Exploring the Mediating Role of Student Engagement in the Relationship Between Virtual Reality Interactivity and Creativity in a Project-Based Learning Environment

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Received: April 1, 2025 Accepted: April 29, 2025 Online Published: May 12, 2025

doi:10.5430/jct.v14n2p262 URL: https://doi.org/10.5430/jct.v14n2p262

Abstract

Virtual Reality (VR) environment, due to its immersive and interactive characteristics, can effectively enhance learners' on-site experience, and gradually become a new educational scene. Existing studies have shown that compared with traditional teaching environments, learning methods using VR technology can significantly improve the teaching effect, but the internal mechanism of promoting the development of creativity is not clear. Therefore, this study carried out a quasi-experimental study under the framework of Project-Based Learning (PBL) and set two sets of control conditions of VR-PBL and traditional PBL to collect learners' participation and creativity performance data systematically. A standardized scale was used to measure learners' perception of VR interactivity and their multi-dimensional learning input (emotional and cognitive dimensions), and an expert scoring method was used to evaluate the creativity test works of painting. The results show that: (1) VR technology significantly improves the level of learning engagement by enhancing interactivity; (2) Learning engagement is positively correlated with creativity performance; (3) Learning engagement had a partial mediating effect between VR interactivity and creativity performance. This study provides a new perspective for designing VR-based educational intervention programs and provides a practical reference for fostering creativity through optimizing interactive learning environments.

Keywords: virtual reality, creativity, student engagement, project-based learning, art and design education

1. Introduction

In recent years, Virtual Reality (VR) technology has rapidly advanced and attracted global interest in the field of education (AlGerafi et al., 2023). Several international initiatives have emphasized the transformative potential of VR in reshaping traditional pedagogy. For example, the European Commission introduced the Digital Education Action Plan 2021–2027 to promote the integration of emerging technologies in learning environments (European Education Area, 2023). Similarly, the U.S. Department of Education launched the Education Innovation and Research (EIR) Program to support technology-enhanced instructional approaches (U.S. Department of Education, 2024). In Asia, Singapore's Ministry of Education has implemented VR-based chemistry laboratories in secondary schools, demonstrating practical applications of immersive learning (Han & Fung, 2024).

Unlike conventional teaching tools as slideshows, videos, or static presentations, VR environments provide learners with technology-mediated experiences that may promote deeper engagement through interactivity, responsiveness, and spatial presence (Spittle et al., 2022). These capabilities enable students to engage with dynamic, three-dimensional scenarios that simulate real-world situations or even scenarios that are otherwise inaccessible (Damaševičius & Sidekerskienė, 2024).

Even though VR can significantly enhance learners' engagement due to its rich sensory experiences, there is also evidence suggesting that excessive sensory stimulation may lead to cognitive overload or distraction, potentially undermining its benefits (Lee et al., 2025; Nahum-Shani et al., 2022). So it is essential to investigate not only the effects of VR itself, but also how learners' engagement mediates its impact on higher-order outcomes such as creativity. To effectively structure and contextualize such immersive experiences, a pedagogical framework that supports student autonomy and active inquiry is essential.

Moreover, Project-Based Learning (PBL) has emerged as a robust pedagogical model that emphasizes authentic problem-solving, collaboration, and real-world task engagement (Rehman et al., 2024). PBL has been shown to promote critical thinking and foster creativity by situating students in complex, context-rich environments (Maor et al., 2023; Zulyusri et al., 2023). However, traditional implementations of PBL often rely on two-dimensional, conventional tools (Küçük - Avcı et al., 2024), which may limit the depth of student engagement.

Although prior research has documented the positive effects of VR on learning outcomes (Petersen et al., 2022; Yu, 2023), few studies have systematically explored the mechanism by which VR influences creativity in educational contexts, particularly through the mediating role of student engagement. Most existing studies focus on immediate performance metrics or domain-specific skills (Villena-Taranilla et al., 2022), often overlooking engagement as a dynamic process variable that may help explain how technology impacts creative performance. This study, therefore, addresses the following research question: Does VR use, when integrated within a PBL framework, enhance student engagement and thereby augment creative outcomes?

Understanding the interplay between VR, student engagement, and creative performance is crucial for both theoretical and practical reasons. Theoretically, this research aims to extend existing models of technology-enhanced learning by introducing student engagement as a pivotal mediating construct, thereby offering a more nuanced explanation of how technology-supported environments influence students' creative performance in the visual arts.

Practically, the findings will provide actionable insights for educators and curriculum designers seeking to implement VR-enhanced PBL interventions. By delineating how student engagement, both emotional and cognitive functions as a pathway linking VR use and students' creative performance, this study offers evidence-based recommendations for designing effective, learner-centered instructional strategies.

2. Literature Review

2.1 VR Environments and Educational Outcomes

VR is growing rapidly in many fields due to its potential to create highly immersive and interactive learning environments (Pramanik, 2024). Different from traditional instructional formats like lectures or textbooks, VR can make learners mirror or extend actual contexts through simulated spaces and engagement in experiential activities (Crogman et al., 2025). These features have been linked to increased motivation, greater learner autonomy, and improved understanding across disciplines, including science, medicine, and the visual arts (Asad et al., 2021).

It is proven that such environments can support constructivist and experiential learning paradigms and it emphasizes active participation and the situation construction of knowledge (AlGerafi et al., 2023). VR is also able to support spatial exploration, multi-sensory input, and real-time feedback in the creative domain. It is a promising way to cultivate imagination, experimentation, and self-expression (Serna-Mendiburu & Guerra-Tamez, 2024). This has made VR an increasingly relevant tool in art and design education, where open-ended tasks and individualized outcomes are central to learning processes (Ozkan, 2023).

The educational impact of VR is shaped not only by its technological features but also by how learners respond to and interact with the environment (Asad et al., 2021). Studies show that simply introducing VR does not automatically result in deeper learning or more creative outcomes. Engagement, which is defined here as students' cognitive and emotional involvement in learning, is often cited as a mediating factor that determines whether students make meaningful use of VR tools (Huang et al., 2021; Lin et al., 2024). Yet, many existing studies continue to focus narrowly on content retention, usability, or short-term academic performance, leaving less explored the broader developmental outcomes such as creative performance (Mantry, 2024).

The literature remains inconclusive about the specific mechanisms through which VR environments contribute to creativity. While some studies report increases in idea fluency, visual originality, or aesthetic quality, others find minimal differences compared to traditional media (Nisha, 2019; Serna-Mendiburu & Guerra-Tamez, 2024). These mixed results suggest a need to shift the focus from "whether VR works" to "how VR works," like how it supports complex learning goals like creativity. Understanding the role of student engagement in this process is critical, especially in project-based settings where students are expected to take initiative, collaborate, and generate novel outputs.

2.2 Student Engagement as a Mediator between VR and Creative Performance

Student engagement has been widely recognized as a crucial factor in explaining how educational technologies influence learning outcomes (Lin et al., 2024). Rather than being a passive response to novel tools, engagement reflects students' active involvement in learning tasks and is associated with deeper processing and higher achievement (Huang et al., 2021). According to Fredricks et al. (2004), engagement comprises three interrelated dimensions: behavioral, cognitive, and emotional. This study focuses specifically on the emotional and cognitive dimensions, which are most relevant in contexts where internal motivation and mental effort are central to the creative process.

Immersing in a VR-supported learning environment, learners can be engaged emotionally and cognitively. Emotionally engaged learners may experience greater interest, enjoyment, and personal connection to tasks, while cognitively engaged learners demonstrate mental investment, strategic thinking, and persistence (Pramanik, 2024). These forms of engagement are especially important in art and design education, where creativity requires not only technical skill but also sustained attention, experimentation, and personal meaning-making (Ozkan, 2023; Serna-Mendiburu & Guerra-Tamez, 2024).

Empirical studies have shown that VR can initially enhance engagement due to its novelty and interactivity. However, without meaningful learning tasks or scaffolding, such engagement may not last. Creative performance is unlikely to improve when learners engage only superficially with technology. As a result, scholars increasingly suggest that engagement, particularly cognitive and emotional, functions as a mediating mechanism linking technological affordances to learning outcomes (Huang et al., 2021). In this context, understanding how VR environments influence creativity requires examining how learners think and feel throughout the creative process.

2.3 Creative Performance as an Educational Outcome

Creativity is a fundamental outcome in contemporary education, particularly in the visual arts, where students are not only expected to master technical skills but also to develop the ability to produce novel, expressive, and aesthetically coherent work. Across a range of educational policies and curricular frameworks, creative capacity is increasingly regarded as essential for preparing learners to participate in innovation-driven societies and creative economies (Akca & Kavak, 2021).

Within research literature, creativity has been conceptualized in multiple ways: as a psychological trait, a cognitive process, a social construct, or an observable performance outcome (Brandt, 2021). In arts education, there is a growing consensus that creativity should be assessed not only through divergent thinking tasks or self-reports but also by evaluating students' actual creative outputs (Esola, 2022).

Several empirical studies have examined how learning environments support or constrain creative performance. Project-based learning (PBL) has been widely associated with improvements in creativity due to its emphasis on open-ended tasks, iterative processes, and student agency (Lavli & Efendi, 2023). In parallel, VR-supported learning has shown potential to enhance creative engagement by simulating complex design contexts, expanding expressive possibilities, and encouraging exploration (Hui et al., 2022). However, most of these studies treat creativity as a direct outcome of instructional intervention, without exploring the psychological or behavioral processes that mediate this relationship.

2.4 Project-Based Learning as a Conduit for Creative VR Integration

Project-Based Learning (PBL) has been widely recognized for its capacity to support creativity by engaging learners in an authentic and open-ended problem-solving environment. Its emphasis on sustained inquiry, collaboration, and iterative design can greatly help learners in creative development (Almulla, 2020). Learners situated in PBL environments are often required to apply knowledge in novel contexts, test prototypes, and reflect on outcomes, and these processes promote higher-order thinking and innovation (Kuo, 2024).

When combined with VR, PBL may offer expanded affordances for creative engagement. Immersive VR environments can simulate complex systems, visualize abstract phenomena, and enable hands-on interaction with virtual materials. These features potentially enhance the experiential depth of PBL tasks, allowing for more dynamic ideation, experimentation, and refinement. Early evidence suggests that VR-supported PBL contexts may lead to more feasible and inventive outputs compared to traditional settings (Küçük - Avcı et al., 2024).

2.5 Identified Research Gaps and Study Positioning

The preceding review highlights an important gap in the intersection of VR, engagement, and creativity within project-based learning contexts. While VR technologies have demonstrated potential to stimulate student engagement, and PBL has long been valued for its alignment with creative problem-solving, little is known about the specific mechanisms through which these elements interact. Existing literature rarely addresses how student engagement mediates the relationship between VR integration and creative performance, particularly in extended, project-based educational settings.

In response to these gaps, the present study investigates whether and how VR, when embedded within a PBL environment, enhances student engagement to a level that meaningfully supports creative performance. This inquiry contributes to a more process-oriented understanding of technology-enhanced creativity and provides a basis for instructional design that moves beyond motivation and interactivity to emphasize learner-centered creative development.

3. Method

This study employed a quasi-experimental design with a pre-test–post-test control group to examine the mediating role of student engagement in a VR-supported PBL setting.

3.1 Participants

The participants in this study were 80 second-year students majoring in Advertising Art and Design at a higher vocational college in Zhejiang Province, China. Among them, 32 were male and 48 were female, with an average age of 20.8 years. To ensure the validity of the experimental outcomes, all participants had no prior exposure to formal VR training or specialized instruction in VR-based art learning prior to the study. Furthermore, all students had normal or corrected-to-normal vision and voluntarily provided informed consent before participation.

Participants were randomly assigned to two groups. The control group (n = 40) received conventional instruction usin PBL in a physical classroom setting. The experimental group (n = 40) followed the same PBL framework but completed the packaging design task using VR technology, specifically through HTC VIVE devices. Both groups were taught by the same experienced instructor with the same curriculum, task objectives, and durations.

3.2 Instructional Context and Experimental Design

3.2.1 Overview of the “Packaging Design” Course

The study took place in Packaging Design, a core course for Advertising Art and Design majors. This course trains students to combine visual communication, brand identity building, and creative problem-solving. To assess how immersive VR affects creative outcomes, the course was restructured around a PBL framework, integrating VR tools into critical design phases.

The main project tasked students with creating original packaging for a hypothetical brand in categories like cultural products, food, or cosmetics. The project followed a structured process: early stages covered basic skills like illustration and layout design; middle phases focused on developing packaging structures and graphic systems; final stages required full visual branding and physical/digital prototypes. While the control group used traditional sketching and digital software, the experimental group employed VR to build 3D models, test structural options, and adjust layouts interactively. Both groups shared identical learning objectives, project requirements, and grading standards.

3.2.2 PBL Framework and Implementation

The course was delivered over five weeks, comprising 12 sessions and totaling 56 instructional hours. The instructional design followed the seven-stage structure of project-based learning, adapted from the Gold Standard PBL framework. The following table 1 summarizes the instructional alignment with core PBL elements.

3.2.3 Instructional Environment and Technology Integration

The control group conducted their design tasks in a conventional computer lab equipped with standard graphic design software. In contrast, the experimental group utilized the institution’s VR Innovation Lab, a space designed to meet immersive learning standards. Each VR station included a head-mounted display, motion controllers, and a high-performance graphics workstation. Instructional demonstrations were supported by an interactive whiteboard.

The immersive software environment was developed by the research team using the Unity platform. It featured a VR-based design application tailored to packaging design instruction, incorporating tools for sketching, structural modeling, and visual simulation. The space was divided into two functional zones: (1) a theoretical instruction area for lectures and group discussions, and (2) an immersive creation zone for individual student practice. This configuration ensured that each participant had access to extended hands-on engagement during the project cycle.

Table 1. Instructional Alignment with Core PBL Elements

PBL Element	Teacher Role	Student Role	Instructional Purpose
Challenging Problem	Introduce a weekly project task, e.g., "Design packaging for a cultural gift item"	Analyze task requirements and discuss use scenarios	Stimulate design motivation
Sustained Inquiry	Provide case studies, explain key concepts (e.g., illustration style, box structure)	Collaboratively research and propose design ideas	Support knowledge building
Authenticity	Emphasize the market/user relevance of the task	Apply personal experience to creative ideation	Increase task relevance and immersion
Student Voice & Choice	Allow selection of visual style and medium	Independently or collaboratively develop original concepts	Encourage agency and individual expression
Reflection	Prompt self-evaluation and mid-project feedback	Document creative process and adjustments	Enhance self-awareness and decision-making
Critique & Revision	Provide peer and instructor feedback	Modify design based on critique	Improve process and output quality
Public Product	Organize interim presentations and VR-based simulations	Present outcomes, engage in critique discussions	Develop communication and presentation skills

3.3 Measures

This study adopted a pre-test–post-test design to assess changes in students' creativity and engagement throughout a VR-supported PBL instructional intervention.

3.3.1 Creative Performance

Students' creative performance was evaluated using a drawing-based instrument adapted from Clark's Drawing Abilities Test (Clark, 1989). This test was originally designed to identify visual arts talent and includes four drawing tasks assessed across four dimensions: sensory properties (line, shape, texture and value), formal properties (composition, rhythm, unity and balance), expressive properties (mood and originality), and technical properties (techniques and correctness of solution).

In this study, students were given a timed drawing task titled Quick Packaging Sketch, simulating a real-world design challenge. Three experienced faculty members in advertising art and design independently rated the submissions using a standardized rubric. The inter-rater reliability (Cronbach's α) was 0.922, indicating strong scoring consistency.

3.3.2 Student Engagement

Student engagement was measured using a 7-item questionnaire adapted from Henrie et al.'s (2016) instrument designed for technology-mediated learning environments. The adapted version focused on two dimensions: emotional engagement (e.g., interest, enjoyment, sense of belonging) and cognitive engagement (e.g., attention, strategy use, reflective thinking). Each item was rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

The instrument was pilot-tested and revised based on expert feedback from the fields of educational technology and art education. Internal consistency reliability was high (Cronbach's α = 0.904), and content validity was confirmed through expert review.

3.4 Experimental Procedure

The experiment was conducted over five weeks, consisting of 12 class sessions (three sessions per week, each lasting four instructional hours). A pre-test–post-test control group design was employed to compare changes in students' creative performance and engagement under different learning conditions.

During the first session of Week 1, all participants completed the pre-tests, which included the creative sketch task and the engagement questionnaire. Subsequently, both groups were introduced to the course objectives, project requirements, and basic technical training. Students in the experimental group received an orientation on VR equipment and software functions, while students in the control group were introduced to conventional digital design tools.

Weeks 2 through 4 constituted the main instructional phase. Students in both groups worked on the same packaging design project, following a PBL framework structured around seven core elements: problem initiation, inquiry, authenticity, student agency, reflection, critique and revision, and public presentation. Each session resulted in the production of a small-scale design outcome, with task complexity gradually increasing. While the control group completed design tasks using sketching, paper models, or pen tablets, the experimental group performed equivalent tasks in an immersive VR environment using the HTC VIVE system and custom-designed packaging design software.

In the final session of Week 5, all participants completed the post-tests, submitted their final design outcomes, and participated in a classroom showcase. This concluding phase allowed for both summative assessment and informal peer feedback across conditions.

3.5 Data Collection and Analysis

Data collection occurred over a five-week instructional period during a scheduled course in the Advertising Art and Design program. A pre-test–post-test quasi-experimental design was used, involving one experimental group and one control group. Before the instructional intervention, all participants completed the pre-test measures of creative performance and student engagement. The same measures were administered again at the end of the fifth week.

Creative performance was assessed through a structured drawing task evaluated by three independent expert raters. Engagement data were collected via a paper-based questionnaire distributed and retrieved during class hours. To ensure data quality, all students were briefed on the anonymity and voluntary nature of participation, and responses were screened for completeness before analysis.

All data were coded and entered into SPSS 27.0 for statistical analysis. Descriptive statistics were first computed to summarize the distributions of key variables. The reliability and validity of the instruments were assessed using Cronbach's alpha, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity.

Inferential analyses included independent samples t-tests to compare group means before and after the intervention, and paired samples t-tests to assess within-group change. To explore the structural relationships among variables, linear regression analyses were conducted to assess the effects of VR on engagement and creativity, and the effect of engagement on creativity. Finally, a mediation analysis was performed to test whether engagement mediated the relationship between VR use and creative performance. A significance threshold of $p < .05$ was applied throughout.

4. Results

4.1 Descriptive Statistics and Instrument Validation

Descriptive statistics for the main variables—student engagement and creative performance—are presented in Tables 2 and 3. For both measures, scores were derived from the sum of all item responses on their respective instruments. Engagement scores were based on a 7-item, 5-point Likert scale, while creativity scores were based on a 12-item expert rating scale. As shown in the tables, both engagement and creativity scores increased notably in the experimental group and control group from pre-test to post-test.

Table 2. Descriptive Statistics of Learners' Engagement

Group	Min.	Max.	Mean	Std. Deviation
Experimental Group (VR)-pre test	4	24	14.55	6.724
Control Group (no VR)-pre test	10	32	17.90	4.241
Experimental Group (VR)-post test	18	32	25.85	4.923
Control Group (no VR)-post test	9	32	17.90	5.300

Table 3. Descriptive Statistics of Learners' Creativity

Group	Min.	Max.	Mean	Std. Deviation
Experimental Group (VR)-pre test	24	45	34.75	6.727
Control Group (no VR)-pre test	19	44	34.20	5.836
Experimental Group (VR)-post test	37	56	45.95	5.633
Control Group (no VR)-post test	29	51	41.05	5.735

Validity of the instruments was evaluated through Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. The engagement scale yielded a KMO value of 0.861 and $p < .001$, indicating sampling adequacy and factorability. Similarly, the creativity scale showed a KMO value of 0.885 and $p < .001$, confirming construct validity.

4.2 Pre-Intervention Equivalence Testing

To ensure group comparability before the intervention, an independent samples t-test was conducted to examine whether there were any significant differences in creative performance between the experimental and control groups at the pre-test stage. The t-test revealed no statistically significant difference between the two groups, $p = .784$.

These results indicated that prior to the intervention, both groups were equivalent in terms of their baseline creative performance. This established a valid foundation for interpreting post-test differences as effects of the instructional treatment rather than pre-existing disparities.

4.3 Post-Intervention Effects: T-Test Analysis

To evaluate the effects of the VR-enhanced PBL intervention on students' creative performance, both independent and paired samples t-tests were conducted.

An independent t-test comparing post-test creativity scores between experiment and control group revealed a statistically significant difference between groups. $p = .010$. This result suggests that students in the VR condition demonstrated significantly greater improvement in creative output than those in the conventional PBL setting.

Paired samples t-tests were also conducted to examine within-group improvements from pre-test to post-test. As indicated in Table 4, the experimental group showed a significant increase in creativity scores, and the control group also demonstrated a significant gain. Although both groups improved, the magnitude of change was substantially greater in the experimental group.

Table 4. Paired Samples T-Test Results: Pre- and Post-Test Creativity Scores

		Paired Difference			
		Mean	SD	Std. Error Mean	p-value
Experiment	Before-After	-11.200	2.608	.583	<.001
Control	Before-After	-6.850	1.309	.293	<.001

Taken together, these findings suggest that the integration of VR into the PBL environment produced a more pronounced enhancement in students' creative performance.

4.4 Regression Analysis

To explore the relationships among key variables, a series of simple linear regression analyses were conducted. First, the effect of VR use on students' creative performance was examined. As shown in Table 5, VR was a significant predictor of creativity, $p < .001$. This result suggests that VR has a linear regression relationship with creativity.

Table 5. Regression Analysis between VR and Creativity

	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	Beta	p-value
(Constant)	23.550	3.102		<.001
VR	11.200	1.962	0.679	<.001

Next, VR was tested as a predictor of student engagement. Table 6 shows that the regression model was statistically significant, p < .001, indicating that VR use was associated with greater emotional and cognitive engagement.

Table 6. Regression Analysis between VR and Engagement

	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	Beta	p-value
(Constant)	3.250	2.946		.277
VR	11.300	1.863	.701	<.001

Finally, engagement was tested as a predictor of creative performance. As shown in Table 8, engagement significantly predicted creativity, p < .001. This finding supports the hypothesis that student engagement contributes meaningfully to creative performance in project-based design tasks.

Table 7. Regression Analysis between Engagement and Creativity

	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	Beta	p-value
(Constant)	23.442	2.075		<.001
Engagement	.837	.095	.818	<.001

These regression analyses provide initial evidence of a possible mediating relationship, wherein VR influences creativity in part by enhancing engagement. This hypothesis is tested more directly in the mediation analysis in the next section.

4.5 Mediation Analysis

To further investigate the underlying mechanism linking VR use and creative performance, a mediation analysis was conducted using student engagement as the proposed mediator. This analysis tested whether the effect of VR on creativity operates indirectly through increased engagement.

Table 8. Regression Analysis between VR Engagement and Creativity:

	Unstandardized Coefficients		Standardized Coefficients	
	B	Std. Error	Beta	p-value
(Constant)	21.315	2.418		<.001
VR	3.427	2.112	.208	.113
Engagement	.688	.131	.672	<.001

As shown in Table 8, when both VR and engagement were entered into the regression model simultaneously, engagement remained a significant predictor of creativity (p < .001), while the direct effect of VR on creativity was no longer statistically significant (p = .113). This shift in significance suggests that the influence of VR on creative outcomes is mediated by student engagement.

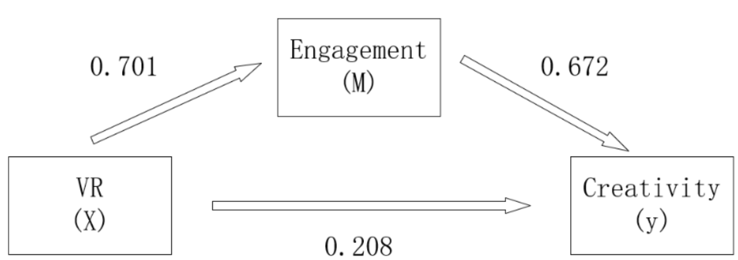

Figure 1. Mediation Model

A visual representation of the mediation model is presented in Figure 1. As shown, student engagement (emotional and cognitive) fully mediates the effect of VR interactivity on creativity. The dashed arrow indicates that the direct path from VR to creativity becomes non-significant when engagement is included in the model.

Taken together with the previous regression results, these findings indicate that VR does not directly enhance creativity in isolation. Rather, its effect on creative performance is realized through its capacity to foster deeper emotional and cognitive engagement. This supports the hypothesis that engagement functions as a full mediator in the relationship between VR and creativity within a project-based learning context.

5. Discussion

5.1 Overview of Key Findings

The study confirmed that integrating VR into PBL significantly improved students' creative performance. However, the enhancement was not solely a direct effect of the technology itself. Instead, engagement, particularly emotional and cognitive involvement, partially mediated the relationship between VR use and creativity. Immersive technologies are commonly believed to lead directly to enhanced creativity in learning environments (Bourgeois-Bougrine et al., 2022). The present findings indicate that student engagement plays a key role in helping these tools become effective learning resources.

These results provide empirical support for reframing creativity in technology-rich learning not as an automatic output, but as a process contingent on how students engage with tasks, tools, and contexts.

5.2 Reconsidering the Role of VR in Creative Learning

Although VR environments are often praised for their immersive and interactive qualities, the present findings suggest that these affordances are not pedagogically impactful unless they foster sustained engagement. The experimental group benefited not because of the presence of VR, but because VR facilitated deeper involvement in the creative process by enabling exploration, iteration, and emotional connection to the design task.

This challenges the dominant narrative in educational technology that emphasizes technological novelty as a driver of learning. Novelty may initiate interest, but without task relevance and instructional alignment, that interest does not translate into meaningful outcomes. The fact that the direct effect of VR on creativity became non-significant after controlling for engagement suggests that VR, if poorly integrated, may be functionally inert.

This suggests that simply using VR is not enough. If it is added without thoughtful design, it may turn into a surface-level feature instead of a tool for deeper learning. What matters more is how the technology is used to create space for thinking, experimenting, and reflecting. Instead of just giving students access to virtual tools, educators need to design learning tasks that encourage students to be active, focused, and expressive throughout the creative process.

5.3 The Mediating Role of Engagement

The mediation analysis showed that engagement fully explained the effect of VR on creative performance. This supports the view that VR alone does not drive creativity; rather, it supports emotional and cognitive engagement, which in turn enhances creativity (Huang et al., 2021; Lin et al., 2024).

This finding brings critical nuance to current literature on technology-enhanced creativity, which often assumes a direct link between digital tools and innovative thinking. While previous studies have noted increased motivation and curiosity in VR-based environments, few have articulated how these affective and cognitive states actually translate into sustained creative work (Cheng et al., 2023; Lee et al., 2022; Poupard et al., 2023). By foregrounding engagement as a mediating process, this study addresses those gaps by situating engagement as a dynamic, multi-dimensional mediator and aligning with recent findings by Cheng et al. (2023) and Poupard et al. (2023), which call for learner-centered design in immersive VR settings.

This finding suggests an important implication: technology should be evaluated not just by its features, but by its ability to support sustained student engagement. This highlights a shift from media-centered to learner-centered approaches in educational design.

5.4 Theoretical and Practical Implications

Theoretically, this study affirms that VR-supported creativity arises through engagement, not from technology alone. This is consistent with constructivist and PBL approaches (AlGerafi et al., 2023; Ozkan, 2023), which emphasize learner interaction with tools and tasks.

It also supports Lee et al. (2025), who caution that novelty effects may fade without proper design. Pramanik (2024) adds that engagement must be intentionally cultivated. Our results confirm that creativity improved only when students were emotionally and cognitively engaged.

Practically, as Rehman et al. (2024) and Maor et al. (2023) suggest, VR must be integrated into learner-centered, inquiry-driven tasks. Teachers need support not just in tool use, but in designing scenarios that sustain engagement. Without this, VR may offer little real benefit.

Future studies should consider longer timelines to explore how engagement and creativity develop over time. Doing so will help refine models of immersive learning that focus on the learner, not the tool.

5.5 Limitations and Future Directions

While the study yields promising results, several limitations warrant attention. The sample was limited to students from a single vocational institution in China, which may constrain the generalizability of the findings. Future research should include diverse educational levels and cultural contexts to validate and expand the model.

The study relied on short-term, task-specific measures of creativity. Although these capture immediate performance outcomes, they may not reflect the longer-term development of creative capacity. Longitudinal designs could provide deeper insight into how engagement and creativity evolve over time in VR-enhanced learning environments.

Engagement was measured through self-report and inferred from questionnaire data. While reliable, this approach could be complemented by behavioral or observational metrics to capture the dynamic nature of learner involvement more fully.

The VR system used in the study was custom-developed and domain-specific. Future work could examine how commercial or platform-agnostic tools perform in similar contexts and whether different VR features, such as interactivity and realism, exert distinct effects on engagement and creativity.

6. Conclusion

This study investigated how virtual reality (VR), embedded within a project-based learning (PBL) environment, influences students' creative performance in art and design education. Central to the inquiry was the mediating role of student engagement, specifically emotional and cognitive involvement, as a process variable linking the use of VR to enhanced creativity.

The findings demonstrate that while VR can support the development of creative outcomes, its effectiveness is not direct. Instead, VR operates through its capacity to foster meaningful engagement. Students in the VR condition exhibited significantly greater gains in both engagement and creativity than those in the control group. Regression and mediation analyses further confirmed that engagement fully mediated the effect of VR on creative performance, highlighting its central function in technology-enhanced creative learning.

Theoretically, the study contributes to a more nuanced understanding of immersive learning by reframing engagement not as a byproduct of technology but as the key mechanism through which complex outcomes like creativity emerge. Practically, the results provide guidance for educators and curriculum designers seeking to integrate VR into creative disciplines. The findings suggest that the success of VR integration depends not on the novelty of the tool itself, but on the intentional design of tasks that promote sustained, student-centered engagement.

Future research should expand the scope of inquiry to include diverse learner populations, longitudinal designs, and multi-modal engagement measures. More attention should also be paid to the comparative effects of different VR features and instructional models on creativity. In doing so, researchers and practitioners can better align technological innovation with pedagogical effectiveness in fostering creativity in the digital age.

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Acknowledgments

We express our deepest gratitude to all who contributed to the completion of this research. We thank the students and teachers who were involved in this study. We thank the support from the college to provide the opportunity and platform for our research. Thanks to the internal mechanism of promotingall for your contributions and teamwork.

Authors contributions

Dr. Lidan He was responsible for the study design, data collection, analysis, and manuscript writing. Prof. Shaharuddin Bin Md Salleh provided academic supervision and contributed to the revision of the manuscript. Dr. Cai Liu assisted in data collection. Dr. Yulin Zhou provided technical support and equipment assistance. All authors read and approved the final version of the manuscript.

Funding

This work was supported by the Natural Key Research and Development Project of Zhejiang Province [Grant No. 2025C01075], and in part by the Ningbo Natural Science Foundation [Grant Nos. 2024Z148, 2024Z234, 2024H008, and 2023Z236].

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Obtained.

Ethics approval

The Publication Ethics Committee of the Sciedu Press.

The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

Provenance and peer review

Not commissioned; externally double-blind peer reviewed.

Data availability statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Data sharing statement

No additional data are available.