs a systematic review technique to thoroughly assess and compare the use of VR in higher education for the enhancement of college students' creativity. Specifically, our focus is to collect empirical studies from higher education with students from different majors as participants, which combine different types of VR technologies to enhance learners' creativity. To further explore relevant research cases, the systematic literature review was conducted to answer the following research questions (RQs):

(1) What are the trends in using VR to improve students' creativity in higher education from 2014 to 2023?
(2) What are the types of learning materials developed using VR technology and classroom organization factors?
(3) What are the research types and data collection methods on using VR technology to improve students' creativity in higher education?
(4) What aspects of student development does VR technology promote?

## Theoretical frameworks

**Connection of creativity with higher education**. Creativity is the ability to generate, develop, and express original ideas that are new, useful, and valuable (Guilford, 2017; Supena et al., 2021). It involves the ability to discover connections, patterns, and possibilities that others may not see, and to transform these insights into innovative solutions, artistic expressions, or new ways of thinking (Durnali et al., 2023; Sawyer and Henriksen, 2024). Many mental operations, such as creative problem-solving, critical thinking, and divergent thinking, are part of the creative process (Giancola et al., 2022). VR aids these procedures by creating an immersive environment in which students may investigate numerous solutions to a problem, try out different ideas, and receive immediate feedback on their progress. VR is transforming education by providing interactive simulations that enable students to engage in actual problem-solving (Jantanukul, 2024). Another way is via its collaborative capabilities, which enhance group brainstorming and peer recommendations (Fromm et al., 2021). The compatibility of VR with the cognitive aspects of creativity provides it an excellent medium for fostering inventive ideas.

It is worth noting that students' creativity is affected by personal factors as well as the educational environment (Conradty and Bogner, 2020). Educators and institutions need to understand the personal traits and characteristics that affect creativity, such as intrinsic motivation, personality traits, cognitive abilities, and diverse life experiences. In addition, it includes establishing a learning atmosphere that makes students feel comfortable, providing modern technology tools, spaces, and extracurricular activities that stimulate creative thinking and problem solving. The improvement of creativity may promote learners to have a deeper understanding of the subject and encourage students to explore concepts beyond rote memorization. It can also increase student engagement and motivation in the process of completing some creative projects and assignments, making learning more enjoyable and effective (Wakefield et al., 2022).

At present, many countries in the world have advocated taking positive measures and introducing emerging technologies to improve the creativity of college students in recent years (Gray and Morris, 2022; Han and Abdrahim, 2023). This shows that

improving learners' creativity has attracted the attention of a wide range of researchers. Some previous empirical studies that are often used to enhance learners' creativity include interdisciplinary learning that broadens horizons and promotes innovative problem-solving skills by integrating different knowledge fields (Wright and Wrigley, 2017), makerspaces by providing an environment conducive to experimentation and practical application of ideas (Wu et al., 2021), artistic integration to promote students' imagination, emotional expression, and symbolic thinking (Corral et al., 2023). These methods have been well demonstrated in improving students' creativity. However, enhancing creativity by providing interactive and immersive learning experiences that stimulate college students' innovative thinking through technology integration is still in the exploration stage.

**VR in higher education**. The development of VR can be traced back to Morton Heilig invented the "Sensorama" in 1962, a multisensory simulation experience device, which laid the foundation for the concept of VR, although it did not achieve full VR (Lele, 2011). VR primarily immerses viewers in a computer-generated three-dimensional world by creating an entirely virtual environment, as opposed to AR, which superimposes digital information or virtual objects over the actual world. Important success factors for VR technologies include immersion, interaction, and user engagement (Berkman and Akan, 2018; Freina and Ott, 2015). In the past years, high-quality VR devices are usually expensive, compatibility issues between different VR devices may limit user experience and content access, and long-term use of VR headsets may cause motion sickness (Jensen and Konradsen, 2017; Tromp et al., 2018; Weech et al., 2018). Although VR technology can create virtual environments for users, one thing that must be considered is that these environments may produce an overwhelming flow of information for users, which may have negative physical and mental effects (Redaelli, 2023; Vehteva et al., 2021; Zwart, 2023). Therefore, these potential factors are significant obstacles faced by numerous researchers and educational institutions. However, the continuous advancement of VR in recent years has not only benefited from the improvement of hardware technology, such as display resolution, processor performance, and sensor accuracy, but also the promotion of software development and content creation to alleviate or solve these problems (Mofatteh et al., 2024; Rogers, 2020). It can be found that VR has gradually evolved from an early experimental technology to a technology with broad application prospects in higher education.

In current higher education, the advantages shown by VR have led more and more researchers to try to integrate it into the learning of different subjects, thereby promoting changes in educational models and providing learners with a variety of learning tools. The importance of varying degrees of involvement in the creative process should not be overlooked (Žammit, 2023). Using a HMD and motion tracking, fully immersive VR creates an engaging environment that can improve cognitive flexibility, attentiveness, and fluency, all of which are crucial for creative thinking. To provide a more accessible and less intense experience, semi-immersive VR uses larger monitors or projection systems. It may still encourage innovation, yet to a lesser degree. Even with limited immersion, non-immersive VR (such desktop-based systems) might allow users explore their creativity through interactive simulations and virtual collaboration tools.

In the application of VR in education, given its ability to provide more hands-on experiences, it has shown great potential in helping students understand key elements of courses and demonstrations (Hutchinson, 2025). Some empirical studies have verified its improvement in education quality and learning outcomes in many aspects, including that VR provides a highly immersive learning environment for medical students to practice surgery in a virtual operating room to prepare for their future clinical rotations and careers (Francis et al., 2020; Sandella, 2025), and architectural students can perform architectural design and construction simulations in a virtual environment without worrying about the risks of actual operations (Giancola et al., 2022; Kandi et al., 2020). Even educational institutions on limited finances may take use of VR to take their students on field trips to virtual museums, historical sites, and labs all around the globe (Alnagrat et al., 2023; Bachiller et al., 2023; Huber et al., 2020). Furthermore, 69 publications were selected from 28 databases represented by Google Scholar in a recent research by Sümer and Vaněček (2024) that demonstrates the utilization of VR in higher education from 2017 to 2023. Based on the findings, the annual number of linked instances was in the single digits from 2017 to 2020, but starting in 2021, a significant amount of researchers are attempting to use VR technology, so the number is expected to grow dramatically. Since VR offers enormous promise for facilitating remote learning, boosting practical skills, facilitating innovation and research, and improving learning outcomes, it is reasonable to state that it is already becoming a vital component of higher education.

**Students' creativity in VR learning**. Creativity is considered one of the top five 21st century skills in 2025 and plays a vital role in higher education (World Economic Forum, 2020). At present, most lecturers in higher education still teach some basic knowledge and professional knowledge in the traditional oral way. The classroom model that simply uses paper and pen to let students brainstorm is inefficient and difficult to stimulate their creativity (Zhang, 2018). Guaman-Quintanilla et al. (2022) believes that creative students can go beyond the basic skills and knowledge expectations of the past, especially when considering the implementation of new technologies. For college students, VR is an emerging immersive technology that can help them learn in a creative environment and break the shackles of traditional thinking. As an effective and novel learning tool or material, the immersive learning environment provided by VR can stimulate students' imagination (Chang et al., 2020), and the highly interactive environment allows students to actively participate in the learning process (Li et al., 2023), provide personalized learning experiences according to students' learning progress and interests (Wei and Yuan, 2023), and practice and apply in a near-real environment (ElGewely and Nadim, 2020). This fully demonstrates that VR provides learners with a platform for diversified experiences, allowing them to freely express their creativity after divergent thinking.

On the contrary, from the perspective of educators and curriculum developers, the application of VR technology is also of far-reaching significance. For example, by integrating knowledge from different disciplines in a virtual environment for project development, diverse perspectives can inspire students to think about problems from different angles and promote the formation of innovative thinking (Young et al., 2020). In addition, VR as a new assessment tool for educators, can track students' learning behaviors and outcomes in a virtual environment in real time, so as to more accurately assess their creativity development and adjust teaching strategies in a timely manner (Rzanova et al., 2023). VR also allows course developers to design personalized learning paths based on students' interests and abilities, so that each student can develop creativity at a pace that suits them (Fisher and Baird, 2020). In general, popularizing VR in different disciplines and fields in higher education to enhance students' creativity has good development prospects.

## Methodology

**Search strategy**. This study conducted a systematic search to identify empirical research on the use of VR technology to enhance students' creativity in colleges and universities around the world. The studies selected for this review, published between 2014 and 2023, were identified using five databases: Springer Link, ScienceDirect, Web of Science, ProQuest, and Google Scholar. The keyword search terms were combined in the scanning phase:

("Virtual Reality" or "Virtual Reality Technology") AND ("Higher Education" or "Tertiary Education" or "College Students") and ("Creativity" or "Creative" or "Creative Thinking" or "Innovation" or "Creation"). In addition, more relevant publications were found as additional materials based on the reference lists of some articles. Table 1 presents the sources of information and the number of publications identified in each database.

**Eligibility criteria**. In this systematic review, the inclusion and exclusion criteria were set to guide and help filter the literature and ensure that the research questions were substantively addressed during the review process. Table 2 provides a detailed overview of the inclusion and exclusion criteria. To guarantee the quality and relevance of the studies, this research used stringent inclusion and exclusion criteria to choose 16 papers. VR's primary role in the project, its emphasis on higher education, and the ability to quantify results connected to creativity were all important considerations in the selection process. The research not fitting into these criteria was not considered (e.g., research not related to VR or not conducted in an educational setting).

In addition, this study also employed two search strategy tools: SPIDER (Sample, Phenomenon of Interest, Design, Evaluation, and Research Type) and PICO (Population, Intervention, Comparison, Outcomes). The strength of PICO is that it can collect quantitative data with greater sensitivity and in a way that ensures that relevant studies are not overlooked, while SPIDER allows for a more nuanced understanding of complex phenomena and is suitable for qualitative and mixed methods searches (Korstjens and Moser, 2017; Eriksen and Frandsen, 2018).

**Selection**. During the selection process, this study evaluated the relevance of the selected studies to other research by reviewing their titles, abstracts, methods, and results. Five online databases were searched based on previously developed keywords, resulting in 365 publications that met the inclusion criteria. In addition, the researchers found three additional articles by manually searching the literature list sources. Finally, the researchers identified a total of 368 publications. After screening according to the inclusion and exclusion criteria, we found that 16 papers met the requirements, 55 articles were duplicates, 269 papers did not meet the keyword criteria, and 28 were non-empirical studies. It can be found that the included studies cover a range of disciplines, including education, engineering, design, and psychology. However, there is limited representation of STEM fields (science, technology, engineering, and mathematics), which indicates a gap in the current literature. The flowchart in Fig. 1 shows a summary of the publication selection.

**Table 1 Publications from five databases.**

| Databases | Number of publications |
|---|---|
| Springer Link | 65 |
| ScienceDirect | 57 |
| Web of Science | 13 |
| ProQuest | 76 |
| Google Scholar | 154 |
| Manual searches | 3 |
| Total | 368 |

**Synthesis**. For the synthesis, the researchers used narrative text and thematic analysis, which helps integrate various types of research (Xu and Zammit, 2020). Initially, the researchers narrowed the topic scope and only summarized findings and results related to the research question. The selected publications were excluded from the research scope if their content did not involve higher education and did not use VR to enhance students' creativity. Table 3 provides details of the included publications.

## Results

This section discusses the results of the four research questions posed. Firstly, the current trends were identified by exploring the progress that researchers have made in using VR to enhance creativity among college students over the past ten years. The second question helped researchers discover the types of VR and learning materials currently being used. In addition, the study explored the types of research involved in the current study and how the collected data were used. Finally, aspects of VR that promote student development were also discussed.

**The trends in using VR to improve college students' creativity from 2014 to 2023**. As shown in Fig. 1, a total of 368 articles were included in this study, of which 16 articles involved using VR to help students of different majors in colleges and universities improve their creativity. From Fig. 2, we can see that the trend between 2014 and 2023 reflects the dynamic and continuous development of this interdisciplinary field, which is characterized by both active periods and obvious periods of stagnation.

It is noteworthy that only two articles were published between 2014 and 2017, one in 2016 and the other in 2017, highlighting the early stages of research into VR for creativity in higher education. These early studies may be viewed as experimental or exploratory, laying the foundation for later, more in-depth research. In 2018, only two papers showed that the potential of VR to cultivate creativity in higher education is still an emerging concept, with limited exploration by academics. This may be attributed to a variety of factors, including the infancy of VR technology, high cost, limited accessibility, and lack of widespread integration with educational courses. Early adopters may see the promise of VR as a tool for immersive learning experiences, but

**Table 2 The details about exclusion and inclusion criteria.**

| Inclusion Criteria | Exclusion Criteria |
|---|---|
| Published between 2014 and 2023. | Published before 2014 or after 2023 |
| VR as primary or secondary tool. | Not included VR. |
| International peer-reviewed journal and conference. | Reports, book chapters, letters or dissertations. |
| Full-text paper and written in English. | Written in other languages. |
| VR is used in higher education for improve students' creativity. | VR is not used in higher education for improve students' creativity. |

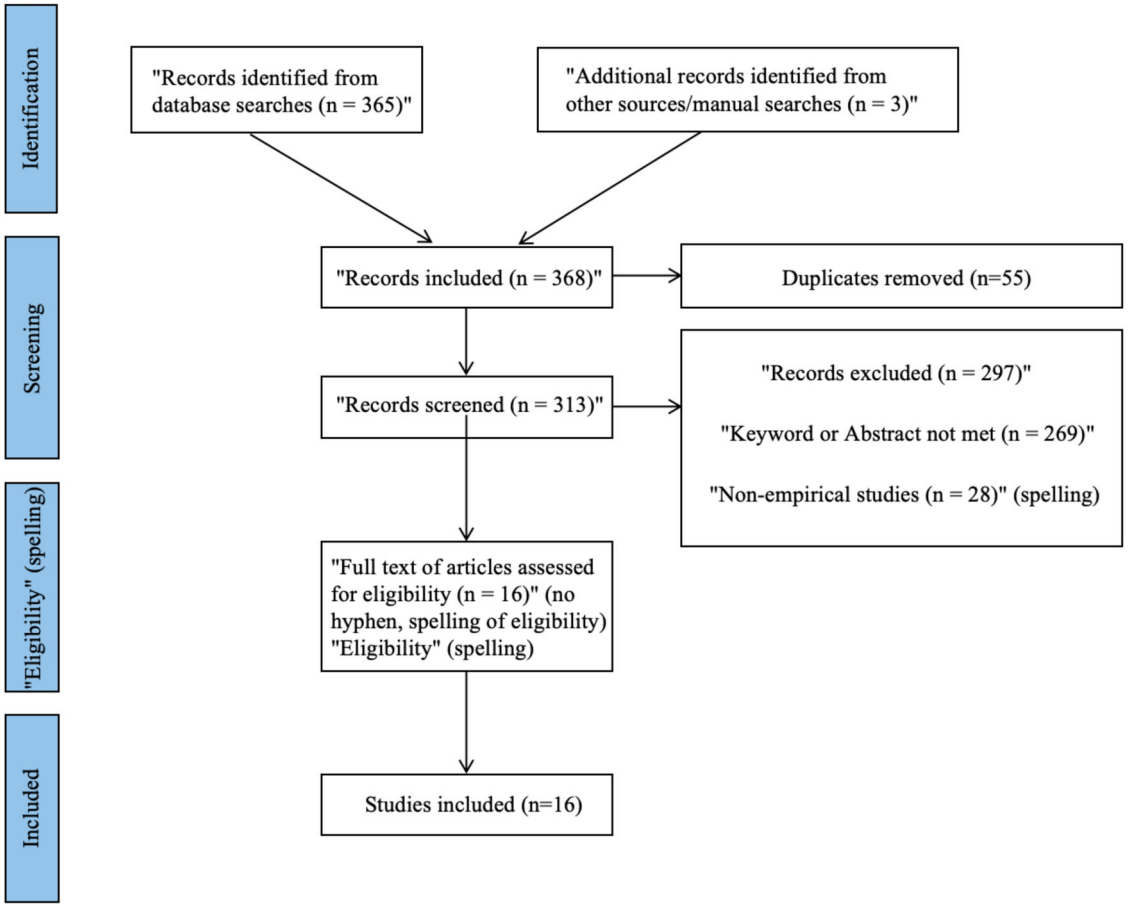


**Fig. 1** The summary of PRISMA-based selection.

**Table 3 Research papers included in this study.**

| No. | Author(s), year | Aim of study |
|---|---|---|
| 1 | (Shieh et al., 2016) | To discuss the effects of creative thinking instruction on students' creative thinking abilities by VR. |
| 2 | (Lin et al., 2017) | To test the effects of VR exploratory education on promoting creativity. |
| 3 | (Chandrasekera and Yoon, 2018) | By using VARK to assess students' learning styles and explore their effects on the use of AR and VR in the creative design process. |
| 4 | (Yang et al., 2018) | To explore the effects of immersive VR on individual creativity and factors associated with creativity. |
| 5 | (Bonnardel and Pichot, 2020) | To compare the use of dynamic and static characters in creative and collaborative design activities. |
| 6 | (Huang et al., 2020) | To explore learners' learning experiences in VR using a new design collaboration model. |
| 7 | (Obeid and Demirkan, 2020) | To examine the influence of immersive and non-immersive VDEs on design process creativity in basic design studios. |
| 8 | (Tang et al., 2020) | To investigate and compare students' learning outcomes with MR design support and traditional teaching materials. |
| 9 | (Lee et al., 2021) | To develop a feasible teaching model prototype using a VR environment and explore its potential to promote creativity among fashion design students. |
| 10 | (Houzangbe et al., 2022) | To compare two sketching modalities through dedicated creativity support tools. |
| 11 | (Li et al., 2022) | To discuss the influence of the experience of virtual restorative environment on individual creativity. |
| 12 | (Lyn et al., 2022) | To use VR technology to support engineering training and improve engineering training |
| 13 | (Alhulail and Singh, 2023) | To explore the impact of emerging multimedia technologies, including AI, AR, and VR on the development of learning agility and creativity among university students. |
| 14 | (Barbot et al., 2023) | To introduce VIVA, rated using a modern extension of the classic product-based creativity assessment method. |
| 15 | (Ríos et al., 2023) | To investigate how VR role games impact self-learning in higher education settings. |
| 16 | (Wu et al., 2023) | To explore practical methods for online virtual simulation course platforms to teach creative thinking knowledge, and design opportunities for online teaching activities. |

they are only a small number of people who try to apply it to enhance creativity. The lack of any papers published in 2019 may indicate slow adoption or research lags as institutions and researchers evaluate initial findings or face practical challenges in implementing VR in educational settings. However, the number of publications on VR and creativity in higher education increased significantly after 2020, with four studies published in that year alone. This spike likely reflects the accelerated adoption

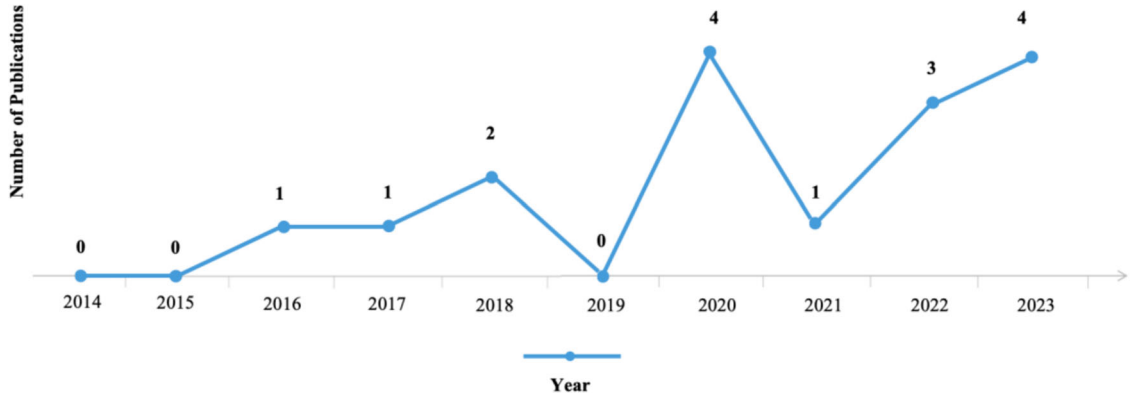


**Fig. 2** The trends in using VR to improve college students' creativity from 2014 to 2023.

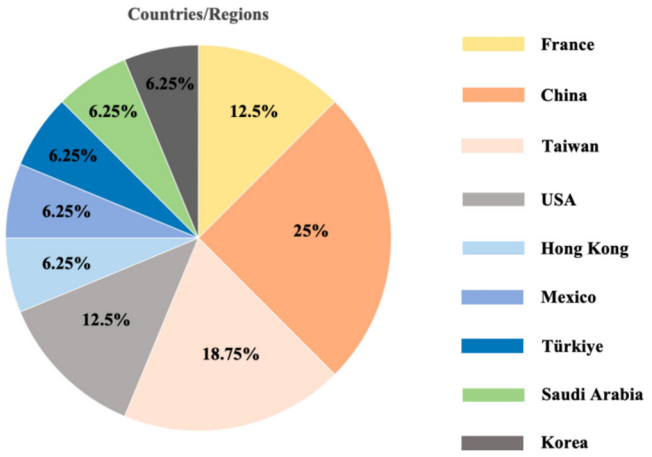


**Fig. 3** Distribution of publication countries.

of digital technologies during the COVID-19 pandemic, as educators sought innovative ways to engage students in remote learning environments. The absence of papers in 2021 may reflect a period of consolidation, as researchers and educators took time to assess the results of the previous year's surge in research. Interestingly, three papers in 2022 and four papers in 2023 suggest a renewed interest in the role of VR in education, particularly in enhancing creativity. Trends over the past decade showed a relatively slow early development of research in this area, but developments over the past five years suggest that despite recognition of VR's promise, much work remains to be done to fully realize its potential to foster creativity across a wider range of disciplines.

Geographically, the included studies are distributed across Europe, Asia, and North America, highlighting the global interest in VR as an educational tool, as shown in Fig. 3. At present, there are no publications in South America, Africa, and Oceania. It is worth noting that Asia leads with 10 papers, indicating that the region is particularly focused on educational innovation and technology integration. This is likely driven by factors such as rapid technological advances, large investments in educational technology, and a cultural emphasis on adopting cutting-edge tools to improve learning outcomes. Europe and North America, while lagging slightly behind, also showed considerable engagement, likely driven by similar motivations and the presence of leading research institutions and universities that prioritize educational innovation. The increase in publications during and after the pandemic highlights the potential for VR to help students in higher education adopt novel educational methods, while the geographic distribution of research highlights global recognition of VR's potential to change the way creativity is taught and cultivated in higher education.

**The types of learning materials developed to improve college students' creativity by using VR and classroom organization factors**. Table 4 presents an overview of the 16 selected articles, each of which developed distinct VR-based applications, models, platforms, and systems designed to immerse learners in virtual environments using electronic devices such as computers, mobile phones, and HMDs, with the goal of enhancing creativity.

Firstly, Shieh et al. (2016) explored the impact of using a creative thinking instruction model based on VR on students' creative thinking abilities, while Lin et al. (2017) proposed a model to promote optimal creativity through VR combined with exploratory education. Additionally, Chandrasekera and Yoon (2018) used VARK to assess students' learning styles and then explored the changes in students' creativity in the creative design process using AR and VR-based interfaces. Meanwhile, Yang et al. (2018) introduced a wearable VR device to examine the effects of immersive VR on personal creativity, investigating related factors such as flow, attention, and meditation. Likewise, Bonnardel and Pichot (2020) compared the use of dynamic versus static characters in creative and collaborative design activities within virtual spaces on computers. Additionally, Huang et al. (2020) focused on 3D modeling in VR and explored learners' experiences through a new design collaboration model that integrates the concept of a learning community. At the same time, Obeid and Demirkan (2020) analyzed the impact of immersive and non-immersive virtual design environments (VDE) on creativity within a basic design studio, paying particular attention to spatial ability, flow state, and motivation. Furthermore, Tang et al. (2020) developed a mixed reality (MR) application on the HoloLens system to investigate and compare the effectiveness of MR-supported design learning with traditional textbook-based approaches.

Building on this research, Lee et al. (2021) presented the steps used to create a fashion design education course in a VR environment that encourages students to be creative. Likewise, Houzangbe et al. (2022) employed a custom 3D sketching application to contrast two sketching modes—one in VR and the other on a 2D interactive whiteboard—utilizing a specialized Creativity Support Tool. In addition, Li et al. (2022) constructed an interactive restorative environment using VR, based on restorative environment theory, to explore its influence on individual creativity. Moreover, Lyn et al. (2022) used VR technology to support engineering training teaching, improve engineering training teaching methods, and explore the changes in students' interests and creativity during the participation process. Meanwhile, Alhulail and Singh (2023) studied the impact

**Table 4 Types of learning materials.**

| No | Author(s), year | Types of learning materials |
|---|---|---|
| 1 | (Shieh et al., 2016) | Creative thinking instruction model based on VR |
| 2 | (Lin et al., 2017) | 3D exploration education model based on VR |
| 3 | (Chandrasekera and Yoon, 2018) | AR interface and VR interface |
| 4 | (Yang et al., 2018) | A wearable technology functioning as a smart phone |
| 5 | (Bonnardel and Pichot, 2020) | Featuring dynamic personas based on virtual space |
| 6 | (Huang et al., 2020) | A 3D modeling practice field based on VR |
| 7 | (Obeid and Demirkan, 2020) | Immersive and non-immersive VDEs |
| 8 | (Tang et al., 2020) | An MR application (HoloLens system) |
| 9 | (Lee et al., 2021) | A instructional model based on VR |
| 10 | (Houzangbe et al., 2022) | A customized 3D sketching application |
| 11 | (Li et al., 2022) | Three VR scenes (Unity interactive development system) |
| 12 | (Lyn et al., 2022) | VR-based technical engineering practice training teaching |
| 13 | (Alhulail and Singh, 2023) | Emerging multimedia technologies, including AI, AR, and VR |
| 14 | (Barbot et al., 2023) | A new IVR-based visual creativity assessment application |
| 15 | (Ríos et al., 2023) | Metaverse of VR using the Mozilla Hubs platform |
| 16 | (Wu et al., 2023) | An online virtual simulation course platform |

of emerging multimedia technologies, including AI, AR, and VR, on the development of learning agility and creativity among university students. And Barbot et al. (2023) introduced a novel immersive VR-based (IVR) paradigm for visual creative assessment, known as VIVA, where users create 3D drawings in response to prompts and then evaluate them using an updated version of the traditional product-based creative assessment method. Finally, Ríos et al. (2023) examined a VR Metaverse developed on the Mozilla Hubs platform, exploring how virtual and augmented reality role-playing games can impact student self-learning and creativity in higher education settings. In a related study, Wu et al. (2023) explored practical methods for teaching creative thinking knowledge and designing opportunities for teaching activities through online virtual simulation course platforms.

On the other hand, classroom organizational factors are crucial to creating an effective learning environment. From the existing cases, we can find that these factors include the integration of emerging technologies and digital materials as essential teaching tools; student-centered education and focus on cultivating diverse talents and personal potential; comparing immersive VR and traditional learning environments; introducing VR-based 3D modeling practice areas to modify traditional learning models; highlighting the role of studio-based practical learning environments; the integration of hybrid physical-virtual systems in the classroom; dedicated CSTs for both VR and a 2D interactive whiteboard; promoting creativity through immersive settings; emphasizing the integration of assessment tools into the learning environment; and examining the role of the use of role-playing games for group work and interactive activities. It can be found that the design of the learning environment, the complexity of the tasks, and the integration of assessment methods are also crucial to cultivating creativity in these environments.

In summary, the 16 articles collectively illustrate the diverse and innovative approaches to leveraging VR technology for enhancing creativity in higher education settings. These studies cover various applications, from wearable devices and virtual design environments to mixed reality and immersive VR-based assessment tools. They explore a wide range of factors influencing creativity, including attention, flow, motivation, and collaborative learning. By integrating VR into educational settings, these studies suggest that learners can experience a deeper engagement and a more enriched learning experience, ultimately leading to enhanced creative outcomes. These works highlight the growing importance of VR as a tool for educational change, which can significantly affect the way creativity is cultivated and assessed.

**Research types and data collection methods to improve college students' creativity by using VR**. The third question of this study sorted out the types of research and data collection methods that used VR to enhance college students' creativity. As shown in Table 5, a clear pattern emerged when studying the types of research and data collection methods that investigated the effects of VR on college students' creativity. The vast majority of the articles analyzed (13 out of 16 articles) used quantitative research methods, reflecting a preference for measurable, data-driven methods to study creativity in this context. The dominance of quantitative research suggests that people pay more attention to producing statistically significant findings that can be generalized to a larger population. The preference for these methods indicates that people want to quantify creativity and evaluate the specific effects of VR on creative outcomes in a structured way. However, there are almost no qualitative studies, and only three studies used qualitative methods, which highlights a potential gap in the literature. Qualitative methods can provide a deeper understanding of learners' subjective experiences and perceptions, but are underrepresented. The prevalence of quantitative methods indicates a preference for measurable results, nonetheless, this method may overlook subjective and contextual elements that influence creativity. The few current qualitative studies include interviews or observational studies, which limit our understanding of students' VR experiences and the cognitive processes behind creative thinking. Identifying this deficiency is essential for achieving a more thorough comprehension of the influence of VR on creativity.

On the other hand, it can be found that the existing research relies on questionnaires, scales, tests, and surveys as the main data collection methods, which further emphasizes this trend. Among them, questionnaires are particularly prominent and are used in more than half of the studies. Although questionnaires are helpful in collecting a wide range of data, they may not fully capture the complexity of how VR affects individual creativity. Future research can benefit from incorporating more diverse methodological approaches, including qualitative research, to gain a more comprehensive understanding of the role of VR in cultivating college students' creativity. This can not only enrich the existing body of knowledge, but also address the limitations of current data collection methods.

**Aspects of promoting student development by VR**. From these collected studies, the aspects that promote student development by VT are as follows:

**Table 5 Research types and data collection methods.**

| Author(s), year | Research types | Data collection methods |
|---|---|---|
| (Shieh et al., 2016) | Quantitative | Surveys |
| (Lin et al., 2017) | Quantitative | Surveys |
| (Chandrasekera and Yoon, 2018) | Quantitative | Surveys |
| (Yang et al., 2018) | Quantitative | Surveys and electroencephalography (EEG) measurements |
| (Bonnardel and Pichot, 2020) | Quantitative | Questionnaire |
| (Huang et al., 2020) | Quantitative | Scale |
| (Obeid and Demirkan, 2020) | Quantitative | The students' questionnaire, test, scale and survey. |
| (Tang et al., 2020) | Quantitative | Open-ended and multiple-choice questions. |
| (Lee et al., 2021) | Qualitative | Questionnaires and post-interview |
| (Houzangbe et al., 2022) | Quantitative | Two questionnaire |
| (Li et al., 2022) | Quantitative | Three creativity tests |
| (Lyn et al., 2022) | Quantitative | Questionnaire |
| (Alhulail and Singh, 2023) | Quantitative | Surveys |
| (Barbot et al., 2023) | Quantitative | Consensual assessment |
| (Ríos et al., 2023) | Qualitative | An argumentative journal, a photographic analysis, and a questionnaire. |
| (Wu et al., 2023) | Mixed methods | Scale and in-depth interviews |

Firstly, one of the most consistent findings across the studies is the significant impact of VR on fostering student creativity. Several studies emphasize VR's potential to foster creativity in students. Shieh et al. (2016) demonstrated that creative thinking instruction via VR heightened both fluency and sensitivity in creative abilities compared to traditional methods. Lin et al. (2017) further extended this by showing that combining VR with exploratory education optimizes creativity and leadership skills, highlighting VR's dual role in fostering personal and collaborative development. Yang et al. (2018) identified that immersive VR enhances individual creativity by engaging cognitive processes like attention and flow, providing a foundation for creative output through mental relaxation and focus. Chandrasekera and Yoon (2018) et al., provided different students with AR and VR interfaces in the creative design process, and the results showed that there was a relationship between learners' preferences and creativity.

In addition, VR also has a powerful role in promoting collaboration and design-based creativity. Bonnardel and Pichot (2020) demonstrated that dynamic characters in virtual spaces support more creative, collaborative design activities than static ones. Similarly, Huang et al. (2020) introduced a VR-based collaborative design model, showcasing that learners in the VR environment experienced higher levels of motivation and creativity in 3D modeling, thus fostering deeper engagement in creative tasks. Obeid and Demirkan (2020) compared immersive and non-immersive virtual design environments, showing that immersive VR facilitated a stronger flow state and higher creativity in design students. Moreover, studies like Tang et al. (2020) highlight the value of VR in design education. Their findings show that MR-supported learning surpasses traditional methods by significantly enhancing students' geometric analysis, model visualization, and creative approaches. This suggests that MR and VR environments create more dynamic, engaging educational experiences that foster systematic and creative problem-solving. Lee et al. (2021) also found that the developed VR-based teaching model prototype facilitated collaborative exploration and promoted fashion design students' creativity.

Similarly, Houzangbe et al. (2022) focused on comparing sketching modalities, revealing that VR-supported creativity tools can better stimulate and engage students in early design ideation. This reinforces the idea that immersive technologies create a more stimulating learning environment, which, in turn, nurtures creative potential. Meanwhile, Li et al. (2022) explored the role of restorative environments in VR, showing that such spaces significantly enhance individual creativity, particularly in environments with free exploration. This highlights the importance of cognitive load management within VR, suggesting that carefully designed environments can foster both relaxation and creativity. Additionally, Lyn et al. (2022) used VR technology to teach practical training courses and found that it helped significantly improve students' interest in participating in practical training and their creativity during practice, and improved teaching effectiveness and quality.

At the same time, Alhulail and Singh (2023) validated that emphasizing the deployment of VR technology is essential to fostering the learning agility and creativity of college students. Furthermore, Barbot et al. (2023) introduced a VR-based creativity assessment paradigm (VIVA), which demonstrated that immersive VR could reliably measure creativity through interactive 3D tasks. This shows the potential for VR not only to foster creativity but also to evaluate it in educational settings. Likewise, Ríos et al. (2023) emphasized the role of VR role-playing games in promoting self-learning, critical thinking, and collaboration in higher education, suggesting that immersive environments help bridge gaps between traditional and modern educational methods. Finally, Wu et al. (2023) described the development process of an online course platform based on creative thinking virtual simulation. The results showed that the platform has expanded the practical field of virtual simulation technology and enriched the teaching methods for cultivating students' creativity. In summary, these studies collectively underscore VR's transformative potential in promoting creativity, collaborative learning, critical thinking, and self-directed education.

## Discussion

This study examined the trends in using VR technology to enhance college students' creativity from 2014 to 2023. Our findings reveal several key insights into the application of VR in higher education, particularly in fostering creativity.

Systematic review methods have been shown to be effective in identifying key issues and trends in VR in education. Moreover, over the past many years, the emergence of this technology has brought new learning materials to students at different educational levels, addressing the lack of immersion, interactivity, and low engagement in traditional classrooms (Di Natale et al., 2020; Liu et al., 2020; Pellas et al., 2021). Unlike previous research that has broadly considered VR in educational contexts, this study's

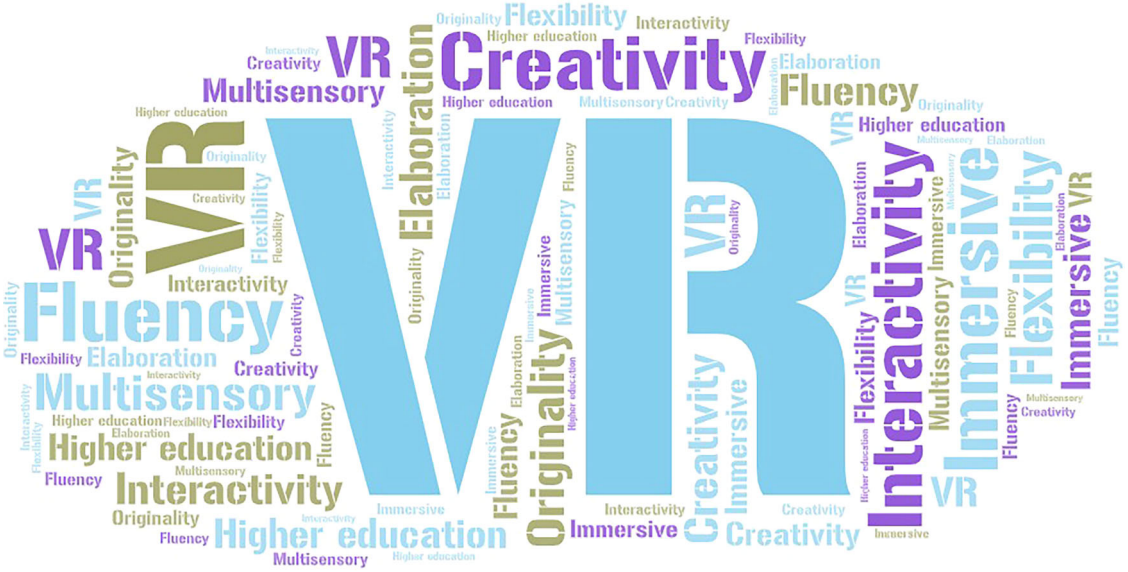


**Fig. 4** Distribution of publication countries.

focus on college students and creativity offers a novel and meaningful contribution to the field.

**Implications and future work**. This study highlights the increasing relevance of VR technology in enhancing creativity among college students, pointing to a clear trend in the educational research community. There is a clear bias in the geographical distribution of the included research, 10 out of 16 come from Asia, whereas none come from Africa or South America. Potential publishing biases and structural inequalities in access to VR technology and research funding are likely responsible for this discrepancy. To address this, researchers in the future should focus on policies and financing that encourage underrepresented regions to use VR in higher education. For instance, if universities, governments, and tech companies worked together, we might build regional collaborative research networks and create lower-cost VR solutions.

The analysis of recent publications reveals a strong focus on quantitative research methods, particularly the use of questionnaires, scales, tests, and surveys to assess the impact of VR on creativity. However, the limited number of studies indicates that this area of research is still in its nascent stages, particularly within higher education. To further understand how students' individual experiences and external influences impact their ability to be creative in VR settings, future studies should give preference to qualitative methods like ethnographic research and interviews. Research methods such as ethnography and interviews can provide insights into the mental and emotional workings of creative thought, while VR technologies in the classroom can be studied through ethnographic investigations. A more complex perspective of VR's effect on imagination may be revealed with the use of these methods, which will supplement current quantitative studies.

At the same time, the types of learning materials developed in these studies include VR-based platforms, applications, and immersive systems. These materials often emphasize interactivity, multisensory engagement, and the ability to simulate real-world scenarios, offering students opportunities to explore creative problem-solving in ways that traditional learning environments do not typically allow. Despite these innovations, the scarcity of qualitative studies means that the personal and contextual factors influencing students' creative development through VR remain unexplored.

Moreover, the results of this review are well aligned with Guilford's divergent thinking framework, which emphasizes fluency, flexibility, originality, and elaboration as the four key elements (Runco and Acar, 2012; Silvia et al., 2013). In terms of fluency, VR enables students to generate a large number of ideas quickly by providing a dynamic and responsive environment. By using a VR brainstorming tool, Huang et al. (2020) demonstrated that students came up with more ideas when using VR as opposed to more conventional techniques. The flexibility of VR allows students try out different ways of examining problems. VR's ability to transport users to other worlds and enable them to switch between different ways of thinking is one way it promotes cognitive flexibility (Yang et al., 2018). In terms of originality, VR promotes creativity by creating an environment without hazards for testing out new ideas. This is essential for creating novel solutions, and students are able to try out unusual ideas without worrying about failing (Bonnardel and Pichot, 2020). VR's interactive features and collaborative platforms make it easy to explore and enhance ideas, which is great for elaboration. For instance, in the case of Obeid and Demirkan (2020), students may improve the depth and complexity of their ideas by constantly improving their products in VR-based design environments. VR has the ability to enhance creativity among college students by creating educational environments that encourage different types of divergent thinking, as these elements shown in Fig. 4.

In addition, the philosophical implications of VR in higher education are substantial, since they pose questions about the essence of creativity and the influence of technology on human thinking in humans. Araya and Marber (2023) state that new forms of expression and interaction made possible by developing technologies like VR have the ability to reimagine conventional ideas of creativity and learning. For instance, VR's potential to imitate real-life situations while also offering immersive experiences challenges the boundaries between physical and virtual worlds, opening up new avenues of imaginative discovery for students. On the other hand, this raises the ethical and epistemological problems of how students' perceptions of their own agency and the veracity of virtual experiences are affected. To get a better understanding of VR's function in fostering creativity, future studies should take these philosophical arguments into consideration as well.

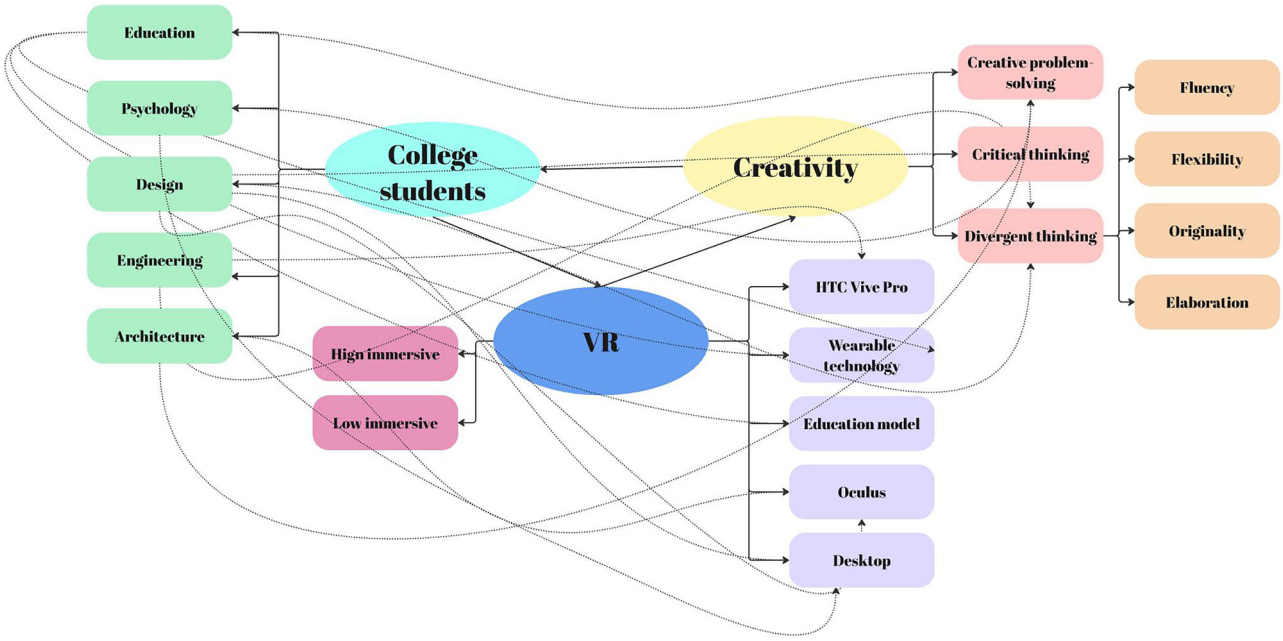


**Fig. 5** Interdisciplinary application of VR for college students' creativity.

**Interdisciplinary development**. Currently, the use of VR technology to enhance the creativity of college students from different disciplines is being explored. Some existing studies include:

(a) A creative thinking teaching model based on VR can enhance the creative thinking ability of students in the School of Education. (Shieh et al., 2016).
(b) A VR-based 3D exploration education model on promoting the creativity of students in the School of Education. (Lin et al., 2017).
(c) A wearable technology developed based on VR that can be used as a smartphone enhances the personal creativity of students from the School of Education (Yang et al., 2018).
(d) AR interface and VR interface are used to enhance design students' creativity in the creative design process. (Chandrasekera and Yoon, 2018).
(e) A virtual space-based comparison of the use of dynamic and static characters in creative and collaborative design activities by psychology students (Bonnardel and Pichot, 2020).
(f) A 3D modeling practice field based on VR technology was created to help industrial design students complete the modeling learning experience experiment (Huang et al., 2020).
(g) Based on immersive VDE by using Oculus Rift DK2, help students from the Department of Interior Architecture and Environmental Design complete design tasks (Obeid and Demirkan, 2020).
(h) An MR application was developed based on the HoloLens system to help the Faculty of Engineering and the School of Design conduct design activities. (Tang et al., 2020).
(i) A VR-based instructional model prototype is used to help fashion design students to explore collaboratively and promote creativity. (Lee et al., 2021).
(j) Based on the HTC Vive Pro Eye VR system, helping engineering students complete creative tasks (Houzangbe et al., 2022).
(k) VR-based virtual environment to explore the impact of this environment experience on individual creativity represented by students from language, electronic engineering, and landscape architecture majors (Li et al., 2022).
(l) A practical training course based on VR technology helps to enhance the interest of engineering students in participating in practical training and their creativity in the practice process. (Lyn et al., 2022).
(m) A virtual classroom based on VR technology was used to improve the learning agility and creativity of university students. (Alhulail and Singh, 2023).
(n) Based on IVR, helping design students from various disciplines create 3D drawings based on prompts (Barbot et al., 2023).
(o) Based on the VR metaverse of the Mozilla Hubs platform, helping students from the School of Education to conduct practical activities. (Ríos et al., 2023).
(p) An online virtual simulation course platform is used to cultivate the creative thinking ability of psychology students. (Wu et al., 2023).

The interdisciplinary application of VR in higher education reflects its versatility and potential to enhance creativity in different academic contexts, as shown in Fig. 5. Various disciplines have begun to experiment with using VR to meet specific educational needs, from enhancing personal creativity in educational students to achieving complex design tasks in industrial design and engineering. These interdisciplinary applications show that VR has gradually become a new teaching option for educators. It cannot be ignored that the implementation of VR in these different fields also highlights some challenges. The need for specialized equipment and the technical complexity associated with VR technology may limit its accessibility, especially in less technologically advanced regions or institutions. In addition, while VR shows promise in enhancing creativity, its effectiveness varies across disciplines, suggesting that a more targeted approach may be needed to maximize its benefits in each specific context.

Moreover, the findings of this systematic review indicate a growing movement to integrate VR into universities with the aim of fostering creativity, especially in creative disciplines like art, design, and engineering. But there are not sufficient VR uses in the STEM fields, which means there should be more specialized applications for these fields. For instance, VR's potential in STEM (science, technology, engineering, and mathematics) education has been underexplored, despite its widespread adoption in

design education to facilitate spatial reasoning and collaborative problem solving. Given this gap, there is a chance for future studies to investigate the potential of VR for supporting creative thinking in disciplines like chemistry, physics, and biology, where virtual labs and immersive simulations can have a breakthrough impact. Moreover, the integration of VR has been less prevalent in fields like the social sciences and humanities, maybe due to a deficiency of customized applications or perceived significance. This also indicates the necessity for further multi-disciplinary study to investigate how VR might be tailored to enhance creativity across a wider range of academic disciplines.

In addition, advancements in human-computer interaction have transformed not just how individuals interact with digital systems but also interpersonal communication and our connection to the natural world, including conventional values associated with truth, beauty, and goodness (Ho and Vuong, 2024). As digital and virtual environments become increasingly integrated into daily life, they change social dynamics, redefine our perception of reality, and mediate our interactions with artificial and natural environments. Therefore, it is crucial to critically examine the evolving role of human-computer interaction in shaping technological advancements as well as fundamental human values and social interactions.

**Perspective of technical**. The development and implementation of VR-based tools to enhance creativity among college students has primarily involved platforms such as VR headsets, personal computers (PCs), and mobile devices. These technologies enable students to engage with VR content through varying degrees of immersion, which are generally categorized as low to moderate immersion experiences. While these immersion levels have been shown to help foster creativity, current research has great potential in exploring highly immersive VR technologies, especially head-mounted displays (HMDs). HMDs are able to create fully immersive environments that allow students to interact with learning materials in a more dynamic and intuitive way than traditional or semi-immersive methods. This deep immersion can allow students to explore abstract concepts and complex scenarios in a more tangible and interactive way, thereby stimulating greater creativity.

However, there are still certain technical obstacles to VR's broad acceptance in the classroom, such as its expensive cost, the potential for motion sickness, and the complexity of the equipment required, all of which make it difficult to implement in institutions of higher education. Policymakers and educators should think about establishing collaborations with tech businesses to create accessible and inexpensive VR solutions to these challenges. One way to lower costs and increase accessibility is through the use of subsidized HMDs and freely available platforms. Educator and student training programs may also help with technological issues and make sure that VR technologies are used effectively in creative learning environments. In addition, VR interventions can both reduce implicit bias and inadvertently exacerbate implicit bias (Nguyen and Ho, 2025; Possati, 2023). This duality also implies the need for careful ethical considerations when developing and implementing VR technology.

**Limitations**. The primary limitations of this study highlight the challenges inherent in drawing broad conclusions about the effectiveness of VR in enhancing creativity within higher education. With only 16 relevant articles available, the study's findings are constrained by the limited scope of existing research. This small sample size reduces the ability to make comprehensive comparisons across different educational settings and disciplines, thereby limiting the generalizability of the conclusions. Moreover, the diverse professional fields represented in these studies further complicate direct comparisons, as the impact of VR on creativity may vary significantly depending on the context.

In addition, this review may be influenced by publication bias, since papers with favorable results are more frequently published and included in academic databases. The exclusion of databases such as IEEE and ACM may have constrained the review's reach, especially in disciplines like engineering and computer science. Subsequent reviews need to fix these shortcomings by doing extensive searches across a diverse array of databases and using gray literature to guarantee a more thorough and equitable representation of the research.

Another limitation is the methodological homogeneity among the included articles. The predominance of pilot or quasi-experimental studies, coupled with the scarcity of qualitative research, means that the current body of work offers a limited understanding of the nuanced ways in which VR might influence creativity. The lack of qualitative studies, in particular, restricts insights into the subjective experiences and contextual factors that could play a crucial role in exploring VR's true potential. In addition, most studies may focus on short-term interventions and outcomes. This limits researchers from evaluating the effects of VR on creativity in the long term, which is essential for the sustained benefits of integrating VR into educational practice.

## Conclusion

Previous systematic reviews have highlighted the potential of VR or other emerging digital technologies to enhance learners' creativity in educational settings (Hui et al., 2022; Li et al., 2022; Tang et al., 2022). However, these studies have not specifically focused on higher education. Addressing this gap, the current systematic review centers on college students, a group that has received limited attention in this context. This study synthesized 16 relevant publications from 2014 to 2023, selected based on established inclusion and exclusion criteria. The analysis identifies trends in development and regional distribution over the past ten years, examines the types of learning materials used in existing research, categorizes the types of studies conducted, and reviews the data collection methods employed.

An overview of the empirical studies included in this research reveals that using VR to enhance creativity in higher education is not only feasible but also holds significant promise. While previous research has largely focused on general educational settings, this study specifically addresses the unexplored area of college students' creative development. Educators can effectively incorporate VR into creative learning environments by: (1) initiating small-scale pilot projects to assess VR's efficacy in targeted courses; (2) collaborating with instructional designers and VR developers to design tailored applications that align with educational goals; and (3) offering training and support to both students and faculty to facilitate successful integration.

Overall, several important gaps in the current knowledge should be filled by further studies. First of all, VR has the potential to revolutionize STEM education through the use of interactive simulations and virtual laboratories that foster students' critical thinking, originality, and problem-solving skills. Second, VR's efficacy in different types of learning settings (e.g., individual compared to collaborative, formal compared to informal) may be better understood through interdisciplinary research. Thirdly, in order to determine the best ways to incorporate VR into college courses and assess the long-term impacts of VR on creativity, longitudinal studies are required. Lastly, in order to dive further into the subjective experiences and contextual aspects that impact creative growth in VR settings, future

study should make use of qualitative approaches like case studies and interviews. By using these strategies, educators and researchers may fully harness VR's ability to foster creativity in a variety of academic contexts.

## Data availability

No datasets were generated or analysed during the current study.

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## Author contributions

Haiqin Yu: Conceptualization, investigation, validation, supervision, funding acquisition, project administration, and writing—review and editing. Jiawei Wang: Methodology, Software, Data Curation, Formal Analysis, Visualization, Resources, Writing—Original Draft, and Writing—Review and Editing. Both authors have made equally significant contributions to the work and share equal responsibility and accountability for it.

## Competing interests
The authors declare no competing interests.

## Ethical approval
Ethical approval was not required as the study did not involve human participants.

## Informed consent
None of the authors conducted studies involving human participants in this article.

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