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Beyond Tools and Training: Building Sustainable Learning Environments that Evolve with AI

Danah Henriksen[1] · Lauren J. Woo[1] · Punya Mishra[1]

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Abstract

This article examines how educational organizations can build sustainable learning environments that evolve with artificial intelligence (AI) and generative AI (GenAI). Drawing on systems thinking, organizational learning, and educational change research, we argue that effective integration requires attention beyond tools and training to the ecological conditions that influence adoption and implementation. We explore how physical and digital learning spaces, organizational culture, professional development, and leadership practices influence whether AI amplifies or undermines learning. Using the Five Spaces for Design in Education framework, we highlight the importance of adaptability, psychological safety, and collaborative networks in navigating uncertainty and preventing deterministic narratives of technological inevitability. We find that the future of AI in education depends not on the technologies themselves but on the human choices and resilient ecosystems that guide their use.

Keywords Educational technology · Education · Systems · Generative artificial intelligence · GenAI · AI · Artificial intelligence in education · Sustainable learning · Designing environments

– *"The environment is where we all meet, where we all have a mutual interest; it is the one thing all of us share. It is not only a mirror of ourselves, but a focusing lens…" ~ Lady Bird Johnson*
– *"A system is never the sum of its parts; it's the product of their interaction." ~ Russell Ackoff*

Introduction

In this series, we have explored the transformative potential of generative artificial intelligence (GenAI) across educational dimensions. Through interviews with leading researchers (Henriksen et al., 2024; Mishra & Henriksen, 2024), analysis of practitioner experiences (Dunnigan et al., 2023; Oster et al., 2024), and historical examinations of AI's evolution (Mishra et al., 2025), we have examined GenAI tools' fundamental nature (Mishra et al., 2024), essential tensions between control and agency (Mishra et al., 2025), and how educators are using these technologies in practice. This work noted significant challenges not only with GenAI technologies themselves but with their interactions and applications within learning environments and systems.

Our stance differs somewhat from most discussions of AI in education. Many of these can take on a technological determinist framing, implying that once a new tool appears, schools are compelled to change in a singular, inevitable direction. However, we suggest that technologies acquire impact only through the cultural, organizational, and systemic contexts in which they are embedded (Cabrera et al., 2001). The distinction is key because it moves us beyond implementation strategies to examine the conditions that determine whether AI transforms learning or merely adds complexity to established practices. Rather than assuming AI will determine education's trajectory, we focus on how educators can construct environments that channel its potential productively while resisting the myth of inevitability. Our research reveals a critical challenge: How do we create learning environments that can evolve thoughtfully with AI, rather than simply adopting AI tools within existing structures?

✉ Danah Henriksen
danah.henriksen@asu.edu

Lauren J. Woo
lauren.woo@asu.edu

Punya Mishra
punya.mishra@asu.edu

[1] Arizona State University, Tempe, AZ, USA

Consider the following scenario: A middle school implements an AI tutoring system with considerable investment in training and technology. Yet, six months later, the system sits unused because teachers found it too time-consuming to integrate into existing workflows, students became frustrated with its limitations, and administrators realized they had not planned for ongoing technical support and professional development (Fullan, 2020). This pattern reveals the difference between innovation adoption and innovation implementation (Rogers, 2003). Here, even though the school technically adopted the AI technology, it failed to implement the organizational changes needed for sustainable integration.

Research consistently shows that sustainable innovation should have what Zhao and Frank (2003) term "ecological compatibility" between new technologies and existing educational systems. However, GenAI poses a unique challenge because its capabilities differ so sharply from past technologies, requiring that we aim to reimagine approaches to teaching, learning, and assessment (Mishra et al., 2023). Successful AI integration involves building learning environments capable of continuous adaptation as technologies evolve. Sustainable AI integration therefore depends on the resilience and adaptability of the learning environments we create. In this piece, we connect to systems thinking, organizational learning, and educational change, to explore how educators can create environments that harness AI's potential while preserving the human dimensions of teaching and learning. An important note: this article discusses both traditional AI and GenAI. While GenAI represents the current focus of educational attention, we sometimes use "AI" as an umbrella term when discussing principles applying to both traditional and generative systems, and "GenAI" when referring specifically to tools like ChatGPT and other large language models.

The Ecology of AI-Enhanced Learning

Understanding AI integration in education requires a kind of "systems thinking," or the ability to see complex relationships that determine how organizations function (Senge, 2006). Rather than focusing on individual tools, systems thinking considers how AI integration affects the relationships among students, teachers, content, pedagogy, and organizational structures.

This ecological perspective is important because the unique characteristics of GenAI tools fundamentally alter relationships within systems in ways that ripple through organizations unpredictably (Mishra et al., 2023). When students can collaborate with AI to generate ideas and solve problems, traditional dynamics among students, teachers, and content may shift profoundly. When teachers can use AI to personalize learning and automate feedback, their roles evolve in directions that existing frameworks may not fully accommodate. Further, such a systems perspective is crucial for countering deterministic claims that argue AI will inevitably disrupt core educational practices. While provocative, such arguments risk overstating AI's autonomy. Whether AI transforms or merely complicates learning depends less on its technical capacity than on how schools configure their systems, processes, and cultures around it. The impact of any given technology is mediated by culture and context, which reinforces the need for education systems to consciously design environments that align AI's potential with human goals and values.

Research on complex adaptive systems may indicate why some educational organizations successfully integrate new technologies while others struggle (Holling, 2001). Resilient systems share characteristics that let them maintain essential functions while adapting to changing conditions. These include redundancy and diversity in approaches to achieving learning goals, feedback loops that offer ongoing information about system health, distributed leadership that shares ownership across stakeholders, and capacity for experimentation that embraces learning from both successes and failures (Gichuhi, 2021; Kayes, 2015). In this sense, two schools can adopt the same AI system, but their outcomes may diverge radically depending on whether they have built resilient ecosystems with feedback loops, distributed leadership, and a culture of experimentation.

Educational ecosystems with these characteristics might navigate AI integration more effectively because they are already designed for adaptation rather than stability. They maintain multiple pathways to educational goals, so technical issues with an AI system do not derail learning. They also have open communication lines to access feedback about implementation effectiveness from stakeholders, using it to refine approaches continuously. They distribute decision-making about AI rather than imposing top-down mandates that may not fit local contexts.

Perhaps most importantly, resilient educational ecosystems embrace what March (1991) calls "exploration," or willingness to experiment with new approaches despite uncertain outcomes. Traditional educational cultures often prioritize certainty and minimizing risks, but AI's rapid evolution demands cultures that can navigate uncertainty while maintaining focus. This requires "psychological safety," or the belief of individuals within a system that they can take risks without negative consequences (Edmondson, 1999).

One further challenge lies in what some scholars call "cognitive offloading." By making it easier and faster to generate ideas, or even complete cognitively complex tasks, AI can strip away the friction that is often essential for deep learning. Just as societies developed gyms and physical education to compensate for technology reducing physical labor, schools of the future may need to deliberately design opportunities for mental struggle, persistence, and productive difficulty. Building in such "cognitive workouts" can be some insurance against AI "deskilling" learners, instead building their capacity for critical thinking and resilience. Learning environments that evolve with AI demand building "adaptive capacity," or the ability to respond thoughtfully to changing circumstances without losing core purpose (Uhl-Bien & Arena, 2018). This comes from a clear educational vision focused on learning goals, learning-oriented culture that sees challenges as opportunities, collaborative problem-solving drawing on diverse perspectives, and reflective practices that examine outcomes through systematic inquiry.

Designing Spaces for Human-AI Collaboration

The design of learning spaces has long been recognized as crucial for educational effectiveness, with research demonstrating clear relationships between physical environments and student engagement, teacher practice, and learning outcomes (Barrett et al., 2015). As schools integrate AI tools, they will need to reconsider how both physical and digital spaces can support new forms of human-AI collaboration while preserving human connections.

AI-enhanced learning emphasizes collaboration, iteration, and personalized exploration, suggesting different spatial configurations. For example, in a composition classroom, AI writing assistants may allow for collaborative approaches where students share AI-generated ideas, critique different outputs, and build upon each other's human-AI collaborations. These activities work better in spaces that allow easy regrouping, shared displays for examining outputs, and comfortable areas for discussing writing processes and decisions. Research shows that flexible environments supporting multiple configurations lead to more varied and engaging pedagogical approaches (Imms & Byers, 2017). For AI integration, this flexibility becomes even more important because educators are still discovering how to blend human and artificial intelligence in learning activities.

While physical spaces matter considerably, digital environments where students interact with AI tools may be even more crucial for sustainable integration. Digital learning environments encompass not just AI tools themselves but the broader technological ecosystem: learning management systems, communication platforms, digital portfolios, assessment tools, and interfaces connecting them all. Effective digital environments for AI integration prioritize coherence and ease of use over impressive features that may create cognitive overhead and overwhelm educational benefits (Davis, 1989). The most sustainable digital environments integrate capabilities into existing workflows, reducing learning curves while making AI feel like natural extensions of existing practices (Zhao & Frank, 2003). However, these streamlined environments must also address the risk that AI poses by reducing the "necessary friction" for learning through cognitive offloading. Sustainable digital learning spaces may therefore require strategic moments where certain tools are withheld to ensure genuine engagement with content, allowing AI to augment rather than replace critical thinking and deep learning.

Digital environments must also support transparency and reflection. Students need easy ways to document human-AI collaboration processes, share experiences with AI tools, and reflect on how these tools affect their learning. Teachers need visibility into how students use AI tools for different learning goals. Similarly, evaluating the outputs and outcomes of students' AI usage becomes challenging in the context of assessments. When it comes to traditional assessment approaches, AI tools tend to create "assessment disruption" or conditions that demand fundamental rethinking rather than minor adjustments (Newton, 2007). For instance, if students can use AI to generate essays, how should educators evaluate their work? What constitutes academic integrity when human-AI collaboration is encouraged in some contexts but not others?

Sustainable assessment in AI environments shifts focus from evaluating products to understanding processes, aligning with contemporary assessment theory emphasizing formative rather than summative evaluation (Black & Wiliam, 1998). Rather than asking whether a student's essay demonstrates mastery, educators might examine how effectively students used AI suggestions to revise ideas, how thoughtfully they evaluated suggestions, or how well they integrated AI content with their own original knowledge. This process-focused approach requires new forms of documentation, making learning visible. Students might maintain portfolios, and teachers might use rubrics evaluating evidence of productive human-AI collaboration.

We extend beyond physical and digital environments to draw on the Five Spaces for Design in Education framework (Warr et al., 2020). This framework identifies five interrelated design spaces—artifacts, processes, experiences, systems, and cultures—each shaping how technologies are enacted. Importantly, it assumes that artifacts (like AI tutors or writing assistants) rarely determine outcomes on their own; their effects are mediated through processes (teaching routines, assessment practices), experiences (student engagement, teacher interactions), systems (institutional structures, policies), and cultures (shared beliefs and values). From a Five Spaces perspective, AI tools are one artifact. Their impact depends on whether educators reconfigure assessment processes, design collaborative experiences, adapt departmental systems of support, and cultivate cultures of iterative experimentation rather than product-only evaluation.

Organizational Culture and the Innovation Imperative

The success of AI integration depends on organizational factors behind the scenes, including practices, patterns, norms, systems, and culture shaping how educators approach change and innovation—all factors that often determine whether promising innovations flourish or fade (Fullan, 2020). Determinist narratives, however, obscure this reality by implying that disruption is a property of the technology itself. The real challenge is cultural: schools that valorize certainty and compliance will suppress the experimentation AI requires, or choose solutions that narrow pedagogical opportunities, while those that foster psychological safety and risk-taking will harness its generative possibilities.

This dimension becomes critical for AI integration because these technologies challenge traditional assumptions about teaching, learning, and assessment, where coordinated responses are more important than individual adaptations. Traditional educational cultures often reflect broader societal expectations that schools provide stable, predictable experiences (Cuban, 2013). Teachers are expected to implement proven practices, administrators seek innovations with guaranteed returns, and assessment systems reward consistent performance. These tendencies, while understandable given education's high stakes nature, can create cultures resisting the experimentation necessary for effective AI integration.

AI technologies evolve so rapidly that evidence-based practices may become outdated before their effectiveness is definitively established. Applications may reveal unexpected limitations when implemented at scale. Additionally, students' comfort with AI tools may develop faster than teachers' ability to guide their use. Shifting social or technological realities require organizational cultures that embrace exploration, or specifically, a willingness to experiment despite uncertain outcomes (March, 1991).

Schools with cultures of experimentation share several characteristics that research identifies as crucial for sustainable innovation (Senge, 2006). They normalize learning from failure and celebrate educators who take thoughtful risks and share both successes and challenges openly, creating psychological safety. They provide resources for iteration, recognizing that innovation requires cycles of implementation and refinement.

Edmonson (1999) noted that cultures of experimentation develop through deliberate leadership practices and structural support. Leaders can model experimental mindsets by sharing their own learning processes and uncertainties about AI integration, allocating resources for professional learning, going beyond initial training to include ongoing reflection and collaboration. They can also create communication systems that support sharing both positive and negative experiences around what works and what does not.

Traditional professional development often follows a workshop model, where teachers attend sessions on new practices, receive initial training, and are expected to implement independently (Joyce & Showers, 2002). However, this can become outdated given the rapid pace of change in this technology, keeping educators feeling perpetually behind rather than confident and capable.

Effective professional development for AI integration focuses on building general capacities rather than specific technical skills, emphasizing adaptability over predetermined competencies (Darling-Hammond et al., 2017). Sustainable programs have the potential to help educational stakeholders develop flexible mindsets that are grounded in contextually sensitive frameworks for evaluating AI applications, AI-enhanced learning experiences, and human-AI collaboration. This capacity-building approach requires developing ongoing professional learning communities (DuFour et al., 2008), giving teachers access to both technical and pedagogical expertise and helping them identify the possibilities of AI in their educational context. This could mean establishing AI learning cohorts who meet regularly, providing a safe space for exploration, support, feedback, and reflection. By bringing together diverse perspectives and experiences, teachers can identify both opportunities and challenges that might not be apparent to educators working in isolation. Professional development must also address ethical questions that AI integration raises. For example, what constitutes appropriate collaboration between students and AI systems? How can educators help students develop critical literacy for evaluating AI outputs? These questions require ongoing dialogue and collective reflection among educators sharing responsibility for student learning.

AI integration demands that leadership articulate a clear vision while keeping implementation flexible, consistent with research on educational leadership in times of change (Leithwood et al., 2020). Leaders also need to help organizations understand why AI integration matters for student learning, how it aligns with institutional values, and what success looks like. They must balance enthusiasm for AI's potential with realistic assessments, avoiding both uncritical techno-enthusiasm and paralyzing risk aversion. Leaders need to communicate confidently about AI's educational value while acknowledging uncertainties and modeling the thoughtful experimentation they expect organization-wide. This requires what Heifetz and Linsky (2002) describe as "adaptive leadership," or the ability to help organizations navigate new learning rather than applying existing solutions. While effective leaders do not need to be AI experts, they do need strong pedagogical knowledge to evaluate whether AI uses enhance learning or merely add complexity (Robinson et al., 2008).

Because no single school or district can navigate AI integration alone, sustainable AI integration requires collaborative networks facilitating shared learning and mutual support among educators, researchers, technology developers, and community partners (Lieberman & Grolnick, 1996). These networks take many forms and reflect diverse contexts and needs. Some districts form regional consortiums to conduct pilot programs, and others partner with universities to conduct AI research. Many participate in national networks facilitating practice sharing and collaborative problem-solving. Effective networks balance local autonomy with collective learning, recognizing that AI integration must be tailored to specific contexts while creating opportunities to learn from diverse experiences (McLaughlin & Talbert, 2001).

Implementation as Ongoing Adaptation

The language we use to discuss technology implementation often implies a linear process: schools assess needs, select tools, train teachers, and implement solutions. This linear model misrepresents the reality of meaningful educational change, which research describes as iterative, context-dependent, and requiring ongoing adaptation (Fullan, 2020). Rather than viewing AI integration as a one-time project, schools should embrace ongoing organizational learning and adaptation. This perspective shift has profound implications for planning, resourcing, and evaluating AI initiatives, moving from fixed timelines and predetermined outcomes toward flexible frameworks that evolve with changing technologies. Sustainable change requires adaptation across the Five Spaces: embedding AI artifacts into coherent processes, crafting meaningful learning experiences, aligning artifacts and experiences with supportive systems, and evolving cultures that treat uncertainty as a resource. The 'dual-lens' perspective proposed in recent research (Mishra et al., 2024) highlights the need for educators to work with both short-term lens (supporting teacher knowledge, developing immediate practices, managing risks of bias and misinformation) and a long-term lens (anticipating broader sociocultural impacts, reframing curriculum, and asking systemic questions). AI is therefore not a one-time adoption but an ecological shift requiring constant adaptation.

One of the common mistakes in technology implementation involves trying to transform everything at once, overestimating change speed and scope (Cuban, 2001). Schools buy comprehensive platforms, train all teachers at once, and expect immediate transformation across subjects and grade levels. Historically, this has overwhelmed both technological infrastructure and human capacity, leading to superficial implementation and eventual abandonment.

Sustainable AI integration more likely needs to start from carefully chosen pilot programs, allowing for deep exploration and iterative refinement. Rogers' (2003) work on diffusion of innovations notes that successful adoption of any technology in a broader social context often follows a "staged process" where early adopters experiment before broader implementation occurs. Effective pilots include built-in reflection and documentation processes that capture both successes and challenges systematically rather than relying on informal observations that may overlook important patterns. The transition from pilot to broader implementation requires careful attention to the "pioneer gap," or the difference between what works for enthusiastic early adopters and typical practitioners (Leonard-Barton, 1988). Strategies that worked for early adopters may need thoughtful modification if they are to work for educators with different comfort levels, teaching styles, or contextual constraints.

Contexts vary dramatically in available resources, from technology access to technical support capacity and professional development budgets. Sustainable AI integration strategies must acknowledge these variations rather than assuming universal access to optimal conditions (Darling-Hammond, 2010). Schools with limited resources may need implementation strategies that maximize educational impact while minimizing technological complexity and recurring costs. This might mean focusing on cost, prioritizing the integration of AI applications with existing systems, or developing partnerships to share costs and expertise among multiple schools. Research suggests that limitations can actually encourage more thoughtful implementation when educators must focus on specific applications that clearly serve educational priorities (Warschauer & Matuchniak, 2010).

Integration strategies must adapt to different levels and subjects, each with distinct pedagogical traditions shaping how AI tools can be used effectively. Elementary implementations might emphasize AI supporting storytelling and basic skill development while preserving the hands-on experiences young learners need, maintaining focus on creativity and curiosity. Secondary education can leverage AI to enhance critical thinking and research capabilities while building AI literacy for higher education. Subject-specific applications vary significantly: mathematics might use AI tools for visualizing complex problems and multiple solutions, while language arts may focus on writing development and textual analysis.

For instance, Arizona State University's Writing Programs have developed approaches that illustrate these subject-specific considerations (Woo et al., 2023). In foundational English courses, students use multiple AI tools (e.g., Wordtune and ChatGPT) to refine their work through iterative processes throughout the semester. They critically reflect on the implications of using these tools in writing processes, with many reporting that AI sometimes provided better options for expressing ideas, while other times AI suggestions showed them that their original writing was actually better. For any educational approach, the goal is to maintain focus on human decision-making and creativity while building AI literacy skills.

Most importantly, effective implementation requires sustainable change management supporting ongoing adaptation and improvement, rather than approaching AI integration as a one-time initiative with fixed endpoints. Change management in educational organizations must balance urgent technological evolution with the deliberate pace necessary for meaningful pedagogical transformation (Fullan, 2020). Sustainable change processes include regular assessment of implementation from multiple perspectives, recognizing that teachers, administrators, students, and their families all experience AI integration differently. Comprehensive evaluation requires data from diverse stakeholders collected through varied methods to provide holistic descriptions of implementation progress and challenges.

Communication systems must keep all stakeholders informed about progress, challenges, and adaptations while building transparency, trust, and community engagement. Professional learning must continue throughout implementation, recognizing that meaningful change occurs over time through sustained practice and reflection (Joyce & Showers, 2002). Most importantly, sustainable implementation maintains focus on educational goals rather than technological capabilities, avoiding "technological solutionism" that treats technology as an end in itself (Cuban, 2001).

Conclusion: Building Learning Environments That Evolve

Our exploration of sustainable AI integration reveals a core insight: the environments we create for learning matter as much as the tools we provide. This directly challenges deterministic narratives that AI, simply by being, will inevitably revolutionize education. What matters is whether schools design for adaptability across artifacts, processes, experiences, systems, and cultures. AI's future in education is not predetermined. Rather, it will be co-constructed through human choices, organizational priorities, and cultural commitments.

The middle school scenario noted in the introduction illustrates the difference between technology adoption and meaningful integration, between adding new tools to existing practices and creating learning environments capable of evolving with technological change. Schools succeeding in long-term AI integration will recognize this distinction and invest in building adaptive capacity rather than simply purchasing platforms or providing training programs.

Sustainable AI integration requires attention to multiple interconnected dimensions. Physical and digital learning spaces must support human-AI collaboration while preserving social connections. Organizational cultures must embrace experimentation while maintaining focus on educational goals. Professional learning systems must build educators' adaptive capacity to engage creatively with rapidly transforming technologies.

Most importantly, successful AI integration is fundamentally about building learning organizations in the fullest sense (Senge, 2006). Such organizations approach AI integration as ongoing collective inquiry rather than a uniform solution. This requires sustained investment in organizational development, professional learning, and collaborative networks, with leadership that balances technological enthusiasm and pedagogical wisdom. Educational organizations developing genuine adaptive capacity will be better positioned to evolve thoughtfully as technologies advance, creating environments that prepare students not just to use AI tools effectively but to think critically about their role in an AI-saturated world.

Leaders and policymakers could use the Five Spaces framework as a diagnostic tool, examining whether they have artifacts that fit their context, processes that align, experiences that foster agency, systems that support human-centered scaling, and cultures that tolerate experimentation. This diagnostic approach becomes concrete when leaders ask critical questions: Who benefits and who is left behind? What biases are embedded? How does AI reshape ecosystems it enters? How can we reclaim agency? These questions (Postman, as applied in Mishra et al., 2024) are a centering element that educators might use to approach AI critically and contextually rather than fatalistically.

The story of AI in education is still being written—in fact, it is just beginning. By focusing on building environments that can evolve with AI, we may be best situated to harness its transformative potential while preserving the human connections and educational purposes that make learning meaningful.

Data Availability Not applicable.

Declarations

Competing interest The authors declare that they have no competing interests.

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