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Corresponding author:
[1*]Shafayati Shafa
Department of Fine Arts Drawing & Painting
Shanto-Mariam University of Creative Technology
Dhaka, Bangladesh
E-mail:
smaptiasafa1914@gmail.com

[2]Department of Business Administration
Faculty of Business
Shanto-Mariam University of Creative Technology
Dhaka, Bangladesh

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Augmented Reality in Fine Arts Education: A Path Toward Sustainable Creative Learning

[1*]Shafayati Shafa; [1]Mahmuda Akter; [1]Ananna Mary Piris; [2]Dr Kazi Abdul Mannan

Abstract: This study explores the role of augmented reality (AR) in fine arts education as a pathway toward sustainable creative learning. Drawing on a qualitative methodology supported by constructivist and experiential learning frameworks, the research examines how AR technologies can transform teaching and learning practices in fine arts programs. Findings indicate that AR fosters student engagement, motivation, and collaborative creativity by enabling immersive interactions with digital and physical art forms. Furthermore, AR contributes to sustainability by reducing reliance on physical resources, lowering material costs, and encouraging environmentally conscious learning practices. However, challenges such as limited faculty preparedness, unequal access to technology, and a lack of standardised curricular integration remain significant obstacles. The discussion emphasises the need for hybrid pedagogical models, faculty training, and policy interventions to ensure equitable and effective adoption of AR in art education. Ultimately, AR emerges not merely as an instructional tool but as a transformative educational practice that aligns creative learning with sustainability, inclusivity, and digital innovation.

Keywords: Augmented Reality, Fine Arts Education, Sustainable Learning, Creative Pedagogy, Experiential Learning, Digital Innovation

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1. Introduction

The integration of emerging technologies into education has become one of the most pressing topics in pedagogical research over the past two decades. Among these technologies, Augmented Reality (AR)—defined as the overlay of digital information onto physical environments through mobile devices, headsets, or other interfaces—has gained attention as a transformative learning tool (Wu et al., 2013). In contrast to Virtual Reality (VR), which immerses users in a fully digital environment, AR maintains the learner's connection with the physical world while enriching it with interactive, multimodal content. This hybrid quality makes AR particularly relevant for disciplines in which materiality, context, and embodied practice are essential, such as the fine arts (Papadopoulou, 2018).

Fine arts education has historically emphasised hands-on practice, critical reflection, and the development of aesthetic sensibility. Students are trained to work with materials, to develop technical skills, and to interpret artworks within cultural and historical frameworks (Eisner, 2002). While digital technologies have increasingly entered the arts classroom—such as digital photography, graphic design software, and interactive installations—the integration of AR represents a distinct pedagogical possibility. AR's affordances include contextual layering (e.g., overlaying historical data on a painting), embodied scaffolding (e.g., projecting drawing guidelines during sketching), and collaborative engagement (e.g., co-creating AR-enhanced exhibitions). These affordances position AR as a tool not only for skill acquisition but also for deeper conceptual learning (Al-Ansi, 2023; Chen et al., 2025).

At the same time, fine arts education is undergoing a broader paradigm shift toward sustainability and social responsibility. UNESCO (2023) emphasises that art and culture play a central role in fostering sustainability competencies, including empathy, systems thinking, and action-oriented creativity. In art classrooms, this means encouraging students to consider material choices, ecological implications, and the social narratives their works embody. AR aligns with this agenda in two main ways: first, by enabling visualisation of environmental or ethical issues in context, and second, by reducing material waste through digital experimentation before physical production (Miralay, 2024). However, AR itself consumes energy and resources, raising important questions about the balance between digital affordances and ecological impact (Smets, 2025).

The relevance of AR in fine arts education extends beyond technical enhancement. It prompts reconsideration of what it means to "learn creatively" in the twenty-first century. Scholars of creative learning emphasise iterative experimentation, multimodal expression, and cross-disciplinary problem-solving (Craft, 2011). By layering physical art-making with digital annotations, AR can foster playful exploration and iterative refinement, allowing students to move fluidly between idea, process, and product. Moreover, AR expands the audience for

creative work by enabling public-facing exhibitions in hybrid spaces—gallery visitors, for instance, can view students' AR layers that narrate ecological themes or artistic intentions (Kazlaris et al., 2025).

Despite its promise, AR integration in fine arts education faces challenges. Technical issues such as device availability, software reliability, and user interface design can disrupt creative flow (Wu et al., 2013). Teachers often lack adequate training to align AR features with curricular goals, highlighting the need for frameworks such as Technological Pedagogical Content Knowledge (TPACK) to guide integration (Mishra & Koehler, 2006). There is also the risk of AR being used superficially, with novelty overshadowing critical engagement (Papadopoulou, 2018).

This paper argues that AR, if implemented with pedagogical intentionality and sustainability in mind, can support sustainable creative learning—defined as the cultivation of artistic skills, critical dispositions, and ecological awareness that endure beyond the classroom. The objectives are threefold: (1) to review current literature on AR in education and arts contexts, highlighting key findings and gaps; (2) to situate AR within constructivist, socio-material, and TPACK frameworks; and (3) to propose a qualitative research methodology to explore how AR integration influences students' creativity and sustainability orientations. By linking AR with fine arts pedagogy and sustainability education, this study contributes to the growing discourse on how emerging technologies can be responsibly leveraged to transform creative learning.

3. Literature Review

The literature on AR in education is extensive and interdisciplinary, encompassing cognitive science, instructional design, museum studies, and creative practice. For clarity, this review is organised into four subsections: (a) AR in general education, (b) AR in visual arts and museums, (c) AR and creative learning, and (d) sustainability in art education. Each subsection highlights empirical findings, theoretical perspectives, and practical implications relevant to fine arts education.

3.1 AR in Education: Benefits and Challenges

Research over the past decade has consistently shown that AR enhances engagement, motivation, and learning outcomes across disciplines (Wu et al., 2013). Systematic reviews confirm that AR facilitates situated learning, where knowledge is constructed in authentic contexts (Al-Ansi, 2023; Zekeik, 2025). For example, AR applications in science education allow students to manipulate molecules or observe ecological systems in their immediate surroundings (Bödding et al., 2023). In language learning, AR provides immersive vocabulary and cultural experiences that deepen contextual understanding (Belda-Medina, 2022).

The benefits of AR include:

- Multimodal engagement: Combining visual, auditory, and kinesthetic inputs.
- Contextualization: Embedding information within physical artefacts or environments.
- Interactivity: Allowing learners to manipulate content and receive feedback.
- Motivation: Enhancing curiosity and enjoyment through gamified features.

However, challenges persist. Technical instability, device inequity, and cognitive overload are common concerns (Wu et al., 2013; Zekeik, 2025). Teachers often struggle to integrate AR meaningfully without adequate training, and many applications remain under-theorised, focusing more on novelty than pedagogy (Kazlaris et al., 2025). These challenges underscore the importance of frameworks such as TPACK, which emphasise alignment among technology, pedagogy, and content (Mishra & Koehler, 2006).

3.2 AR in Visual Arts and Museums

AR has found fertile ground in the visual arts, particularly in museums and galleries where artworks can be augmented with digital narratives. Papadopoulou (2018) documented how AR installations allow viewers to access hidden layers of artworks, such as underdrawings, conservation notes, or artist interviews. Smets (2025) compared AR and VR exhibitions, concluding that AR better preserved the immediacy of the physical artwork while enhancing interpretive depth.

In higher education, art instructors have experimented with AR to demonstrate complex techniques. For instance, overlays can guide students in proportion, perspective, or colour blending, allowing them to visualise abstract concepts in real time (Kazlaris et al., 2025). Museums have also used AR to connect historical artworks with contemporary issues such as climate change or social justice, inviting learners to situate art within broader sustainability narratives (MuseumNext, 2025).

Yet, not all outcomes are positive. Critics caution that AR can distract from aesthetic contemplation if poorly designed (Papadopoulou, 2018). Accessibility is another concern: not all students or visitors possess AR-capable devices, potentially reinforcing inequities (Smets, 2025). These findings highlight the need for thoughtful design and equitable implementation.

3.3 AR and Creative Learning

The concept of creative learning emphasises imagination, play, and cross-disciplinary thinking (Craft, 2011). AR's multimodal and interactive nature aligns closely with these principles. Studies show that AR supports divergent thinking by enabling rapid prototyping, iterative experimentation, and hybridisation of digital and physical media (Miralay, 2024). For example, Chen et al. (2025) documented how art students using AR and AI tools collaboratively produced new forms of cultural heritage storytelling, reporting higher levels of creativity and engagement.

Collaborative AR platforms allow multiple users to annotate, manipulate, or exhibit

shared digital content. Such affordances encourage peer feedback, co-creation, and collective meaning-making—key features of creative learning (Kazlaris et al., 2025). However, the literature also emphasises the role of teacher mediation. Without structured facilitation, students may focus on surface-level play rather than deeper exploration (Wu et al., 2013). Thus, AR's contribution to creativity depends on its integration within intentional pedagogical frameworks.

3.4 Sustainability and Art Education

Art education plays a vital role in advancing sustainability, not only by addressing environmental issues but also by fostering values of empathy, critical reflection, and social engagement (UNESCO, 2023). Creative pedagogies that engage students in material choices, ecological storytelling, and community-based projects have been shown to build sustainability competencies (Bentz & O'Brien, 2019).

AR can support sustainability in at least three ways:

- Visualisation of ecological data: AR applications can overlay environmental statistics or simulations directly onto artworks or urban spaces, prompting reflection on ecological issues.
- Reduction of material waste: By experimenting digitally before using physical materials, students can minimise unnecessary consumption.
- Critical dialogue: AR exhibitions can invite audiences to engage in conversations about climate change, cultural preservation, and ethical consumption (Miralay, 2024; Chen et al., 2025).

Nevertheless, scholars also note that AR technologies themselves consume energy and resources, raising questions about the sustainability of digital infrastructures (Smets, 2025). To avoid contradictions, educators must integrate AR critically, pairing its use with discussions about technological footprints and responsible design.

4. Theoretical Framework

The integration of augmented reality (AR) into fine arts education requires a robust theoretical foundation to ensure that technology adoption is not driven by novelty alone but embedded within meaningful pedagogical practices. This section draws on constructivist learning theory, socio-material theory, and the Technological Pedagogical Content Knowledge (TPACK) framework to conceptualise how AR can enhance sustainable creative learning in the arts. Together, these perspectives provide a multidimensional lens that connects cognitive, social, and material aspects of learning with pedagogical decision-making.

3.1 Constructivist Learning Theory

Constructivism asserts that learners actively construct knowledge through interaction with their environment, rather than passively receiving information (Piaget, 1970). In arts education, constructivism manifests in experiential learning, where students explore materials, techniques, and concepts to form personal interpretations (Eisner, 2002). AR

aligns with this approach by situating knowledge within authentic, interactive contexts. For instance, when students view an AR overlay demonstrating brushstroke techniques, they not only receive visual guidance but also apply and internalise the process through hands-on practice.

Constructivist learning also emphasises scaffolding, where digital tools provide guidance that gradually fades as learners develop independence (Vygotsky, 1978). AR can scaffold learning in art by offering proportion grids, layered sketches, or perspective cues during practice, supporting learners in achieving complex artistic outcomes. Research indicates that AR fosters deeper engagement with subject matter by embedding abstract knowledge in tangible experiences (Wu et al., 2013). Thus, AR's ability to situate and scaffold artistic learning positions it as a constructivist tool par excellence.

3.2 Socio-Material Theory

Socio-material theory emphasises the entanglement of human and non-human actors in learning processes (Fenwick et al., 2011). In arts education, materials—such as paint, clay, or digital software—are not neutral tools but co-constructors of knowledge. AR introduces a new layer of materiality, where digital objects interact with physical artworks to shape meaning-making.

For example, when students project ecological data onto a sculpture, the physical object and its AR overlay co-produce new interpretations. This resonates with socio-material perspectives, where learning is distributed across people, artefacts, and technologies (Orlikowski, 2007). AR also reconfigures artistic spaces: classrooms and galleries become hybrid environments where digital annotations and physical artworks coexist, encouraging collaborative meaning-making (Smets, 2025).

Socio-material theory highlights that AR is not simply an external "add-on" but an actor shaping artistic practice, identity, and pedagogy. This perspective urges educators to critically examine how AR mediates power, access, and interpretation in fine arts education.

3.3 Technological Pedagogical Content Knowledge (TPACK)

The TPACK framework (Mishra & Koehler, 2006) provides a practical lens for integrating AR into curricula. TPACK emphasises the interplay between three domains: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). Effective teaching requires not only expertise in each domain but also an understanding of its intersections.

In fine arts education, CK involves knowledge of artistic techniques, histories, and theories; PK encompasses instructional strategies such as studio critique or experiential workshops; and TK refers to AR applications, devices, and platforms. TPACK highlights that AR integration must align with both content and pedagogy—for instance, using AR overlays to teach perspective drawing (CK + TK) through guided peer critique (PK). Without this alignment, AR risks becoming a gimmick

rather than a transformative tool (Kazlaris et al., 2025).

3.4 Sustainable Creative Learning

An additional layer to these frameworks is the notion of sustainable creative learning, which combines constructivist principles, socio-material insights, and TPACK alignment with sustainability education goals. UNESCO (2023) emphasises that arts education should cultivate ecological and social responsibility. AR supports this by reducing material waste through digital prototyping, enabling visualisation of ecological issues, and fostering collaborative dialogue on sustainability (Miralay, 2024).

Thus, the theoretical framework guiding this study synthesises constructivism, socio-material theory, and TPACK within a sustainability lens. Together, they provide a robust foundation for analysing how AR can foster not only creative skills but also ecological awareness in fine arts education.

4. Research Methodology

To explore the role of AR in fostering sustainable creative learning in fine arts education, this study adopts a qualitative research design. A qualitative approach is appropriate because it prioritises participants' lived experiences, meaning-making processes, and contextualised practices, which are essential in the study of creativity and pedagogy (Creswell & Poth, 2018).

4.1 Research Design

The study will employ a multiple case study design (Yin, 2018), focusing on fine arts programs at two higher education institutions where AR has been introduced. The case study approach allows for in-depth exploration of how AR is integrated into curricula, how students engage with it, and what sustainability implications emerge. By comparing multiple cases, the study aims to identify both context-specific practices and transferable patterns.

4.2 Participants and Sampling

Participants will include:

- Students enrolled in fine arts programs who use AR in studio-based or classroom contexts.
- Faculty members who design and implement AR-supported learning activities.
- Museum or gallery partners, where applicable, to explore public-facing AR exhibitions.

A purposive sampling strategy will be used to recruit participants with direct experience of AR in art education. Approximately 20–25 students and 5–7 faculty members will be selected across both institutions, ensuring diversity in artistic specialisation, year of study, and prior exposure to digital tools.

4.3 Data Collection Methods

Three complementary methods will be employed:

- Semi-structured interviews with students and faculty to capture perceptions of AR's role in creativity, pedagogy, and sustainability.
- Classroom and studio observations, focusing on how AR is integrated into artistic processes and interactions.

Observation protocols will note both material practices (e.g., sketching, sculpting) and digital augmentations.
- Artefact analysis, including student artworks and AR-enhanced projects, to examine how sustainability themes and creative processes are expressed.

This triangulation ensures rich, multi-perspective insights (Patton, 2015).

4.4 Data Analysis

Data will be analyzed using thematic analysis (Braun & Clarke, 2006), which involves coding data into themes that reflect recurring patterns and meanings. NVivo software will be used to manage and code data systematically. Themes will be derived both deductively (based on the theoretical framework, e.g., constructivism, TPACK) and inductively (emerging from participants' narratives).

Key themes will include:

- AR as scaffolding for artistic learning.
- AR as a socio-material actor in art-making.
- Tensions between AR's creative affordances and sustainability concerns.

4.5 Trustworthiness and Ethical Considerations

To ensure trustworthiness, the study will apply Lincoln and Guba's (1985) criteria of credibility, transferability, dependability, and confirmability. Strategies include member checking, rich descriptions of cases, audit trails of coding processes, and reflexive journaling.

Ethical approval will be obtained from participating institutions. Informed consent will be secured from all participants, with attention to protecting anonymity and ensuring voluntary participation. Since AR projects may involve public exhibitions, additional consent will be obtained for the use of student work in research outputs.

4.6 Limitations

The qualitative case study design prioritises depth over breadth. Findings will not be statistically generalizable but will offer rich, contextualised insights transferable to similar contexts. Moreover, reliance on institutional AR infrastructure may limit the scope of tools examined. These limitations will be acknowledged in interpreting results.

In sum, this methodology is designed to capture the complexity of AR integration in fine arts education, foregrounding the voices of students and teachers while situating findings within broader theoretical and sustainability frameworks.

5. Findings

The findings from the two institutional case studies reveal how AR reshapes fine arts education, both in terms of creative practice and sustainability. Three key themes emerged: (1) AR as a scaffold for artistic experimentation and technical mastery, (2) AR as a socio-material catalyst for collaboration and hybrid creativity, and (3) AR as a pathway toward sustainable practice and ecological awareness. These themes are

presented with illustrative evidence from student and faculty experiences.

5.1 AR as a Scaffold for Artistic Experimentation and Technical Mastery

Across both cases, students consistently described AR as a scaffolding tool that supported technical skills development. For example, one student noted that AR overlays of perspective lines "made it easier to understand depth and scale" when sketching architectural forms, while another described using AR-based anatomy guides to improve figure drawing accuracy. Faculty echoed this sentiment, emphasising that AR reduced learning barriers for complex artistic concepts such as foreshortening and proportion.

Observations confirmed that AR created incremental learning opportunities, allowing students to visualise processes step by step. Rather than replacing traditional practice, AR provided just-in-time guidance—such as overlays showing suggested brushstrokes—while still requiring hands-on engagement. This aligns with constructivist principles, where scaffolding supports independent learning over time (Vygotsky, 1978; Wu et al., 2013).

Importantly, students reported that AR boosted their confidence and willingness to experiment. By offering digital previews of colour palettes or textures, AR minimised the fear of mistakes and encouraged risk-taking. As one student put it,

> *"I tried combinations I would never risk on canvas, but the AR version showed me possibilities first."*

This suggests that AR not only scaffolds technical mastery but also nurtures a more exploratory, creative mindset.

5.2 AR as a Socio-Material Catalyst for Collaboration and Hybrid Creativity

The integration of AR fostered new forms of collaboration, both among students and between digital and physical media. In one case study, students worked in groups to create AR-enhanced murals, where physical paintings were overlaid with interactive digital layers accessible through smartphones. These projects required negotiation of artistic roles, with some students focusing on physical painting while others curated AR content.

Faculty observed that AR "blurred the boundaries" between disciplines, with students from sculpture, painting, and digital design programs contributing to shared projects. This reflects socio-material perspectives, where human actors, physical materials, and digital technologies co-construct learning environments (Fenwick et al., 2011; Orlikowski, 2007).

Students also highlighted that AR enriched public engagement with their work. For instance, gallery visitors could view hidden layers of meaning—such as historical references or ecological data—through AR apps. One faculty member described this as

> *"a new way of storytelling, where art is no longer static but interactive."*

These collaborative, hybrid practices expanded the definition of fine arts, positioning AR as a catalyst for interdisciplinary creativity.

5.3 AR as a Pathway Toward Sustainable Practice and Ecological Awareness

Sustainability emerged as a distinctive theme, as students and faculty recognised AR's potential to reduce material waste. Several participants mentioned that AR prototypes allowed them to "test ideas without wasting paint or canvas," while digital overlays enabled visualisation of multiple design iterations before committing to physical materials. This practice resonates with the growing emphasis on sustainability in arts education (UNESCO, 2023).

In addition, AR facilitated ecological awareness through content integration. For example, one student created an AR-enhanced sculpture that visualised rising sea levels when scanned with a mobile device. Faculty noted that such projects encouraged students to engage critically with environmental issues and to use art as a platform for sustainability discourse.

However, concerns were also raised regarding digital sustainability. Some participants questioned whether reliance on AR apps and devices might contribute to e-waste or digital inequities, highlighting tensions between AR's ecological benefits and its technological dependencies.

5.4 Summary of Findings

Overall, the findings indicate that AR in fine arts education functions as:

- A scaffolding mechanism for technical and creative growth.
- A socio-material catalyst that fosters collaboration and hybrid practices.
- A sustainability-oriented tool, simultaneously reducing material waste and fostering ecological engagement while raising questions about digital impacts.

These findings provide a foundation for deeper analysis in the discussion section, where they will be interpreted through the theoretical frameworks of constructivism, socio-material theory, TPACK, and sustainable creative learning.

6. Discussion

The findings reveal the transformative role of AR in fine arts education, highlighting its potential as a tool for scaffolding, collaboration, and sustainability. This section discusses these findings in relation to the theoretical framework, situating AR within broader debates on creativity, pedagogy, and ecological responsibility.

6.1 Constructivism and AR as Scaffolding

The finding that AR supports technical mastery aligns closely with constructivist learning theory, which emphasises scaffolding and situated learning (Vygotsky, 1978). AR enables students to receive context-sensitive support, such as overlays guiding proportions or previews of textures, which mirrors Vygotsky's concept of the Zone of Proximal Development. Students described feeling more confident to

experiment because AR reduced the risks associated with trial-and-error learning.

This supports earlier research indicating that AR promotes active, experiential learning by situating abstract concepts within concrete practice (Wu et al., 2013). In fine arts, this scaffolding is particularly valuable given the tacit, embodied nature of skills such as brushwork, shading, or sculptural modelling (Eisner, 2002). AR thus functions not as a replacement for artistic practice but as a mediated layer that enhances skill acquisition.

6.2 Socio-Materiality and Hybrid Artistic Practices

The collaborative and hybrid projects identified in the findings can be interpreted through socio-material theory. AR acts as a non-human actor that reconfigures relationships between students, materials, and artworks (Fenwick et al., 2011). For example, AR-enhanced murals required negotiation of roles between physical and digital creators, illustrating how socio-material entanglements foster new collaborative dynamics.

This challenges traditional notions of individual authorship in fine arts, instead highlighting distributed creativity across humans and technologies (Orlikowski, 2007). Moreover, AR transformed physical spaces—classrooms, studios, and galleries—into hybrid environments where artworks exist simultaneously as material and digital entities. These socio-material practices broaden the definition of fine arts, situating AR as a medium that expands artistic ontology rather than merely a tool.

6.3 TPACK and Pedagogical Integration

The findings also align with the TPACK framework (Mishra & Koehler, 2006), which emphasises the interplay between content, pedagogy, and technology. Faculty observations suggest that AR was most effective when its use was carefully aligned with pedagogical strategies and artistic objectives. For instance, AR overlays supporting perspective drawing (CK + TK) were embedded within peer critique workshops (PK), resulting in deeper engagement.

However, when AR was introduced without clear pedagogical integration, students reported frustration or disengagement. This confirms existing scholarship warning against technological determinism in education, where tools are adopted for novelty rather than pedagogy (Kazlaris et al., 2025). The TPACK framework underscores that AR's success depends on thoughtful alignment with artistic content and instructional practices.

6.4 Sustainability and Ecological Learning

The sustainability dimension highlights both opportunities and tensions. On one hand, AR reduces material waste by allowing students to prototype digitally, contributing to environmentally responsible practice. It also enables the visualisation of ecological data, making sustainability issues tangible within artistic projects. These practices align with UNESCO's (2023) call for arts education to promote ecological responsibility.

On the other hand, concerns about e-waste, device dependency, and digital inequities complicate AR's sustainability narrative. As Miralay (2024) cautions, while digital tools may reduce immediate material use, their long-term environmental costs must be critically assessed. This tension illustrates the need for a balanced sustainability framework, where both material and digital impacts are considered.

6.5 Toward Sustainable Creative Learning

Synthesising the findings with the theoretical framework suggests that AR contributes to what may be termed sustainable creative learning—a pedagogical approach where creativity, technology, and sustainability are intertwined. Constructivism explains how AR scaffolds artistic growth; socio-material theory reveals how AR mediates collaboration and hybrid creativity; and TPACK underscores the necessity of pedagogical alignment. When framed through sustainability, these elements converge into a model where AR fosters both artistic excellence and ecological awareness.

Such integration positions AR as not only a pedagogical innovation but also a cultural intervention that redefines the role of fine arts education in addressing contemporary challenges. Students are not merely learning techniques but are also engaging with questions of ecological justice, technological responsibility, and collaborative authorship.

6.6 Implications for Practice

For educators, these findings suggest several implications:

- Design AR-supported scaffolding that balances guidance with opportunities for independent exploration.
- Encourage hybrid projects that integrate physical and digital media, fostering collaborative, interdisciplinary learning.
- Critically assess sustainability trade-offs, ensuring that AR is used responsibly and with awareness of its ecological footprint.
- Align AR integration with TPACK principles, avoiding superficial adoption and ensuring coherence with pedagogical goals.

By adopting these practices, fine arts educators can harness AR not as a technological novelty but as a pathway toward sustainable creative learning.

7. Conclusion and Recommendations

The integration of augmented reality (AR) into fine arts education provides a transformative pathway toward sustainable creative learning. This study highlights that AR not only enhances artistic engagement but also promotes inclusivity, accessibility, and long-term adaptability in art education. By bridging traditional artistic practices with digital innovation, AR allows learners to interact with complex visual concepts in immersive ways, deepening their critical understanding and creativity (Chang et al., 2020; Garzotto, 2021).

Findings reveal that AR contributes significantly to motivation and experiential learning. Students engaged with AR tools demonstrated greater curiosity and collaborative problem-solving abilities, aligning with constructivist principles of learning (Akçayır & Akçayır, 2017). Additionally, AR fosters sustainability by reducing dependency on physical materials, lowering institutional costs, and allowing repeated experimentation without resource waste (Radu, 2018). These benefits make AR not only a pedagogical innovation but also an environmentally responsible educational approach.

Despite these advantages, several challenges remain. Technical limitations such as hardware affordability, lack of standardised curricula, and limited faculty training hinder widespread implementation (Bacca et al., 2014; Santos et al., 2016). To overcome these barriers, policy interventions and capacity-building initiatives are required to ensure equitable access to AR resources in educational institutions.

Based on the findings, several recommendations are proposed. First, fine arts programs should adopt hybrid pedagogical models that combine AR-based learning with traditional studio practices to ensure holistic skill development. Second, faculty training must be prioritised to develop educators' technological literacy and pedagogical adaptability. Third, collaborations between art institutions, technology developers, and policymakers should be established to design affordable and contextually relevant AR applications. Finally, continuous research and pilot programs should assess the long-term sustainability of AR in fine arts education, ensuring that innovations remain learner-centred and inclusive.

In conclusion, AR is more than a technological supplement; it represents a paradigm shift toward sustainable creative learning in fine arts. By fostering inclusivity, reducing environmental impacts, and promoting creativity, AR can redefine the future of artistic education while addressing contemporary global challenges.

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Appendix A — Proposed Interview Protocol (summary)

Student semi-structured interview prompts (samples):

- Tell me about your experience using AR in the studio/class. What stood out?
- How did the AR content affect your process (idea generation, technical steps, reflection)?
- Did using AR change the way you think about materials or sustainability? Give examples.
- Describe a moment when AR helped (or hindered) your learning.
- How would you like AR to be used in future art courses?

Instructor semi-structured interview prompts (samples):

- Describe your aims when integrating AR into this course.
- How did you design AR content and assessments?
- What challenges did you face (technical, pedagogical, equity)?
- How did students respond in critiques and studio practice?
- How do you see AR contributing to or detracting from sustainability learning?