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Emerging Technologies as Sociotechnical-Immersive Systems: A Framework and Research Agenda for K-12 Online Learning

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K-12 digital learning is increasingly shaped by emerging technologies layered onto existing digital infrastructures. In practice, the technologies that dominate attention, especially generative and assistive AI, arrive bundled with new assessment tensions, data flows, acquisition constraints, and inequities in access and support. This article proposes a practitioner-oriented framework for understanding emerging technologies as sociotechnical-immersive systems rather than standalone tools. The framework connects the following three lenses: (1) a macro sociotechnical circle that foregrounds policy, markets, equity, and governance; (2) a meso environment-design circle that analyzes how learning experiences are configured through system, narrative, and agency; and (3) a micro educational-approaches circle that focuses on the instructional activities educators enact within those environments, using the Immersive Learning Brain as a map of practice and strategies. We developed this framework through practitioner sensemaking grounded in practitioner focus group data and aligned it with recent research syntheses on emerging technologies. We illustrate the framework through one worked example and two comparative mini-cases. We conclude with an agenda for researchers and practitioners focused on assessment, equitable infrastructure and support, data stewardship, and environment-design descriptions that move beyond technocentric labels.

Keywords: sociotechnical-immersive systems, artificial intelligence, augmented reality, virtual reality, Immersive learning design

INTRODUCTION

K-12 digital learning has always been technology-mediated, but the nature of that mediation is changing. Learning management systems, one-to-one devices, digital curriculum platforms, and virtual programs created a baseline digital infrastructure over the last two decades. Today, that infrastructure is increasingly overlaid by tools and services that are labeled "emerging," especially generative and assistive artificial intelligence (AI), but also augmented/virtual reality (AR/VR) and a growing range of analytics-driven dashboards and recommendation systems. These layers do not simply add new features. They change how instruction is planned, how student work is produced and evaluated, how data moves, and which actors (e.g., students, teachers, vendors, policymakers) have control.

This shift matters because it is uneven. Students and educators do not encounter these technologies on equal terms. Differences in connectivity, device quality, staffing, policy environments, and local capacity shape what can actually be adopted and sustained. Duran (2022) described how long-standing inequities in infrastructure and funding continue to influence the quality and feasibility of technology-rich instruction, especially for students who already face barriers to opportunity. In K-12 digital learning, where access to devices, bandwidth, and support are not optional extras, these gaps become immediate constraints on participation.

At the same time, K-12 online learning is now caught in a rapidly shifting assessment and accountability environment. AI tools that can generate text, solve problems, and provide tutoring are already being used by educators and students, often outside formal policy frameworks. Practitioners describe both practical benefits and deep unease: enthusiasm about support and efficiency coexists with concerns about authenticity, cheating, surveillance, workload, and inequitable consequences.

This article responds to that situation with a framework designed to be usable by practitioners and accessible to researchers. This article intentionally alternates between analytic explanation and designoriented guidance. We signal these shifts explicitly to support both practitioner use and research interpretation. Rather than asking whether a technology works in general, we ask: How do emerging technologies become part of K-12 digital learning systems, and how does their use reshape learning experiences and instructional practice? We propose a three-part conceptual framework (see Figure 1) that:

1. treats emerging technologies as sociotechnical phenomena shaped by policy, markets, equity, and institutional histories (Veletsianos, 2016);
2. analyzes technology-mediated experiences through system, narrative, and agency as dimensions of immersive learning environment design (Beck et al., 2020; Morgado et al., 2025); and

3. focuses on what educators actually do inside these environments by bringing into focus the instructional design, using the immersive learning brain (ILB) clusters of practices and strategies (Beck et al., 2024).

Figure 1. Emerging Technologies as Sociotechnical-Immersive Systems.

We then apply the framework to three kinds of technologies that dominate current discourse in K-12 digital learning: AI, AR/VR, and learning analytics/dashboards. We close with a short agenda of priorities for research and practice over the next decade.

THE FRAMEWORK: EMERGING TECHNOLOGIES AS SOCIOTECHNICAL-IMMERSIVE SYSTEMS

This framework was developed based on a synthesis of three theoretical texts: Veletsianos's (2016) emerging technologies framework, the Immersive Learning Cube (Beck et al, 2020; Morgado et al, 2025), and the ILB (Beck et al, 2024). We then validated our framework utilizing survey responses and online and in-person focus groups hosted by the Digital Learning Collaborative at its annual 2025 conference (DLAC). The conference is regularly attended by K-12 digital learning educators, leaders, and partners.

Detailed methods and thematic coding are reported elsewhere (Barbour et al., 2025a; 2025b). For this article, the DLAC inputs helped surface what practitioners currently treat as consequential when they talk about emerging technologies.

In the DLAC inputs, the "emerging technologies" label was dominated by AI. Roughly 95% of coded comments under that theme referred to AI, while AR/VR and analytics appeared only occasionally. This pattern matters for writing and for interpretation: when K-12 digital learning practitioners said "emerging technologies," they often meant AI.

The framework in Figure 1 is composed of three sections, or circles of a spiral. The point is not to create three separate conversations, but to connect areas that are too often treated in isolation. Circle 1 addresses policy, markets, governance, and equity. Circle 2 provides a usable lens for analyzing how technology is configured into learning environments through system, narrative, and agency. Circle 3 focuses on what educators and students actually do within those environments, the practices and strategies through which learning is orchestrated.

Circle 1: Sociotechnical System (Macro Level)

Emerging technologies are not simply new tools that appear and then get adopted because they are available. Following Veletsianos (2016), we treat them as sociotechnical phenomena: their roles in education emerge from interactions among technologies, institutional histories, cultural expectations, policy decisions, and economic interests. Technological tools mirror how important stakeholders (e.g., institutions, vendors, policymakers, etc.) discuss what innovation really is, and how it should be defined.

Why This Matters in K-12 Digital Learning

Programs sit at the intersection of education policy, procurement, accountability systems, vendor ecosystems, and family expectations. What appears as a local "adoption choice" is often the downstream product of upstream constraints: broadband availability, device procurement, data agreements, state reporting requirements, and staffing capacity. Duran (2022) placed these issues in a longer arc of learning technology adoption, highlighting persistent digital divides and uneven preparation of teachers and leaders. In K-12 digital learning settings, the consequences of those divides are direct: connectivity and device interruptions can become instructional interruptions.

Practical Questions Circle 1 Forces Us to Ask

Circle 1 prompts questions that are often skipped when the conversation is only about features or outcomes:

1. Who benefits, and who bears the costs? Benefits include learning gains, teacher workload reduction, changing learning objectives, or political narratives of innovation. Costs include financial outlays, surveillance risks, inequitable impacts, and staff time required to implement responsibly.
2. What gets standardized? Adoption can standardize data flows, assessment routines, and vendor lock-in.
3. What counts as "success"? Accountability systems can make certain outcomes legible (e.g., test scores, completion, student trajectory), while obscuring others (e.g., critical thinking, personal development, belonging, safety).
4. What equity conditions are assumed? Tools often assume stable broad4.\band, devices, accessible interfaces, and local technical support for students and teachers across all schools. Unfortunately, these assumptions are often unevenly met.

How Circle 1 Shapes Research

If emerging technologies are sociotechnical, then randomized controlled trials for evaluating the effectiveness of interventions and establishing causal relationships alone cannot answer the most important questions, because they focus on outcomes and analytics. We need research that follows technologies through policy regimes, procurement, institutional practice, and lived experiences, often requiring mixed methods and longitudinal designs, which helps us to understand life experiences and context.

Circle 2: Immersive Environment Design (Meso Level)

Circle 2 challenges us to consider how learning experiences are configured. Our environment design approach leverages immersion. It leads us to describe a learning experience using three conceptual dimensions of immersion: system, narrative, and agency. With them, we describe what participants are surrounded by, what meanings are conveyed, and what participants can do to create meaning. This is not about so-called "immersive technologies": a learning experience can be more or less immersive according to different dimensions regardless of whether it uses VR headsets or a simple discussion forum. The point is that emerging technologies often reconfigure these dimensions in subtle ways.

System

The system dimension concerns what surrounds participants and what is available to them: physical places like classrooms and online places (e.g., discussion boards, web pages, apps, virtual worlds, etc.).

K-12 Digital Learning Examples. An AI assistant available inside the learning management system (i.e., embedded in assignments) surrounds students differently than an AI tool accessed in a separate browser tab. A dashboard that is always visible to teachers during grading creates different surroundings than a dashboard only accessed when requested. When considering AR/VR, think of whether they encompass the full visual field and sensory experience of participants or whether they are restricted to a monitor's screen or a QR code.

Design Prompt. Where, exactly, will the technology be present in the student's and teacher's day-to-day environment, and what access (e.g., data, tools, interactions) and perspective (e.g., visual field, etc.) does it bring with it?

Narrative

The narrative dimension concerns providing meaning through the experience. How context is framed, what cues signal importance, what is implied as normal or desirable, and what stories are told about learning, performance, and identity.

K-12 Digital Learning Examples. An AI tutor that portrays confidence in its stance conveys different meaning than one that presents suggestions. A dashboard that ranks students or flags them with icons as at-risk can embed deficit framing, even if the data are accurate. A VR simulation can convey meaning through spatial cues that shape how students interpret events (e.g., being positioned as observer vs. participant). A storyline about a business trying to survive in the big city is infused with its own context, interpretive meaning, and values.

Design Prompt. What meanings does the system communicate—explicitly or implicitly—about what matters, who is successful, and what counts as appropriate participation? What story is being told?

Agency

Agency concerns participants' capacity to bring personalized meaning to the experience. They can do so by interacting, or by being passive: the point is whether their action/inaction is meant to mean something or not. Agency can also extend into tactical and strategic aspects, not just immediate, operational decisions. Examples include choices, the ability to override or question situations, and the range of freedom to explore or contribute.

K-12 Digital Learning Examples. Consider how your participants can create meaning: when using an AI chatbot, can they engage in discussion (as in, say, ChatGPT) or only get a one-shot response to a prompt (as in search engines' responses)? Additionally, can students choose or create their AI chatbots or do they have to select from a limited list? When using AR, can they scan a room freely, or place tags anywhere (e.g., QR codes, cards, etc.)? Or are there restrictions? Can students create their own tags? In VR or AR activities, can students manipulate objects, pose questions, and collaborate, or are they limited to predetermined paths? On a learning analytics dashboard, can teachers override a flag, annotate it with contextual information, or challenge its assumptions? All of these determine the agency dimension of your immersive experience.

Design Prompt. What meaningful choices do students and educators have, and how easily can they contest, override, or reshape what they are experiencing?

Circle 3: Educational Activities (Micro Level)

Circle 3 focuses on the instructional activities inside technology-mediated environments. The same system configuration can lead to very different learning experiences depending on what practices and strategies teachers employ and prioritize. Circle 3 utilizes the ILB framework (Beck et al, 2024).

Why This Matters for Practitioners

Practitioner conversations about emerging technologies often jump from tool capabilities to outcomes (e.g., "Does it improve learning?"; "Does it work?"). The driving consideration should be the pedagogical rationale of the learning designer: one must be aware that a singular use of immersion (e.g., to promote engagement, to switch perspectives) will not by itself, dictate a learning outcome or dynamic. You need to consider your overall stance on learning, to articulate those uses into practices and strategies.

Applying the ILB in K-12 digital learning, the ILB synthesizes work from immersive learning literature by explicitly distinguishing educational practice (i.e., tactical level) from educational strategy (i.e., strategic level) and organizing practices and strategies into six clusters: (1) engagement and scaffolding; (2) active context; (3) real and virtual multimedia learning; (4) presence; (5) collaboration; and (6) traditional practices (Beck et al., 2024). In this article, we use the ILB as a shared vocabulary for describing what educators do and why, not as a new mandate or a checklist.

These clusters are connected to each other (see Figure 5 in Beck et al., 2024). Their nature as "clusters" is because their practices and strategies have more connections in common than others do. What being in a cluster

means is the expectation of more readily being able to combine or leverage other practices and strategies within a cluster, and more innovation or reflection to be necessary, when combining practices and strategies across clusters.

K-12 Digital Learning Examples

If you are already considering using a practice or a strategy in your learning design, it is relatively straightforward to combine it with others in the same cluster. Consider the "Active Context" cluster (see Figure 7 in Beck et al., 2024). One of its practices is "Exploration and experimentation of contexts/processes." However, another practice in that cluster is "Authentic practice and assessment," and a strategy there is "Contextual theories." All three are easily implemented alongside each other. This could be a way to reflect on pathways to change your learning design without major transformations.

But if you are looking after something more involved, more transformational, you could look instead at practices and strategies from other clusters. For instance, looking at the Engagement and Scaffolding cluster, you can find practices such as "Providing automated feedback and/or tutoring" or "Customization theories." Or you could venture into the Collaboration cluster and consider practices such as "Foster collaboration and social activities" and strategies such as "Collaborative learning." Combining these with your original "Exploration and experimentation of contexts/processes" would definitely be more transformational.

Design Prompt

Which ILB practices and strategies from which cluster(s) are you intentionally drawing on for your learning objectives?

The Framework as a Spiral

The framework should be read as a spiral rather than a set of concentric circles, so consider each circle as a level or section within a spiral. Sociotechnical forces shape what technologies are available and how they are governed (i.e., Circle 1). Those forces shape how environments are configured (i.e., Circle 2). Environment configurations enable or constrain instructional activities (i.e., Circle 3). The outcomes and experiences that result, positive, harmful, or ambiguous, then feed back into policy narratives, procurement, and institutional norms (i.e., Circle 1). This loop is how emerging technologies become "normal" or get resisted, redesigned, or rejected.

The value of this framework is not in having three separate circles, but in how they work on each other. Sociotechnical decisions (i.e., Circle 1) show up further down the spiral as design constraints and affordances in the environment design (i.e., Circle 2). Many different sociotechnical aspects (e.g.,

policy priorities, procurement practices, platform business models, cultural narratives about innovation) narrow the range of technology districts can choose from, influencing its availability and use. The result of this is the creation of the encompassing system. Those same aspects strongly influence the narratives they inherit, create, and develop (e.g., AI marketed as a solution to teacher shortages, or analytics framed as accountability tools all influence those aspects). Those same forces affect agency: whether teachers can adapt tools, whether students can opt out, and whether schools are locked into particular data flows and vendor ecosystems.

At the same time, the environment design (i.e., Circle 2) and the educational approaches (i.e., Circle 3) are coupled. How we configure system, narrative, and agency shapes what happens, not how that supports learning processes or outcomes. If during environment design we look at identical positions within the Immersive Learning Cube, those can be deployed within very distinct pedagogical strategies and practices, across different ILB clusters. For example, consider a system that places the student within a factory floor with supporting activities built around fixed narrative sequences and student agency framed by high-stakes monitoring. This system may pull from practices and strategies of the Traditional Practices cluster, or from more formal versions of the Engagement & Scaffolding cluster (e.g., automated feedback). But the same situation could be framed by the Active Context cluster, within an Authentic Learning strategy, or by the Presence cluster, within a practice of "Experiencing a physiological/psychological state." The educational approaches circle then becomes the mechanism that connects design to lived experience, using the ILB. It translates an abstract configuration of system, narrative, and agency into real life pedagogical routines and rationales: the how and why of giving feedback, organizing collaboration, handling authenticity and assessment, and whether presence and socio-emotional learning are foregrounded or sidelined.

The resulting practice and strategy patterns, in turn, generate the data, stories, and outcomes that travel back upstream. Positive results, novelty effects, or political pressure can reinforce certain sociotechnical arrangements. For example, more investment in analytics dashboards or specific AI vendors may reinforce these arrangements, while documented harms or resistance may prompt policy shifts, redesign, or rejection.

As a result, our integrated model is best read as a spiral. Sociotechnical forces shape environment design, and environment design is shaped by educational approaches, based on which ILB practice and strategy clusters are enacted. Those practices and strategies shape student outcomes and experiences, which then feed back into policy, markets, and narratives about what emerging technologies can and should do in K-12 digital learning.

Design prompt: (i.e., Circle 3) Which ILB cluster(s) are you deliberately drawing on for a given learning goal, and how does the environment configuration (i.e., Circle 2) enable or constrain those practices and strategies under local sociotechnical conditions (i.e., Circle 1)?

Applying the Framework

This section applies the framework to three clusters of technologies that dominate current conversations in K-12 digital learning: AI, AR/VR, and analytics/dashboards. Because practitioner discourse overwhelmingly centers on AI, we provide one worked example for AI and then offer two comparative mini-cases for AR/VR and analytics.

Worked Example: Artificial Intelligence in K-12 Digital Learning

AI is the dominant referent when practitioners talk about "emerging technologies." In DLAC Phase Two inputs, nearly all "emerging technology" comments were AI-related. This dominance shapes both policy and practice: when districts say they want to "leverage emerging technologies," AI is often the default.

Circle 1 (AI): Sociotechnical Conditions

AI adoption is not neutral. It is shaped by procurement, platform integration, policy frameworks, and cultural narratives about personalization and efficiency. In many districts, AI is framed as a solution to teacher workload and staffing shortages. Yet this framing can conceal important consequences:

- Assessment and authenticity pressures. Generative AI challenges traditional assumptions about authorship, independent work, and evidence of learning. Practitioner concerns often concentrate on cheating and grading burden, but the deeper issue is that assessment tasks and rubrics may no longer measure what they were designed to measure.
- Data governance and vendor ecosystems. AI systems often require or generate new data flows: prompts, student writing, metadata, usage traces, and analytics outputs. Decisions about where AI runs (i.e., vendor cloud vs district-controlled tools), who owns the data, and how models are updated are sociotechnical governance questions.
- Equity and differential consequences. AI can widen gaps if some students have constant access to high-quality tools and support while others do not. It can also create new forms of exclusion if accessibility and language needs are not addressed.

Circle 1 prompts districts and researchers to ask: Who drives AI adoption? What assumptions about teaching and learning are embedded in that choice? Who benefits, who is burdened, and what forms of control or surveillance are normalized?

Circle 2 (AI): System-Narrative-Agency in Environment Design

AI affects learning environments not only through what it can generate, but through how it is situated in the system, how it frames meaning, and what agency it allows.

System (AI). In K-12 digital learning settings, the system questions are concrete: Is AI embedded in the learning management system, integrated into writing tools, or accessed externally? What data does AI have access to (e.g., student profiles, prior work, discussion posts, grades)? Is AI available on district devices only, or also on personal devices? These decisions shape whether AI becomes an occasional assistant or a pervasive presence.

Narrative (AI). AI systems communicate meaning through tone, confidence, and implied authority. In online learning, where students already rely on mediated cues, AI can become a powerful narrator: Does the AI present answers as final, or does it model uncertainty and invite critique? Does it cite sources and encourage verification? Does it reinforce deficit framing (e.g., "You are behind") or support growth-oriented feedback?

Agency (AI). Agency is where many controversies live: Can students opt out of AI assistance without penalty? Can teachers see when and how AI was used without turning assessment into surveillance? Can educators contest AI recommendations, annotate them with context, and override them?

From a design perspective, the goal is not to maximize AI use but to configure agency so that students can still demonstrate understanding, teachers can exercise professional judgment, and institutions can avoid defaulting into punitive monitoring.

Circle 3 (AI): Instructional Activities and Practice Clusters

Circle 3 shifts the conversation from "AI features" to "what instructional work is being done." Two practice clusters are especially central for AI in K-12 digital learning.

1. **Feedback & scaffolding.** AI can support drafting, tutoring, and formative feedback. But it can also produce over-scaffolded work that hides misunderstanding. The instructional question becomes: What do we want students to do with feedback? In well-designed use, AI feedback is treated as a first pass that students must interpret, critique, and revise—keeping the teacher's role in evaluation and support central.

2. **Authentic activity & assessment.** If AI can generate plausible essays and explanations, authentic assessment cannot rely solely on "produce a finished product." Instead, it may need to emphasize the following: pro-

cess evidence (e.g., drafts, revisions, reflections), critique and comparison (e.g., evaluating multiple AI-generated arguments), oral or interactive demonstrations (e.g., explaining choices in conferencing), and tasks that require local context, personal experience, or situated data.

This is not a call to abandon writing or problem solving, but to redesign what counts as evidence of learning when AI is present.

A Worked K-12 Online Example (Brief Vignette). Consider an online middle school course where students write weekly discussion posts. If AI is ubiquitous, a "write a post summarizing the reading" prompt becomes fragile. A Circle 3 redesign might instead ask students to: 1) post a claim, 2) generate two alternative arguments (including via AI), 3) critique each argument using course criteria, and 4) revise their claim with a justification that references the text.

Circle 2 then guides environment design: the system must make it easy to document revisions and sources; the narrative must frame AI as a draft generator rather than an authority; agency must allow students to choose when to use AI and to disclose or reflect on its use without punishment.

What this Predicts (Short Propositions). AI-related conflicts will concentrate around agency and narrative (e.g., authorship, authority, contestability) more than around raw capability. Equity impacts will be driven less by whether AI exists and more by how it is governed, integrated, and supported. Research that treats "AI use" as a single variable will miss the design decisions that actually shape learning and fairness.

Comparative Mini-Case: AR/VR and Immersive Technologies

AR/VR often attracts high interest but low feasibility in K-12 digital learning contexts. Practitioner comments consistently link AR/VR adoption to infrastructure and capacity constraints: stable broadband, hardware availability, staffing, and time. Systematic reviews similarly highlight high development costs, device requirements, limited teacher training, and accessibility barriers in low-resource contexts (Garg et al., 2025), aligning with broader accounts of persistent infrastructure disparities (Duran, 2022).

What Circle 1 Clarifies

AR/VR is rarely a teacher-level choice. It is an institutional and policy-level outcome: procurement decisions, funding streams, and infrastructure readiness determine whether AR/VR is "on the table" or remains aspirational.

Where Circle 2 Helps

Even when full VR is infeasible, Circle 2 supports realistic design alternatives.

- **System:** Lightweight AR overlays (e.g., QR-based resources, phone-based visualizations) may create meaningful "surroundings" without headsets.
- **Narrative:** Strong narrative framing can compensate for low system immersion (e.g., role-based inquiry, scenario-based prompts).
- **Agency:** Even simple tools can provide high agency if students can explore, annotate, and create rather than only consume.

Where Circle 3 Helps

AR/VR value depends on instructional activities. For example, AR used as a novelty visual aid may not change learning, while AR used to support authentic inquiry or collaborative fieldwork routines may. Practitioners can use the four practice families to articulate intent before selecting technology.

Comparative Mini-Case: Learning Analytics and Dashboards

Learning analytics and dashboards are often presented as neutral supports for monitoring and intervention, but in practice they are entangled with accountability systems and institutional narratives about performance. Practitioners value dashboards for early-warning and visibility, yet they also describe misalignment between state-level reporting tools and the questions programs actually need answered. They express concerns about over-surveillance and deficit framing, and many note that dashboards become "just another chart" without training and interpretive support.

What Circle 1 Clarifies

Dashboards express choices about what counts as success and what is worth measuring. In K-12 digital learning programs, those choices are shaped by state reporting requirements, funding models, vendor ecosystems, and political narratives about accountability.

Where Circle 2 Helps

- **System.** What data is actually being captured, from which platforms, and with what granularity? Are analytics experienced as ambient (i.e., always present through notifications, flags, or embedded panels) or episodic (i.e., pulled only when a teacher asks)? Do dashboards sit inside the learning management system, in a district data warehouse tool, or in vendor portals with separate logins? These placement and integration decisions determine whether educators feel surrounded by analytics and how feasible it is to connect indicators to instructional action.

- **Narrative.** Risk flags, rankings, and color-coded warnings embed interpretations that can stigmatize students or normalize deficit framing, even when the underlying data is accurate. The dashboard does not just display information; it tells a story about what matters and who is "at risk."
- **Agency.** Who can question the dashboard, change views, annotate context, override recommendations, or refuse certain data collection? If only administrators can configure dashboards, teacher agency is reduced to compliance; if teachers and students can interrogate and contest indicators, dashboards can support professional judgment.

Where Circle 3 Helps

Analytics should be tied to ILB practices and strategies, not only reporting. For instance, dashboards can support Engagement and Scaffolding when they help educators target timely, meaningful intervention. They can undermine Active Context and authentic learning when they incentivize superficial compliance behaviors or narrow "success" to what is easiest to count. The key is to connect analytics indicators to instructional questions teachers actually ask, in ways that preserve agency and avoid narrative harms.

IMPLICATIONS AND AGENDA: WHAT TO FOCUS ON NEXT

The framework's central proposal is simple: emerging technologies in K-12 digital learning are best understood as part of a variety of ecosystems shaped by sociotechnical forces. They are aligned with immersion through experience design, and implemented in instructional activities. An encompassing priority in this area would be to reframe K-12 digital learning adoption of a technology from a single event to a process over time. Below are five sub-priorities, written for both practitioners and researchers, stemming from this priority.

Priority One: Redesign Authentic Assessment for an AI-Present World

The growing presence of AI in society means that students and instructors now work with artificial, co-intelligent partners. These partners can be peers, tutors, assistants, consultants, or others. If learning is to remain authentic, students need to be able to use this ecosystem of intelligences. They must engage in dialogue, raise questions, steer the interaction, and judge outputs critically. Students need to be able to set and revise their own goals, and to develop a personal standard of quality. That includes passion, critical ambition, and a sense of what they are aiming to achieve. This makes many traditional assessments fragile. They were designed for contexts in which learners worked mostly alone and assistance was occasional, not continuous.

What Practitioners Can Do Now

Assessment needs to be viewed as a partnership between the students, the teacher, and the AI partners. Back-and-forth interactions provide an avenue for the human partners (e.g., teacher and students) to critically consider AI's contributions. This helps avoid deficit framing and hallucinations but more critically to support differentiation of instruction and offload routine work. The result will be a shift towards assessment of the entire process of learning, including critique, comparison, collaboration, and contextual reasoning.

What Researchers Should Study Next

Identify which assessment workflows are feasible and reliable in K-12 digital learning. Determine how the immersion dimensions relate to these assessment workflows, how present and encompassing are the AIs, and how various narrative framings lead to student interpretations that cultivate self-regulation and self-efficacy. Also, what agency configurations "fit" within each kind of assessment workflow and maximize student learning.

Priority Two: Treat Equitable Infrastructure and Support as the Minimum Requirements, Not as a Remediation

Many emerging technology proposals assume devices, bandwidth, accessibility, and staffing that are unevenly available.

What Practitioners Can Do Now

Audit the assumptions of use for any emerging technology adoption: connectivity, device quality, accessibility supports, staff time, privacy, and family capacity and ensure minimum requirements of equitable infrastructure and support are always met. Alternatively, provide a range of alternatives designed to ensure minimum requirements are met.

What Researchers Should Study Next

Build models of feasibility and sustainability that incorporate infrastructure, staffing, and local capacity as concerns, especially for under-resourced communities.

Priority Three: Make Data Stewardship and Governance Explicit Across AI, AR/VR, and Analytics

Emerging technologies often expand the destinations of information in unfamiliar ways and normalize surveillance. In K-12 digital learning, these expansions can become invisible defaults which may disclose personal data and communications in ways that users are unaware of.

What Practitioners Can Do Now

Establish clear boundaries: what data is collected, who can access it, how long it persists, and what opt-outs exist, paired with communication to administrators, families and students.

What Researchers Should Study Next

Study governance models that move beyond terms-of-service consent toward participatory rule-making with students, families, and educators.

Priority Four: Develop Usable Ways to Design Learning Environments Beyond "We Used AI/VR"

Researchers and practitioners often describe interventions at the technology level, making it hard to understand what actually was done in a specific classroom using specific pedagogical activities.

What Practitioners Can Do Now

Use the Immersive Learning Case sheet as a shared vocabulary to describe how a technology is employed pedagogically (Beck & Morgado, 2024). This will leverage the Immersive Learning Cube (i.e., System-Narrative-Agency) and the ILB (i.e., Strategies and Practices).

What Researchers Should Study Next

Create and validate practical instruments or rubrics that reliably describe environment configurations (i.e., System-Narrative-Agency) and pedagogical activities (i.e., Strategies and Practices) across raters and contexts.

Priority Five: Treat Teacher Learning and Appropriation as a Multi-Year Process

Sustained change depends on educators' capacity to adapt practices, not on one-time tool adoption. Emergency remote teaching increased some competencies, but sustained support remains uneven (Chalkiadakis & Noguera, 2024).

What Practitioners Can Do Now

Invest in ongoing communities of practice and onboarding routines that treat emerging technology integration as iterative and contextual.

What Researchers Should Study Next

Identify which forms of professional learning support durable, equitable practice transformations in K-12 digital learning, and how adoption differs across technologies and contexts.

CONCLUSION

Emerging technologies in K-12 digital learning are not just a new set of tools. They are system-level additions that change workflows, assessment practices, meanings of success, and who has control. The spiral, sociotechnical-immersive framework offered here is designed to help practitioners and researchers see those connections without getting trapped in either technology hype or technology policing. Used as a shared language, this framework can support crossrole conversations among teachers, administrators, researchers, and policymakers, that are otherwise fragmented by toolspecific debates.

By foregrounding sociotechnical conditions (i.e., Circle 1), immersive environment design through system/narrative/agency (i.e., Circle 2), and instructional activities (i.e., Circle 3), the framework highlights that the same technology can produce very different effects across districts and why "technology as intervention" is often the wrong unit of analysis. The priorities outlined here point to a near-term agenda that is both pragmatic and researchable: redesign assessment for emerging technologies, treat infrastructure and support as minimum requirements, make data governance explicit, describe environments in ways that travel across contexts, and invest in long-term teacher appropriation.

In a field where new technologies will continue to arrive faster than our studies can keep up, the goal is not to predict the next tool. It is to keep the focus on how technologies become part of learning systems, and how K-12 digital learning can shape those systems toward equitable and instructionally sound practice.

AUTHOR NOTE

Figure 1 was generated using an AI-based image generation tool (Imagen by ChatGPT) based on prompts provided by the authors. An AI language model (ChatGPT) was used to assist with language editing and restructuring in response to editorial suggestions. All content was reviewed, edited, and approved by the authors, who take full responsibility for the manuscript.

References

Almufarreh, A., & Arshad, M. (2023). Promising emerging technologies for teaching and learning: Recent developments and future challenges. *Sustainability, 15*(8), 6917. https://doi.org/10.3390/su15086917

Barbour, M. K., Borup, J., DeBruler, K., Azukas, M. E., Beck, D., Hodges, C., Rice, M., Rose, R., Short, C. & Siko, J. (2025a). *Bridging the gap between research and practice: A DLAC research agenda phase one*. The Community Advancing Digital Learning. https://www.deelac.com/insight/a-dlac-research-agenda-phase-one/

Barbour, M. K., Borup, J., DeBruler, K., Azukas, M. E., Beck, D., Hodges, C., Rice, M., Rose, R., Short, C., Siko, J., Adelstein, D., Archambault , L., Cuccolo, K., Deschaine, M., Elmendorf, D., Garrett Dikkers, A., Pratt, K., Wilson, E. V. , & Woo, L. (2025b). B*ridging the gap between research and practice: A DLAC research agenda. DLAC – The Community Advancing Digital Learning.* https://www.deelac.com/insight/a-dlac-research-agenda-final/

Beck, D., & Morgado, L. (2025). *Describing and interpreting an immersive learning case with the immersion cube and the immersive learning brain.* In J. M. Krüger et al. (Eds.), Immersive Learning Research Network: iLRN 2024 (Communications in Computer and Information Science, Vol. 2271). Springer. https://doi.org/10.1007/978-3-031-80475-5_8

Beck, D., Morgado, L., & O'Shea, P. (2020). Finding the gaps about uses of immersive learning environments: A survey of surveys. *Journal of Universal Computer Science, 26*(8), 1043-1073. https://doi.org/10.3897/jucs.2020.055

Beck, D., Morgado, L., & O'Shea, P. (2024). Educational practices and strategies with immersive learning environments: Mapping of reviews for using the metaverse. *IEEE Transactions on Learning Technologies, 17*(1), 319-341. https://e-iji.net/ats/index.php/pub/article/view/513

Chalkiadakis, L., & Noguera, I. (2024). K-12 Teacher's appropriation of digital technologies and innovative instruction across EU: A scoping review. *International Journal of Instruction, 17*(1), 415-436. https://e-iji.net/ats/index.php/pub/article/view/513

Chng, E., Tan, A. L., & Tan, S. C. (2023). Examining the use of emerging technologies in schools: A review of artificial intelligence and immersive technologies in STEM education. *Journal for STEM Education Research, 6*(3), 385-407. https://doi.org/10.1007/s41979-023-00092-y

Duran, M. (2022). *Learning technologies.* Springer.

Garg, N., Kaur, A., Ahmad, F., & Dutta, R. (2025). Augmenting education: The transformative power of AR, AI, and emerging technologies. *Human Behavior and Emerging Technologies, 1*. https://doi.org/10.1155/hbe2/5681184

Morgado, L., Beck, D., & O'Shea, P. (2025). Bridging the gaps: an updated mapping of the uses of immersive learning environments. *Virtual Reality, 29*(3), 1-26. https://doi.org/10.1007/s10055-025-01208-y

Veletsianos, G. (2016). *Emergence and innovation in digital learning: Foundations and applications.* Athabasca University Press. https://www.aupress.ca/books/120258-emergence-and-innovation-in-digital-learning/