Exploring Imaginary Worlds: Leveraging Immersive Virtual Reality for Designing & Constructing 3D Environments

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Abstract
In an era defined by technological advancements, the integration of new media, Immersive Virtual Reality (IVR), has revolutionized art and design education, empowering students to explore innovative avenues of creative expression. This presentation outlines the key facets of a university-level art and design course integrating 3D design theory with the concept of imaginary world building. Through a series of creative design challenges, students will develop 3D versions of their own imaginary worlds, infusing personal meaning and elements of storytelling into their compositions. Emphasizing imagination and creative expression, this course employs creative-thinking and problem-solving techniques such as association-making, brainstorming, and media exploration, complemented by concept sketches, group evaluation, and personal reflection. Here, students will either construct 3D scale models or use the IVR-based drawing program, TiltBrush. Separated into 3 groups, students will work: 1) exclusively in VR; 2) solely with scale models; or 3) both on VR-based and model-based versions. Employing the narrative inquiry approach, comparisons will be drawn utilizing surveys, interviews, reflections, sketchbooks, group discourse, and process timelines. With this, the primary aim is to compare the teaching, learning, and working processes across groups, with a secondary aim of examining the use of symbols derived from the exploration of personally relevant themes. This research aims to contribute to the growing body of knowledge by exploring the convergence of IVR technology with established art practices, unveiling novel pedagogical strategies in art education, and outlining the impact of IVR on artistic expression.

Keywords: Art Education, Visual Arts, Design Thinking, Art-Based Research, Creative Thinking, Creative Problem-Solving, Imagination, World-Building, Immersive Virtual Reality

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Introduction

The integration of Immersive Virtual Reality (IVR) into art and design education represents a groundbreaking shift with profound implications for enhancing creativity and student engagement. As a revolutionary tool, IVR offers an innovative platform that enables students to engage in imaginative world-building and visualize abstract ideas with unprecedented depth and clarity (Du, 2021; Jiawei & Mokmin, 2023). This study aims to explore the multifaceted applications of IVR technology, examining its impact on various aspects of learning and creative processes in the context of Art Education.

IVR allows students to transcend traditional educational boundaries by providing an immersive environment where they can interact with their creative work in dynamic and interactive ways. Unlike conventional methods that often rely on two-dimensional representations, IVR creates a three-dimensional space where abstract concepts can be visualized and manipulated in real-time (Araiza-Alba et al., 2021). This immersive experience facilitates a deeper understanding of complex ideas and supports an *Iterative design process*, where students can continuously refine and develop their projects based on immediate feedback (Kolb, 1984).

As IVR technology continues to gain traction across various disciplines, its potential to transform art and design education becomes increasingly apparent. By leveraging IVR, educators can introduce novel approaches to teaching and learning that enhance creativity, critical thinking, and technological literacy (Freina & Ott, 2015). This paper investigates how IVR can be utilized to achieve these educational objectives, comparing its impact on creativity and problem-solving with traditional 3D modeling techniques. Through a comprehensive analysis, the study aims to demonstrate the transformative potential of IVR in fostering a more engaging and effective learning environment.

This research explores the significant role of IVR in revolutionizing art and design education. By providing a robust framework for understanding the cognitive and creative benefits of IVR, the study seeks to highlight how immersive technologies can enhance students' ability to visualize, iterate, and express complex concepts (Suh & Cho, 2020; Molina-Carmona et al., 2018). The findings will contribute to a deeper understanding of IVR's potential to reshape educational practices and prepare students for success in a digitally-driven world.

1. Background Literature

1.1 The Growing Role of IVR in Art Education and Creative Fields

Immersive Virtual Reality (IVR) is increasingly recognized for its transformative impact on art education and other creative fields. IVR technology aims to replicate real-world scenarios, providing immersive learning environments that foster a strong sense of presence. This technology allows for interactive control, communication, and creation of objects, significantly enhancing the learning experience (Asad et al., 2021). IVR promotes cognitive learning experiences that require high levels of visualization and awareness, serving as an effective pedagogical tool to advance students' problem-solving, critical thinking, and rational thinking skills (Asad et al., 2021). The immersive and interactive nature of IVR can substantially improve cognitive skills by providing students with environments that encourage creative exploration (Asad et al., 2021).

One of the remarkable capabilities of IVR is its ability to transform abstract or imaginary thoughts into tangible experiences, promoting active engagement rather than passive observation. This feature is particularly useful in art education, where it supplements practices that are impractical in real life and extends the boundaries of reality for discovery (Dede et al., Asad et al., 2021). In the context of art and design education, IVR stimulates students' artistic creation potential by helping them understand and analyze three-dimensional spaces, thereby overcoming traditional constraints and enhancing creative thinking skills (Jiawei & Mokmin, 2023; Du, 2021).

1.2. Uses of IVR in Art Education and Research

IVR offers a broad spectrum of applications within art education, significantly enriching the learning experience. One primary advantage is its ability to enhance students' comprehension of three-dimensional space, which is crucial for understanding spatial relationships and perspective in art education. Jiawei and Mokmin (2023) argue that IVR enables students to interact with and manipulate virtual environments in ways that traditional methods cannot, leading to a deeper understanding of spatial dynamics and depth perception.

IVR also facilitates the visualization of abstract art concepts by translating them into tangible representations, making complex and abstract ideas more accessible to students. Du (2021) emphasizes that IVR provides a more concrete means of understanding and manipulating artistic concepts, thereby making the learning process more engaging.

Additionally, IVR has significant applications in creating immersive art installations. Traditional art forms are often limited by physical space and material constraints, but IVR allows for the development of interactive artistic experiences that transcend these limitations. Asad et al. (2021) note that students can create and experience art in ways that go beyond the physical world's boundaries, opening new possibilities for artistic expression and interaction.

IVR also offers a flexible platform for experimenting with various artistic techniques and styles. According to Molina-Carmona et al. (2018), this flexibility enables students to explore different mediums and approaches without the constraints imposed by physical materials. This freedom to experiment can lead to innovative artistic outcomes and a deeper understanding of different artistic techniques.

Furthermore, IVR enhances collaboration by facilitating teamwork in shared virtual spaces. This technology allows students to work together on art projects in a more interactive and integrated manner. Freina and Ott (2015) highlight that this collaborative aspect of IVR promotes collective creativity and enhances the overall learning experience.

Lastly, IVR modernizes traditional sculpting and modeling techniques. The use of digital platforms for creating and manipulating 3D models represents a significant advancement over conventional sculpting methods. Suh and Cho (2020) point out that IVR tools offer new possibilities for digital sculpting, allowing for more precise and versatile manipulation of virtual materials.

1.3. Importance of Creative Thinking and Problem-Solving in Art Education

Engaging in arts-based research helps develop creative thinking by transforming authentic artistic practices into inquiries that convey deeper meanings (Barone & Eisner, 2012;

Hernández-Hernández & Fendler, 2013). Material engagement enhances creative thinking and problem-solving through direct interaction with materials, fostering an in-depth understanding of artistic processes (Barad, 2007; Latulipe et al., 2023). Art education rooted in experiential learning helps students convert direct experiences into deeper understanding through critical reflection and exploration (Asad et al., 2021).

IVR enhances experiential learning by immersing students in authentic virtual environments, allowing for first-hand experiences and practice in controlled atmospheres without real-life risks (Asad et al., 2021). By using IVR technology, students can overcome traditional constraints, facilitating new strategies for artistic creation and enhancing their ability to analyze and understand 3D spaces (Jiawei & Mokmin, 2023; Du, 2021).

2. Research Aims and Methodologies

2.1. Research Aims and Essential Questions

This research initiative aims to explore the transformative potential of IVR in art and design education, with a particular focus on imaginative world-building and the instruction of spatial design strategies. World-building involves creating detailed and immersive environments, enabling students to visualize and interact with complex spatial concepts in a three-dimensional space. Offering a unique platform for exploration, IVR allows students to design and manipulate spatial environments with greater ease and flexibility compared to traditional methods (Freina & Ott, 2015; Kwon, 2019). By integrating IVR into the curriculum, the project seeks to investigate how this technology influences students' creative processes, design skills, and overall learning outcomes (Jiawei & Mokmin, 2023; Suh & Cho, 2020).

The study will examine the use of IVR in developing imaginative spaces compared to traditional media. By focusing on world-building, the research aims to determine how IVR can enhance students' understanding of spatial relationships and improve their design skills. Additionally, the research will investigate the impact of IVR on creative thinking and problem-solving abilities. By integrating world-building and spatial design strategies into the study, the research seeks to provide a thorough evaluation of how IVR technology influences creativity and learning. The findings are expected to offer valuable insights into the potential benefits and limitations of IVR in the context of art and design education, ultimately contributing to a deeper understanding of its role in shaping the future of creative practices.

The project is structured around a comparative analysis between groups of art and design students: one utilizing traditional 3D modeling techniques and the other engaging with IVR tools. The research aims to address the following essential questions: How can IVR enhance art and design education? What cognitive and working processes are involved in creative problem-solving in IVR, and how do they compare to traditional 3D modeling techniques? What are the implications of IVR for student engagement, creativity, and learning outcomes? By examining these questions, the study will assess the efficacy of IVR in fostering creative thinking and problem-solving skills, thereby enriching the educational experience and preparing students for future challenges in the creative industries.

2.2. Methodologies

This research investigates the transformative potential of IVR in art and design education, with a specific focus on imaginative world-building, spatial design strategies, creativity, and

problem-solving abilities. A mixed methods framework is employed to comprehensively assess IVR's impact on these educational outcomes.

2.2.1. Research Design and Participant Selection

The study follows a comparative research design over the course of one academic semester, lasting approximately three months. The study involves 12 international students with an interest in art and design. Participants are divided into two or three groups based on their preferred methods: one group exclusively using IVR tools (e.g., Tilt Brush), another using traditional 3D model-making materials (e.g., foam, plaster, paper mache), and a potential third group using both methods. This self-selection process allows for the exploration of natural preferences and their effects on research outcomes, thereby aligning with the research aim of evaluating the potential impact of IVR in enhancing art and design education.

2.2.2 Data Collection Methods

To address the research questions—particularly how IVR influences students' creative processes, spatial design skills, and learning outcomes—a variety of data collection methods are employed:

A: Student Sketchbooks and Teacher Observations: Document the iterative design processes, capturing the evolution of ideas and providing qualitative data on student engagement and creativity.

B: Pre-Test and Post-Test Assessments: The Test of Creative Thinking-Drawing Production (TCT-DP) (Jellen & Urban, 1986) and the Test of Creative Imagination (TCI) (Karwowski, 2008a, b) may be utilized to quantitatively measure changes in creative thinking and imagination. These assessments offer objective evidence of IVR's impact on creativity, directly linking to the research aim of evaluating the cognitive processes involved in creative problem-solving.

C: Questionnaires: The Creative Thinking Self-Efficacy (CTSE) and Creative Problem Solving Efficacy (CPSE) questionnaires (Finke, Ward, & Smith, 1992) assess students' confidence in their creative abilities and problem-solving skills. This data will help determine the perceived impact of IVR on students' creative confidence, aligning with the research question on student engagement and learning outcomes.

D: Art Production and Evaluation: Tools such as the Art Creativity and Achievement Rating (ACAR) and Creative Art Tools (CAT) are used to evaluate the quality and originality of students' artworks. These instruments assess the effectiveness of IVR in enhancing creative outputs compared to traditional methods, thus directly addressing the research aim of comparing design outcomes.

2.2.3 Data Analysis Methods

The data collected will be analyzed using the following methods:

A. Comparative Analysis: Compares the effectiveness of traditional 3D modeling techniques against IVR tools in enhancing spatial design strategies. The analysis will focus on design outcomes, creative processes, and student engagement, providing a detailed evaluation of the

advantages and limitations of IVR. This method supports the research aim of determining how IVR influences students' understanding of spatial relationships and design skills.

B. Narrative Inquiry: Captures detailed accounts of students' interactions with IVR, their creative processes, and reflections on their learning experiences. This qualitative method is aligned with Kolb's experiential learning theory (1984), emphasizing the importance of reflective, personal experiences in learning. The insights gained from these narratives will contribute to understanding the nuanced impacts of IVR on creativity, as per the research objectives.

C. Reflective Analysis: Students engage in reflective analysis to evaluate their creative processes, tool effectiveness, and overall learning journey. This method, informed by Schön's reflective practice (1983), provides deeper insights into students' problem-solving abilities. Reflections will be coded according to Osborne's Creative Problem Solving (CPS) model and the imaginative training program 'Eureka' (Dziedziewicz & Karwowski, 2015), offering valuable perceptions of IVR's impact on their design skills. This method is integral to understanding the cognitive processes involved in creative problem-solving within IVR environments.

2.2.4 Instruments

To thoroughly assess IVR's impact, the following instruments will be utilized:

A. Torrance Tests of Creative Thinking-Drawing Production (TCT-DP): Assesses divergent thinking through tasks that require original responses, providing quantitative data on shifts in creativity.

B. Creative Imagination Scale (TCI): Evaluates the depth of creative imagination, offering insights into how IVR influences students' ability to generate innovative ideas.

C. Creative Thinking Self-Efficacy (CTSE) and Creative Problem Solving Efficacy (CPSE) Questionnaires: Measure students' self-reported confidence in their creative and problem-solving abilities, directly addressing the research aim of evaluating how IVR affects students' cognitive and creative skills.

D. Art Creativity and Achievement Rating (ACAR) and Creative Art Tools (CAT): Evaluate the creative and technical aspects of students' artworks, providing a comprehensive view of the role IVR plays in enhancing artistic outcomes.

By integrating these methodologies and instruments, this study aims to provide a detailed understanding of IVR's impact on creativity, spatial design skills, and problem-solving abilities, contributing valuable insights to the field of art and design education.

3. Theoretical Frameworks

The investigation of IVR in art and design education is underpinned by two foundational frameworks: Experiential Learning Theory (ELT) and Embodied Cognition. These theories provide insight into how IVR can enhance creativity, spatial design skills, and overall educational outcomes.

Experiential Learning Theory (ELT): According to Kolb (1984), ELT emphasizes the importance of hands-on, interactive experiences in learning. It consists of four stages: concrete experience, reflective observation, abstract conceptualization, and active experimentation. ELT posits that learning is enhanced through direct engagement with materials, reflection on experiences, development of abstract ideas, and testing these ideas through further action. In the context of IVR, this framework supports the notion that immersive experiences in a virtual environment align with Kolb's model. Students engage in concrete experiences by interacting with 3D spaces, reflect on their creations, conceptualize new strategies, and experiment with iterative design processes (Kolb, 1984).

Embodied Cognition: This theory, as articulated by Araiza-Alba et al. (2021), argues that cognitive processes are deeply rooted in sensory experiences and physical interactions with the environment. In IVR, students interact with virtual objects as if they were physical entities, which engages multiple senses and physical movements. This sensory immersion enhances cognitive processes such as spatial reasoning and problem-solving. For instance, the ability to "walk around" and manipulate virtual designs helps students intuitively grasp spatial relationships and design principles, supporting deeper cognitive insights and creative breakthroughs (Jiawei & Mokmin, 2023).

Together, ELT and Embodied Cognition offer a comprehensive understanding of IVR's role in education. ELT demonstrates how IVR facilitates a complete cycle of experience, reflection, and experimentation. Embodied Cognition highlights how sensory and physical interactions in IVR can enhance spatial understanding and creativity. These frameworks collectively illustrate how IVR can transform educational practices, creating a more interactive and effective learning environment for art and design students.

4. Course Aims and Objectives

The course aims to cultivate creativity and imagination among students, essential skills in art and design that drive innovation and artistic expression. By prioritizing creativity, the course empowers students to explore their artistic potential and push beyond conventional design thinking, fostering an environment where novel ideas and unique solutions can flourish (Dziedziewicz & Karwowski, 2015). An integral component of this creative exploration is the concept of world-building, which involves constructing detailed and immersive environments. This approach allows students to engage deeply with spatial design and visualization, enhancing their ability to conceptualize and realize complex ideas in three-dimensional space.

Another key aim is to develop students' design and visualization skills. The ability to visualize and translate concepts into tangible forms is crucial in art and design education. This objective addresses the need for students to refine their skills in creating detailed visual representations and to effectively communicate their ideas. Through engagement with both traditional and IVR-based design tools, including world-building techniques, students learn to navigate complex design processes and bridge the gap between abstract ideas and practical implementation. This prepares them for real-world design challenges by allowing them to experiment with creating and manipulating virtual environments, thus refining their spatial awareness and technical skills (Du, 2021).

The course also focuses on fostering critical thinking and problem-solving abilities. Critical thinking involves analyzing and evaluating artistic choices, while problem-solving addresses

design challenges and innovative solutions. Activities and assignments encourage students to critique their own and peers' work, developing their ability to assess design elements critically and make informed decisions. Iterative design processes, including world-building projects, emphasize problem-solving by presenting students with complex scenarios to tackle and adapt to, equipping them with skills necessary to handle evolving industry standards and challenges (Kolb, 1984).

Specific objectives guide students through various stages of their creative development. Firstly, generating conceptual designs and visualizations: students create initial design concepts and develop them into detailed visual representations, enhancing their creative thinking and ability to present and communicate their designs effectively (Freina & Ott, 2015). Secondly, constructing 3D models and virtual prototypes: this objective, particularly relevant in the context of IVR and world-building, allows students to build and manipulate virtual objects and environments, developing technical skills in digital modeling and a deeper understanding of spatial relationships (Suh & Cho, 2020). Lastly, integrating narrative and story elements: by incorporating narrative elements into artistic projects, students learn to infuse their designs with meaning and context, emphasizing storytelling in art and design, and helping students connect their work with broader themes and concepts (Asad et al., 2021).

These aims and objectives address fundamental aspects of art and design education—creativity, visualization, critical thinking, and problem-solving—providing a comprehensive approach to developing artistic and design skills. This alignment with industry needs ensures that students are well-prepared to meet future career challenges and opportunities.

4.1 Teaching Content and Methodology

The teaching content and methodology of the course are structured to ensure a rich and immersive learning experience for students. The course is designed to encompass a broad range of concepts and techniques in both traditional 3D modeling and IVR, providing students with the flexibility to explore and apply various approaches to art and design.

Active learning is central to the instructional approach, with students engaging directly with the material through hands-on projects, interactive workshops, and collaborative activities. This method reinforces theoretical knowledge and allows experimentation in practical settings (Freina & Ott, 2015). Reflective practice is another critical component. By regularly reflecting on their work and learning experiences, students critically analyze their progress, identify areas for improvement, and develop a deeper understanding of their creative processes. These reflective exercises help students gain insight into their strengths and challenges, promoting continuous growth and development (Kolb, 1984). Additionally, the course employs differentiated instruction to cater to diverse learning styles and skill levels. By offering various forms of instruction and assessment, such as visual aids, hands-on activities, and personalized feedback, all students can engage effectively with the course content and achieve their learning objectives (Dziedziewicz & Karwowski, 2015).

4.2 Course Content

The course provides a thorough exploration of both traditional 3D modeling techniques and IVR tools, offering students a broad range of learning opportunities.

Introduction and Foundations: The course begins with an overview of essential design principles and materials, including techniques for 3D modeling and IVR tools. Students will learn fundamental design concepts such as closure, proximity, continuity, similarity, balance, and connectedness, which are critical for advanced design tasks.

Creative Design and Visualization: Students engage in activities to develop their conceptual designs and virtual prototypes. They will participate in brainstorming sessions, drawing exercises, and design challenges, incorporating creative thinking strategies such as word-association, doodle drawing, and mark-making. These exercises help refine their skills in translating abstract ideas into tangible forms.

IVR and Traditional Techniques: The course includes hands-on practice with IVR technology and traditional 3D modeling materials. Students will create and manipulate virtual environments, using IVR to explore spatial relationships and enhance their design capabilities. This phase covers navigation of virtual spaces, interaction with 3D content, and integration of narrative elements into their projects.

Project Development and Evaluation: Students work on projects that involve planning, drafting, creating mock-ups, and refining their designs. They will present their final projects, engage in group evaluations, and provide reactions and reflections. Post-tests and surveys will assess changes in creative thinking and problem-solving skills.

Reflective Practice and Feedback: The course incorporates reflective activities, including peer reviews and individual reflections, to help students evaluate their creative processes and project outcomes. Collaborative activities foster community and provide diverse perspectives on design challenges.

By integrating these components, the course ensures a comprehensive approach to developing artistic and technical skills, preparing students to tackle complex design challenges and harness their creativity effectively.

5. Preliminary Results & Comparative Analysis

The preliminary results from an earlier iteration of the course provide valuable insights into the impact of integrating IVR into art and design education. These findings align with the course's aims and objectives, highlighting how IVR technology influences creativity, design skills, and problem-solving abilities compared to traditional methods.

The initial analysis indicates several benefits of using IVR, such as enhanced spatial visualization and innovative design solutions. However, it also identifies areas needing improvement, which will inform modifications in subsequent iterations of the course. This evolving approach ensures that the course continuously adapts to better meet learning objectives and address any challenges encountered.

The preliminary data thus offers a foundational understanding of IVR's role in student learning outcomes, while also guiding future refinements to optimize the course's effectiveness.

5.1 Ease of Modification and Flexibility

A notable finding is the increased ease of modification and flexibility experienced by students using IVR tools. Unlike traditional 3D modeling techniques, which often involve a more rigid and time-consuming process for design adjustments, IVR offers a dynamic and interactive environment. Students reported greater ease in modifying their designs, adjusting spatial elements, and experimenting with visual aesthetics. This flexibility supports an iterative design process, allowing students to refine their work more efficiently. The real-time modifications and immediate visual feedback in IVR encourage exploration and experimentation, enhancing creativity and aligning with the course's objective of developing design and visualization skills (Jiawei & Mokmin, 2023).

5.2 Immersive Experience and Cognitive Engagement

The immersive experience provided by IVR significantly enhances students' cognitive engagement and spatial comprehension. Participants in the IVR group reported a heightened level of engagement and a deeper understanding of spatial relationships through direct interaction with their virtual designs. This immersive interaction aligns with the course's aim to cultivate creativity and imagination. Engaging with designs in a more intuitive and meaningful way helps students grasp complex spatial concepts and develop advanced visualization skills, thereby enhancing creative thinking and practical design abilities (Araiza-Alba et al., 2021).

5.3 Excitement and User Experience

Students using IVR tools exhibited higher levels of excitement and motivation compared to those using traditional 3D modeling techniques. The engaging nature of IVR, combined with user-friendly programs such as Tilt Brush, contributed to increased enthusiasm and investment in the design process. This positive user experience is directly related to the course's objective of fostering critical thinking and problem-solving abilities. The enhanced engagement and motivation from IVR not only made the learning process more enjoyable but also encouraged students to approach their projects with greater dedication and creativity. This correlation between increased motivation and improved learning outcomes underscores the importance of creating stimulating and immersive learning environments (Dziedziewicz & Karwowski, 2015).

5.4 Challenges and Limitations

Despite the advantages, challenges and limitations were observed, particularly among students using traditional 3D modeling techniques. These students faced difficulties due to limited prior exposure to arts-based tools and the abstract nature of the design activities. The lack of familiarity with advanced tools and techniques posed barriers to fully engaging with the course content. Addressing these challenges is essential to ensure that all students can benefit from the course's objectives and achieve their learning goals. Additional support and resources may be needed to bridge the gap between traditional methods and new technologies (Freina & Ott, 2015).

6. Conclusions

This research underscores the significant impact of integrating IVR into art and design education, reflecting the course's aims and objectives. The findings from the earlier iteration of the course reveal that IVR enhances flexibility, engagement, and motivation among students. IVR tools have demonstrated advantages in modifying and refining designs more efficiently compared to traditional 3D modeling techniques (Jiawei & Mokmin, 2023). The immersive and interactive nature of IVR offers a more engaging platform for exploring artistic potential, which aligns with the course's goals of fostering creativity and problem-solving (Araiza-Alba et al., 2021).

Despite these positive outcomes, the preliminary results also highlight that many participating students lacked formal art and design backgrounds. This diversity in experience levels underscores the importance of providing adequate support and resources to facilitate the transition to new technologies. Addressing these needs is essential to ensure all students, regardless of their prior experience, can fully benefit from the course's innovative methods (Freina & Ott, 2015). The increased enthusiasm and commitment observed among students using IVR further supports its role in developing critical thinking and problem-solving skills (Dziedziewicz & Karwowski, 2015).

As the course evolves, it is clear that while IVR holds considerable promise, ongoing adjustments are necessary to better address the diverse needs of students. The initial journey of integrating IVR has provided valuable insights into its potential and limitations, setting the stage for future improvements. The next phase of this research will focus on refining the course design to enhance its effectiveness and inclusivity. This will involve addressing identified challenges, incorporating feedback, and exploring additional strategies to support diverse learning styles.

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Declaration of Generative AI and AI-Assisted Technologies in the Writing Process

This paper acknowledges the use of generative AI and AI-assisted technologies in the writing process. These tools have been utilized to enhance the clarity, coherence, and efficiency of the manuscript. While AI technologies have supported the drafting and editing stages, all final content and interpretations remain the responsibility of the authors. The use of such technologies has been guided by ethical considerations, ensuring that their application complements and supports, rather than replaces, the intellectual input and scholarly rigor of the research process.

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