Review Article

From Instrument to Inquiry: A Conceptual Framework for the Future of Science- and Technology-Based Arts Education

Bolim Lee[1]

1. LBL Institute of Culture, Arts Education and Engineering, Republic of Korea

Arts education increasingly incorporates generative artificial intelligence, extended reality, sensors, and data as artistic materials. Yet debate about this shift remains dominated by the question of which technologies to introduce, rather than what technological engagement is *for*. This conceptual paper argues that science- and technology-based arts education can be analysed through four positions that technology may occupy in a learning design: as *instrument*, as *medium*, as *subject of critical inquiry*, and as *site of agency and governance*. Drawing on STEAM scholarship, critical data and AI studies, and arts-education theory, the paper proposes that programmes confined to the first two positions risk technological determinism, rapid obsolescence, and widening inequity. It advances four propositions regarding critical literacy, creative agency under generative AI, equity and local context, and educator and evaluation capacity. The paper concludes with implications for practice, policy, and empirical research. The framework is theoretical and has not been empirically tested.

Correspondence: papers@team.qeios.com — Qeios will forward to the authors

1. Introduction

Over the past two decades, arts education has absorbed technologies ranging from digital media production to creative coding, immersive environments, and, most recently, generative AI. Policy discourse has welcomed this convergence. The Seoul Agenda affirmed arts education as a platform for balanced creative, cognitive, emotional, and social development and called for it to address the social and

 doi.org/10.32388/EXIT7G

cultural challenges of the contemporary world[1]. A more recent UNESCO framework for culture and arts education seeks to update earlier international commitments in light of contemporary challenges[2].

Yet the practical conversation often narrows to equipment and skills: which tools to adopt, and how teachers can be trained to use them. This framing treats technology as a neutral addition to an unchanged pedagogy. The research literature suggests why that is insufficient. A major integrative review of STEAM education found wide variation in how the field defines itself and its "A," and noted a general lack of reported learning outcomes for creativity, problem-solving, and arts education[3]. If the arts component remains ill-defined, technology integration can default to the arts serving STEM engagement rather than arts education pursuing its own aims.

This paper asks: *what conceptual positions can technology occupy within arts education, and which configuration best serves the educational purposes of the arts?* It contributes a four-position framework and four propositions intended to guide programme design, policy, and subsequent empirical work.

2. Conceptual Background

2.1. STEAM and the problem of the "A"

STEAM was articulated as an integrative educational framework by Yakman[4] and has since spread through policy and practice. Its conceptual instability is well documented: Perignat and Katz-Buonincontro[3] identified multiple modes of integration (transdisciplinary, interdisciplinary, multidisciplinary, cross-disciplinary, and arts-integration) and varied interpretations of what the arts contribute. Technology-focused arts programmes inherit this ambiguity. Where the arts are valued mainly as a means of making STEM engaging, the distinctive educational contributions of artistic practice, such as the cultivation of judgement, imagination, and expressive form, may be underdeveloped[5][6][7].

2.2. Technology knowledge and critical literacy

Teacher-knowledge models such as TPACK describe how technological, pedagogical, and content knowledge interact[8]. Such models are valuable for professional development but are largely silent on whether the technology itself should be an object of critique. Multiliteracies scholarship, by contrast, treats meaning-making as design across modes and emphasises social futures[9]. Critical studies of educational technology and AI add that tools are embedded in infrastructures of data extraction and

labour[10][11][12]. Documented algorithmic disparities in commercial systems[13] and the social and environmental costs and encoded biases of large language models[14] illustrate why technological competence alone does not equip learners to evaluate the systems they use. Ananny and Crawford[15] further caution that simply "seeing into" a system does not amount to understanding or governing it, which is relevant to educational claims about AI transparency.

2.3. Generative AI and creativity

Experimental evidence indicates that access to generative AI ideas can raise evaluations of individual creativity, particularly among writers who score lower on creativity measures, while making outputs more similar to one another, an effect the authors describe as a social dilemma between individual gain and collective novelty[16]. The study concerns short-story writing and should not be generalised uncritically to all artistic domains. Nevertheless, it highlights a tension that arts education is well placed to address: tools that lower the threshold of production may simultaneously narrow the range of what is produced.

2.4. Constructionist and speculative traditions

Two pedagogical lineages offer resources for rethinking technology in the arts. Constructionism, from Papert[17] to Resnick's[18] account of creative learning through projects, passion, peers, and play, positions technology as a medium for making. Speculative and critical design[19] positions artefacts as provocations that interrogate possible futures. Together they suggest that technology can be both a material and a topic of aesthetic inquiry.

3. Approach

This is a conceptual analysis. It synthesises selected literature from STEAM education, critical data and AI studies, creativity research, and arts-education theory to construct a framework through argumentation rather than data collection. The literature was selected for its relevance to the framework's constructs and is illustrative, not systematic. The propositions are offered as claims to be examined, refined, or refuted by future empirical and design-based research.

4. A Four-Position Framework

Technology can occupy four positions in an arts-education design. These are analytically distinct and typically co-occur.

Position	Guiding question	Typical practice	Characteristic risk
Instrument	How do I operate this tool?	Software training, equipment-based workshops	Rapid obsolescence; skills detached from purpose
Medium	What can I express with this material?	Creative coding, generative or immersive art	Novelty displacing artistic judgement
Subject	How does this technology shape perception, culture, and power?	Critical analysis of datasets, algorithms, authorship	Abstraction without embodied engagement
Site of agency	Who decides how this technology is used, and what do I delegate?	Deliberate human–machine role design, governance discussion	Under-theorised and difficult to assess

The framework's central claim is that educational maturity lies in movement across all four positions rather than in expanding the first two.

5. Propositions

Proposition 1: Critical literacy over tool mastery. Because tools change faster than curricula, programmes that remain at the instrument and medium positions will deliver diminishing and short-lived value. Positioning technology as a subject of inquiry yields more durable learning, such as how recommendation systems shape taste, how datasets encode bias, and to whom a generated image's authorship belongs. Arts pedagogy can approach these questions through sensory and experiential routes[6], including speculative making[19], rather than through abstract instruction alone.

Proposition 2: Creative agency requires deliberate delegation. Given evidence that generative AI can raise individual outputs while homogenising collective ones[16], neither prohibition nor unrestricted use is a defensible default. Learners should practise deciding what to delegate to a system and what to retain as their own judgement, and should compare AI-assisted and unassisted processes. The arts' long

engagement with constraint, chance, and the trace of the body offers a pedagogical resource for this practice[5][7].

Proposition 3: Equity and local context shape what is educationally possible. Models that presuppose costly or proprietary infrastructure convert resource gaps into experiential gaps. Critical scholarship on educational data and automation[11][12] further suggests that dependence on commercial platforms can shift pedagogical control away from schools and communities. Designs combining low-cost, open, and portable tools with local cultural resources are more likely to widen participation and to give different societies' arts education distinct identities. This proposition is consistent with UNESCO's emphasis on diverse learning environments and social cohesion in arts education[1], though the link to technology-specific designs requires empirical testing.

Proposition 4: Educator and evaluation capacity are binding constraints. Requiring teaching artists and teachers to learn each new tool is unsustainable. Collaborative structures in which artists, engineers, educators, and learners experiment together and document their process are better aligned with the pace of technological change. Moreover, evaluation regimes that count participants or equipment use reward what is easily measured, a pattern Biesta[20] critiques as the substitution of measurability for educational value. Assessment should capture qualitative change in critical thinking and expressive range, and should attend to the ethical principles increasingly proposed for AI in society[21].

6. Implications

For practice. Programme designers can audit curricula against the four positions to identify which are absent. Activities pairing making with critique, such as building a generative system and then interrogating its training assumptions, link the medium and subject positions.

For policy. Investment criteria might shift from the acquisition of advanced equipment toward educator learning communities, open and low-cost toolkits, and evaluation frameworks that value inquiry. International arts-education policy, from the Seoul Agenda to its recent update[1][2], provides a legitimating vocabulary for such a shift.

For research. The propositions suggest several empirical agendas: design-based studies of curricula that deliberately traverse the four positions; comparative studies of AI-assisted and unassisted creative processes in non-textual art forms; and investigations of how low-resource configurations affect participation and outcomes.

7. Limitations

The framework rests on a selective, non-systematic reading of the literature and has not been empirically validated. Much of the evidence cited on generative AI and creativity concerns specific tasks and populations, and its transfer to arts education settings is uncertain. The four positions are analytic simplifications; real programmes blend them, and the boundaries between “medium” and “subject” in particular are porous. Finally, the discussion draws chiefly on Anglophone and international-policy sources, and perspectives from specific national arts-education systems merit fuller treatment.

8. Conclusion

The direction of science- and technology-based arts education will be determined less by the pace of technological advance than by the depth of the questions education asks of it. Treating technology only as an instrument or a medium prepares learners to use present tools. Treating it also as a subject of critical inquiry and a site of human agency prepares them to evaluate, resist, redirect, and reimagine the systems that increasingly mediate artistic and public life.

References

1. ^[a] ^[b] ^[c] *UNESCO (2010). "Seoul Agenda: Goals for the Development of Arts Education." UNESCO.*
2. ^[a] ^[b] *UNESCO (2024). "Framework for Culture and Arts Education." UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000376144.*
3. ^[a] ^[b] *Perignat E, Katz-Buonincontro J (2019). "STEAM in Practice and Research: An Integrative Literature Review." Think Skills Creat. **31**:31–43.*
4. ^ *Yakman G (2008). "STEAM Education: An Overview of Creating a Model of Integrative Education." Paper presented at the PATT-19 Conference, Salt Lake City, USA.*
5. ^[a] ^[b] *Dewey J (1934). Art as Experience. Minton, Balch & Company.*
6. ^[a] ^[b] *Eisner EW (2002). The Arts and the Creation of Mind. Yale University Press.*
7. ^[a] ^[b] *Greene M (1995). Releasing the Imagination: Essays on Education, the Arts, and Social Change. Jossey-Bass.*
8. ^ *Mishra P, Koehler MJ (2006). "Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge." Teach Coll Rec. **108**(6):1017–1054.*

9. ^New London Group (1996). "A Pedagogy of Multiliteracies: Designing Social Futures." Harv Educ Rev. **66** (1):60–92.
10. ^Crawford K (2021). Atlas of AI: Power, Politics, and the Planetary Costs of Artificial Intelligence. Yale University Press.
11. a, bWilliamson B (2017). Big Data in Education: The Digital Future of Learning, Policy and Practice. SAGE.
12. a, bSelwyn N (2019). Should Robots Replace Teachers? AI and the Future of Education. Polity Press.
13. ^Buolamwini J, Gebru T (2018). "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification." Proc Mach Learn Res. **81**:77–91.
14. ^Bender EM, Gebru T, McMillan-Major A, Shmitchell S (2021). "On the Dangers of Stochastic Parrots: Can Language Models Be Too Big?" In: Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency (FAccT '21). ACM. 610–623.
15. ^Ananny M, Crawford K (2018). "Seeing Without Knowing: Limitations of the Transparency Ideal and Its Application to Algorithmic Accountability." New Media Soc. **20**(3):973–989.
16. a, bDoshi AR, Hauser OP (2024). "Generative AI Enhances Individual Creativity But Reduces the Collective Diversity of Novel Content." Sci Adv. **10**(28):eadn5290. doi:10.1126/sciadv.adn5290.
17. ^Papert S (1980). Mindstorms: Children, Computers, and Powerful Ideas. Basic Books.
18. ^Resnick M (2017). Lifelong Kindergarten: Cultivating Creativity Through Projects, Passion, Peers, and Play. MIT Press.
19. a, bDunne A, Raby F (2013). Speculative Everything: Design, Fiction, and Social Dreaming. MIT Press.
20. ^Biesta GJJ (2010). Good Education in an Age of Measurement: Ethics, Politics, Democracy. Paradigm Publishers.
21. ^Floridi L, Cowls J (2019). "A Unified Framework of Five Principles for AI in Society." Harvard Data Sci Rev. **1** (1).

Declarations

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.