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A School Must Be Reachable: Digital Infrastructure, Accessible Opportunity, and the Designership Service Obligation

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Evidence-informed policy analysis and prospective comparative implementation protocol

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Abstract

Digital and spatial schools are often evaluated through platform availability, visual sophistication, or participation counts. These measures do not establish that learners can enter consequential intellectual work, obtain human support, demonstrate understanding, and continue after disruption. This evidence-informed policy analysis develops an original infrastructure-to-opportunity chain connecting availability, usable entry, supported participation, intellectual work, credible demonstration, and continuity. It proposes a minimum viable learning service and meaningful exit protections, treating offline alternatives, accessibility, household burden, and public-publication choice as design responsibilities. A prospective six-district, twenty-four-school protocol evaluates a supported Designership inquiry package above a common essential-service floor through a district-stratified matched-pair randomized delayed-start design. Its confirmatory hierarchy distinguishes blinded science-transfer performance, participation, and access success; its economic component reports district and household cost-consequences. Randomization, aligned assessment timing, interference, missingness, subgroup uncertainty, and ethical protections are specified, with an assumption-dependent matched-comparison fallback chosen before outcome inspection. No new intervention data or effectiveness results are reported. The contribution is a falsifiable service framework for governing educational infrastructure by the opportunities it sustains rather than the technologies it displays.

Keywords: Designership, K-12 digital infrastructure, educational equity, accessibility, learning service, matched-pair cluster protocol, cost-consequence analysis, offline learning

1. From a digital campus to an educational service

The consequential question for a digital school is not whether its environment resembles an impressive campus. It is whether a learner can enter a worthwhile task, obtain appropriate support, demonstrate understanding, and continue learning when a device, connection, platform, or personal circumstance fails. A spatial interface may enable an otherwise inaccessible investigation; an ordinary telephone may provide the more effective route to another objective. Designership, as developed here, makes the organization accountable for this relationship between educational purpose and the conditions of participation. Its object is a dependable learning service rather than a predetermined technological form.

The distinction matters for K-12 systems considering virtual campuses, remote research mentorship, and publication of student work. A functioning website is an institution-facing accomplishment. An accessible opportunity to learn is a student-facing accomplishment. These can diverge: a technically available class may depend on uninterrupted broadband, an adult at home, expensive headphones, rapid keyboard entry, or a willingness to display a bedroom. None of these conditions should disappear from an equity assessment merely because they sit outside the school's procurement contract. The infrastructure boundary must follow the learning task into the circumstances in which it is undertaken.

This article develops an original policy framework and a prospective comparative evaluation protocol. It reports no implementation trial, recruited participants, new outcome data, or demonstrated intervention effect. Its evidence base is a purposive selection of official datasets, technical standards, and primary studies, checked against publisher or institutional records; it is not a systematic review. “Educational service obligation” denotes the stewardship standard proposed here, not a new interpretation of statutory duties. Existing legal requirements require separate, jurisdiction-specific review. The contribution is an inspectable infrastructure-to-opportunity chain, a minimum service floor, and an evaluation that can reject attractive but ineffective designs.

2. What the evidence permits-and what it does not

UNESCO's 2023 Global Education Monitoring Report asks whether educational technology serves educational purposes under appropriate conditions, rather than assuming that deployment demonstrates benefit [R1]. U.S. household-access statistics similarly distinguish computer access from access only through a smartphone [R2]. A district should therefore avoid a binary “connected” indicator that erases the difference between reading a message and manipulating a dataset. These sources motivate attention to access conditions; they do not estimate the effect of the service package proposed in this article.

Primary experiments caution against treating hardware as an instructional intervention. Fairlie and Robinson's randomized provision of home computers increased ownership and use without improving the educational outcomes assessed in their California study [R3]. Cristia and colleagues' Peruvian school trial likewise found greater computer access and use without evidence of improved mathematics or language scores over its reported follow-up [R4]. These results do not establish that computers never help. They establish that removing one input constraint need not repair the instructional pathway between access and learning.

Other experiments show why the pathway requires specification. Muralidharan, Singh, and Ganimian evaluated a particular personalized after-school instructional program in urban India and found learning gains [R5]. Angrist, Bergman, and Matsheng found benefits from a combined telephone-and-SMS intervention supporting children through parents during school closure in Botswana [R6]. Neither is evidence that a U.S. virtual school, an immersive campus, or an automated research agent will reproduce those effects. Together, the studies justify comparing complete instructional arrangements, including human support and task design, instead of ranking technologies by apparent sophistication.

Immersion also deserves a testable claim. Makransky, Terkildsen, and Mayer's science-laboratory experiment found greater reported presence alongside poorer learning in its immersive condition [R7]. Its setting and learners limit generalization to K-12 classrooms. The relevant inference is methodological: presence, satisfaction, and visual realism cannot substitute for learning measures. A spatial environment should identify the representation, interaction, or collaboration that requires three dimensions, state the expected benefit, and retain an accessible alternative capable of supporting the educational objective.

3. The infrastructure-to-opportunity chain

The proposed chain contains six distinct links: availability, usable entry, supported participation, consequential intellectual work, credible demonstration, and continuity. Availability asks whether the necessary resources exist at the relevant place and time. Usable entry asks whether the learner can actually authenticate, perceive instructions, navigate, and begin. Supported participation asks whether feedback and assistance arrive before a difficulty becomes exclusion. Intellectual work asks whether the task requires explanation, investigation, design, or justified revision. Demonstration asks whether the resulting evidence supports an interpretation of learning. Continuity asks whether that opportunity survives an interruption or institutional transition.

This is a diagnostic causal hypothesis, not a validated scale. A district might provide devices while authentication remains inaccessible; improve login success while assignments remain intellectually thin; or support excellent work while students lose

all evidence when a subscription ends. Each failure occurs at a different link and calls for a different response. The chain prevents a single utilization dashboard from collapsing these mechanisms into “engagement.” It also locates Movement Thinking's concern with consequential questions and preserved revision within the practical conditions that allow students to act on them.

The chain predicts that infrastructure investments will have heterogeneous educational value because the binding constraint differs across learners and tasks. Adding bandwidth may matter greatly for a student using a shared telephone and little for one whose difficulty is receiving comprehensible feedback. Conversely, a strong mentor cannot remedy an inaccessible assessment interface by encouragement alone. The policy implication is to identify barriers before prescribing solutions, then test whether removing the identified barrier changes participation and learning. The proposal does not require every link to be digital or to be supplied by one vendor.

4. A minimum viable learning service and meaningful exit

The minimum viable learning service is a proposed floor beneath innovation. Before making a digital or spatial task compulsory, a school should document an appropriate device or equivalent route; a workable connection or offline delivery arrangement; accessible task instructions and assessment; a named human contact; a feasible feedback schedule; and a continuity plan. “Equivalent” concerns access to the learning objective and fair assessment, not identical screen experiences. The floor is deliberately broader than software uptime. A system that operates continuously but cannot supply a usable task to a particular learner has not delivered the promised service.

Every core task should have a route map stating what can be downloaded, completed without continuous connectivity, submitted later, or undertaken with school-provided support. Offline work must include a return channel for feedback; a packet left at home is not a complete service. Alternative routes should carry comparable intellectual expectations and timely teacher attention. Requiring a family to negotiate an exception repeatedly turns access into a test of advocacy. Schools should make ordinary routes discoverable in advance, while preserving individualized accommodations and avoiding disclosure of a student's disability to peers.

Meaningful exit includes changing interface, declining optional immersion, leaving the research component, or transferring institutions without forfeiting earned credit or access to one's permitted work. Procurement should specify exportable learner artifacts, readable feedback, version history where appropriate, and a documented transition procedure. These are proposed contractual protections, not claims that all current systems already provide them. Exports must respect other students' privacy and source licenses. Public publication must remain separate from course completion:

a student should be able to demonstrate scholarship privately without accepting searchable, persistent exposure as the price of an education.

5. Accessibility is a task property as well as an interface property

WCAG 2.2 provides testable web-accessibility criteria and explicitly acknowledges that conformance does not address every user need [R8]. It should inform procurement, authoring, and testing, but an automated scan cannot certify that a lesson is usable. A prospective service audit should follow complete tasks, including authentication, finding instructions, handling an error, uploading work, receiving feedback, and exporting an artifact. Human evaluation with relevant assistive technologies is indispensable. Findings should identify the task, configuration, severity, remedy, and retest date rather than produce an unqualified accessibility badge.

For immersive environments, the W3C XR Accessibility User Requirements document identifies issues such as multimodal interaction, motion-agnostic controls, orientation, and alternatives to spatial audio [R9]. It is a Working Group Note, explicitly not a baseline conformance standard or an endorsement of every proposal. Its role here is to structure questions for design and user testing. A headset experience should have an immediate exit, a non-headset route, and a way to communicate discomfort privately. Accessibility should be evaluated before assignment, not discovered when an individual student fails to participate.

CAST's Universal Design for Learning Guidelines 3.0 offer design considerations concerning engagement, representation, and action and expression [R15]. They support planning for learner variability; citing them does not validate a particular curriculum. The proposed protocol therefore separates three questions: whether the interface meets specified criteria, whether learners can complete the task through their chosen route, and whether they learn. Schools should preserve the distinction even when a single purchasing decision addresses all three. A beautiful interface can satisfy neither task accessibility nor the intended educational purpose.

6. Human support, open resources, and institutional accountability

The service floor requires staffing commitments. A named teacher remains responsible for interpreting learning evidence; a support contact helps resolve access failures; and an administrator owns unresolved barriers. Response schedules should distinguish urgent exclusion from ordinary instructional questions and should fit paid working time. An automated assistant may locate a source passage or help formulate a question, but it must provide a clear route to a person when an answer affects assessment, safeguarding, accommodation, or participation. Availability of an assistant does not demonstrate availability of accountable educational support.

Open educational resources can improve adaptability and reduce some licensing constraints. UNESCO's 2019 Recommendation defines their openness through permissions attached to public-domain or openly licensed materials [R10]. A repository's public visibility does not establish permission to translate, adapt, redistribute, or build a paper agent around every item. The proposed service maintains a rights register at resource and version level, preserves original authorship, and distinguishes a new student analysis from a republication. Course publication should add accountable interpretation and inspectable evidence rather than manufacture originality through cosmetic rewriting.

The 2024 U.S. National Educational Technology Plan distinguishes access, design, and use divides [R16]. This framework is compatible with the proposed chain, while the chain adds explicit demonstration and continuity tests. A school board's public service statement should identify the learning purposes, support responsibilities, available alternatives, evidence reviewed, and unresolved barriers. It should not report adoption totals as educational success. Institutional accountability becomes more credible when families can see how an access problem is resolved and how an ineffective investment can be changed or discontinued.

7. Full lifecycle costs and the distribution of burden

The appropriate economic unit is a supported opportunity to learn over a specified period, not the advertised price of a license. Costs include devices, replacement cycles, repair, connectivity, storage, cybersecurity, accessibility work, content preparation, onboarding, help-desk labor, teacher planning, mentorship, assessment, and transition. Spatial provision adds cleaning, fitting, supervision, room preparation, and alternatives for learners who cannot use headsets. Reusing equipment can reduce procurement costs while increasing maintenance. The analysis should therefore state the service configuration and expected useful life instead of assuming a universal price per pupil.

A district perspective alone can conceal transfers to households. Families may supply data plans, electricity, transport to reliable access, translation, supervision, quiet space, and unpaid troubleshooting. Teachers may absorb unrecorded preparation or support time. The proposed economic evaluation reports district expenditure and a wider school-and-household perspective separately. Time is recorded in natural units before assigning any monetary value; alternative valuations are shown because an hour of family time should not become less important merely because household earnings are low. Costs borne by excluded learners must remain visible.

The primary presentation is cost-consequence: incremental resources alongside learning, participation, accessibility, burden, and adverse-event outcomes. It does not compress dignity or access into a speculative financial return. CHEERS 2022 informs transparent reporting of perspective, time horizon, quantities, valuation, assumptions, and uncertainty, while originating in health economics rather than validating this educational design [R14]. Capital costs should be annualized under explicit useful-life assumptions. Scenarios should vary device life, staffing intensity, enrollment, replacement prices, and real discount rates of 0%, 3%, and 5%, with local policy rates also reported.

8. Prospective study: distinguish the service floor from the enhancement

The proposed study recruits six districts and four secondary schools per district, subject to feasibility, agreements, and an independent ethics determination before any recruitment. Grades 8-9 science provide a bounded curricular context. These are planning targets, not an achieved sample. Before baseline, all participating schools remedy urgent access and accessibility failures and adopt the minimum service floor. Essential support is never randomized away. The randomized contrast estimates the additional effect of a supported Designership learning package above this common floor; it cannot estimate the effect of establishing the floor itself.

The enhancement comprises one twelve-week inquiry module, protected teacher co-design time, a named research mentor, accessible low-bandwidth materials, and structured feedback on successive student explanations. Spatial activities are optional representations within the module, with non-headset equivalents; the trial does not isolate a headset effect. Within each district, its four schools form two matched pairs using baseline attainment, enrollment, access constraints, and available support. An independent statistician randomizes one school per pair to immediate enhancement and the other to delayed start. All twelve pairs run concurrently over the same school term; allocation follows baseline enrollment and assessment.

The control schools retain their ordinary curriculum and the common service floor during the comparison term. Both groups complete the same baseline and end-of-term transfer assessments in aligned calendar weeks. Immediate-start schools deliver the

module once before the primary endpoint. Delayed schools may begin it only after that endpoint. A later follow-up may describe durability and implementation in both groups, but cannot preserve the original untreated contrast. This matched-pair parallel design avoids the repeated exposure and time-since-crossover ambiguities of a multi-term rollout. Stepped-wedge designs can be useful, but require explicit treatment of time and correlation [R12].

Schools may share teachers, curriculum, or support, creating interference across assigned groups. Cross-school staffing and material sharing will be mapped before assignment and recorded during the study. Necessary assistance is never restricted to protect a contrast. If district-wide delivery makes school-level separation implausible, the study must instead recruit enough districts for a district-cluster comparison or remain a feasibility study. Its design must change before registration. An impressive pupil count cannot substitute for independent assignment units, and contamination cannot be solved by silently reclassifying schools according to observed compliance.

9. Outcomes, recruitment, and precision

The confirmatory hierarchy begins with learning: blinded scoring of a common science-transfer task at the end of a twelve-week module, adjusted for a parallel baseline task. The rubric assesses use of evidence, explanation of a mechanism, consideration of an alternative, and justified revision. Pilot work outside the analytic sample will examine task accessibility, curricular fit, inter-rater agreement, and score behavior across routes; the rubric and scoring rules are then frozen. Familiarity with a particular interface must not become the construct being assessed. Scorers receive de-identified artifacts and remain unaware of allocation and school.

The second confirmatory outcome is participation: the proportion of the baseline research cohort completing at least four of five common curricular milestones offered in both arms with the same learning goals, timing, and minimum evidence requirements. The milestone denominator is frozen before allocation; unrelated platform events and additional enhancement activities do not enlarge it. The third is access success: the proportion of that cohort completing the same standardized entry-to-feedback task, under each assigned service arrangement, through the learner's preferred supported route without an unresolved blocking barrier. These thresholds are proposed operational choices, not validated natural cutoffs. Accessibility also remains an ethical monitoring constraint irrespective of statistical testing. Screen time, logins, presence, and satisfaction are descriptive rather than learning proxies. Family burden, teacher workload, and discomfort are prespecified secondary outcomes.

Eligibility includes pupils on prespecified target-class rosters. Invitations, permission, assent, and baseline measurement precede allocation, creating a closed consenting baseline cohort for the primary analysis. Approximately sixty eligible learners per

school is an operational planning figure, not a power calculation or enrollment claim. Research participation requires guardian permission and age-appropriate assent, unless an independent ethics body approves a legally permissible alternative. Nonparticipants retain ordinary learning, assessment alternatives, and support. The same cohort is invited to both research assessments; transfers and withdrawals are documented without replacing missing pupils with new entrants. New entrants may join instruction and a separately described implementation cohort, but not the primary analytic cohort.

Simulation-based precision and power analysis will precede recruitment. It will vary school intraclass correlation, matched-pair similarity, baseline-outcome correlation, unequal school sizes, nonresponse, and contamination using independently justified ranges. Twelve matched pairs permit a finite randomization distribution, but cannot guarantee detection of a small educational effect. The protocol will publish its minimum detectable effect and assumptions. If feasible recruitment yields inadequate precision, the study will be described as a pilot and its uncertainty retained. Recruitment totals and participant flow will be distinguished from the number of genuinely independent clusters.

10. Analysis, missingness, and competing explanations

The primary estimand is the intention-to-treat effect of immediate enhancement assignment on end-of-term learning in the baseline cohort. A prespecified baseline-adjusted model includes matched-pair effects and school-level correlation; pair-respecting randomization inference accompanies model-based confidence intervals. The primary contrast gives equal weight to matched pairs, estimating the average pair-level contrast across participating school settings. A prespecified pupil-weighted analysis addresses the different policy question of average benefit across enrolled learners. With only twelve pairs, uncertainty remains material. Allocation, analysis rules, and treatment of unequal school size are fixed before outcome access.

Only the common comparison term supplies the confirmatory treatment contrast. Baseline and endpoint tasks use parallel forms, counterbalanced within schools and equally across assigned groups; no pupil repeats the same items. Timing is aligned across immediate and delayed schools. Implementation measures record actual mentor contact, teacher planning time, route use, and delivery delays; these describe the assigned package rather than replace assignment in the primary analysis. Exploratory compliance-adjusted or mediation analyses require additional assumptions. Attention and added adult time are components, so this trial cannot isolate a technology effect or validate an entire philosophy.

If randomization proves infeasible, a distinct matched-adoption study requires a revised timeline and separate prospective registration. It would collect at least three

comparable pre-adoption measurement periods before using group-time estimates with not-yet-treated schools and conditional parallel trends, informed by Callaway and Sant'Anna [R13]. Matching cannot remove unobserved leadership motivation. Overlap, anticipation, prior trends, concurrent reforms, and enrollment changes require examination; a nonsignificant pretrend does not prove identification. This fallback cannot be chosen after examining treatment outcomes or presented as equivalent to random assignment. Its claims remain explicitly assumption-dependent.

Missing assessments require explanation by route, school, baseline attainment, and reported barrier. An inaccessible assessment is an access failure and missing learning evidence, not proof of low ability. The analysis will report missingness, use prespecified multiple-imputation models when defensible, and show pattern-mixture and worst-plausible-case bounds. Confirmatory tests follow the stated hierarchy with multiplicity control specified at registration; estimates and intervals are reported regardless of significance. Sensitivity analyses will examine contamination and outcome availability without concealing the original intention-to-treat result. An intervention that drives pupils out of observable assessment cannot claim success only among those remaining.

11. Equity, privacy, and a publication boundary for minors

Prespecified heterogeneity examines baseline access constraints, disability-related support needs, socioeconomic disadvantage, language support, and rurality where samples permit safe interpretation. These are not interchangeable categories or biological explanations for performance. Analysis should estimate differences in effects with uncertainty and report small-cell suppression. An average gain does not establish equity if some learners face higher barriers or family costs. Small subgroups may be too imprecisely estimated to establish safety; qualitative access audits and individual remedies remain necessary. The absence of a statistically significant interaction is not evidence that all groups benefit equally.

The data plan uses the least information needed for the stated questions. Student identifiers remain in a separate district-controlled linkage file; research extracts exclude bedroom video, raw voice recordings, gaze traces, biometric inference, and unrelated behavioral telemetry. The U.S. Department of Education's guidance on online educational services provides an authoritative starting point for evaluating privacy arrangements, not a universal legal clearance [R11]. Applicable law, contractual controls, retention, access roles, breach procedures, and cross-border transfers require current local review before collection. Human support and ordinary grades cannot depend on research consent.

Public scholarship needs a separate boundary. A school may assess a student's argument, source use, and revision privately; public release requires a distinct, understandable choice with an age-appropriate process and an explanation of

persistence and searchability. ORCID participation, a public profile, or publication must not be a prerequisite for the compulsory learning activity. An article agent should retrieve only approved public material, identify its source passages, and avoid drawing on private learning records. Copyright, student authorship, safeguarding, and scientific review remain human responsibilities even when assistance makes dissemination easier.

12. Decision rules, limitations, and the contribution to Designership

A decision panel including students, family representatives, teachers, accessibility specialists, and district leaders will set affordability and educational-relevance thresholds before seeing results. Scaling requires an interpretable learning estimate, acceptable participation, no unresolved serious access barrier attributable to the design, and a credible funded support plan. A positive learning average cannot override a known preventable exclusion. A package may warrant revision if participation rises without learning, if gains depend on unsustainable unpaid labor, or if a simpler route delivers comparable outcomes with lower burden. A null estimate should prompt examination of implementation and precision without being relabeled success.

The main limitations are deliberate and consequential. The evidence selection is purposive; its studies come from different populations and cannot yield a pooled effectiveness claim. The service floor is a normative design contribution, not a validated checklist. The proposed trial bundles instructional and organizational changes and cannot isolate each mechanism. Secondary-school science does not represent early childhood, every subject, or every national system. The proposed school-level assignment remains vulnerable to spillover, nonresponse, and implementation problems; its small number of pairs limits precision. Cost projections and subgroup estimates will require cautious interpretation. None of these limits can be repaired by architectural elegance or institutional branding.

Designership earns practical meaning when ambition carries obligations that can be inspected. A digital school should make entry feasible, intellectual work worthwhile, support accountable, evidence credible, and exit possible. The proposed infrastructure-to-opportunity chain translates that position into observable service questions and a comparative research program. Its success would not be a claim that virtual space replaces school. It would be a demonstrated capacity to expand serious learning without transferring hidden costs and exclusions to the learners least able to absorb them. The next contribution is implementation under this protocol, with results reported whether they support or challenge the design.

References and verification record

References retain their original authorship and publication identity. Verification dates below record source and metadata checking; they do not confer review or approval on this article.

[R1] UNESCO Global Education Monitoring Report Team (2023). Global education monitoring report 2023: Technology in education: A tool on whose terms?. UNESCO.

Source: https://www.unesco.org/gem-report/en/publication/technology

Verified 2026-10-16. Official report landing page and report text; governance/access/evidence framing. Not a causal evaluation of the proposed service.

[R2] National Center for Education Statistics (2025). Percentage distribution of children ages 3 to 18, by whether they have home internet access, whether they have access through computer or only smartphone, and selected child and family characteristics: 2022 and 2023. Digest of Education Statistics, Table 702.12.

Source: https://nces.ed.gov/programs/digest/d25/tables/dt25_702.12.asp

Verified 2026-10-16. Official table; distinguishes computer access and smartphone-only access. Data years 2022-2023, table edition 2025. No numerical prevalence claim made.

[R3] Robert W. Fairlie; Jonathan Robinson (2013). Experimental Evidence on the Effects of Home Computers on Academic Achievement among Schoolchildren. American Economic Journal: Applied Economics, 5(3), 211-240.

DOI: https://doi.org/10.1257/app.5.3.211

Source: https://www.aeaweb.org/articles?id=10.1257/app.5.3.211

Verified 2026-10-16. Publisher title, authors, date, DOI, abstract verified. Randomized California home-computer provision; educational outcomes assessed showed no effect.

[R4] Julian Cristia; Pablo Ibarrarán; Santiago Cueto; Ana Santiago; Eugenio Severín (2017). Technology and Child Development: Evidence from the One Laptop per Child Program. American Economic Journal: Applied Economics, 9(3), 295-320.

DOI: https://doi.org/10.1257/app.20150385

Source: https://www.aeaweb.org/articles?id=10.1257/app.20150385

Verified 2026-10-16. Publisher version has 318 schools, distinct from 319 in 2012 working-paper abstract. Cite journal version only; no math/language improvement and cognitive evidence inconclusive.

[R5] Karthik Muralidharan; Abhijeet Singh; Alejandro J. Ganimian (2019). Disrupting Education? Experimental Evidence on Technology-Aided Instruction in India. American Economic Review, 109(4), 1426-1460.

DOI: https://doi.org/10.1257/aer.20171112

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Verified 2026-10-16. Publisher authors, title, DOI, date and lottery-based after-school instructional-program findings verified. Package effect, not hardware or VR effect.

[R6] Noam Angrist; Peter Bergman; Moitshepi Matsheng (2022). Experimental evidence on learning using low-tech when school is out. Nature Human Behaviour, 6, 941-950.

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Verified 2026-10-16. Publisher article/abstract: Botswana randomized SMS and phone-call interventions, combined treatment improved learning. No extrapolated effect estimate used.

[R7] Guido Makransky; Thomas S. Terkildsen; Richard E. Mayer (2019). Adding immersive virtual reality to a science lab simulation causes more presence but less learning. Learning and Instruction,

60, 225-236.

DOI: https://doi.org/10.1016/j.learninstruc.2017.12.007

Source: https://www.sciencedirect.com/science/article/pii/S0959475217303274

Verified 2026-10-16. Publisher and University of Copenhagen institutional record agree on title/authors/DOI/date. Experimental setting not generalized as K-12 effect.

[R8] World Wide Web Consortium (2024). Web Content Accessibility Guidelines (WCAG) 2.2. W3C Recommendation, 12 December 2024.

Source: https://www.w3.org/TR/2024/REC-WCAG22-20241212/

Verified 2026-10-16. Exact dated Recommendation verified. Testable criteria; explicitly does not address every disability-related user need; automated and human evaluation distinguished.

[R9] Joshue O'Connor; Janina Sajka; Jason White; Scott Hollier; Michael Cooper (editors) (2021). XR Accessibility User Requirements. W3C Working Group Note, 25 August 2021.

Source: https://www.w3.org/TR/2021/NOTE-xaur-20210825/

Verified 2026-10-16. Official document editors/date/status verified. Explicitly not baseline requirements or W3C Membership endorsement; cited as exploratory user-needs note.

[R10] UNESCO (2019). Recommendation on Open Educational Resources (OER). UNESCO General Conference, 25 November 2019.

Source: https://www.unesco.org/en/legal-affairs/recommendation-open-educational-resources-oer

Verified 2026-10-16. Official adopted text defines OER through public domain/open license and adaptation/redistribution permissions. No presumption public webpages are licensed.

[R11] U.S. Department of Education, Privacy Technical Assistance Center (2014). Protecting Student Privacy While Using Online Educational Services: Requirements and Best Practices. U.S. Department of Education, February 2014.

Source: https://studentprivacy.ed.gov/resources/protecting-student-privacy-while-using-online-educational-services-requirements-and-best

Verified 2026-10-16. Official guidance page and original PDF verified; scope online educational services. Historic guidance is starting point, not assertion of current universal legal compliance.

[R12] Karla Hemming; Terry P. Haines; Peter J. Chilton; Alan J. Girling; Richard J. Lilford (2015). The stepped wedge cluster randomised trial: rationale, design, analysis, and reporting. BMJ, 350, h391.

DOI: https://doi.org/10.1136/bmj.h391

Source: https://www.bmj.com/content/350/bmj.h391

Verified 2026-10-16. Publisher/PubMed authors/title/DOI/date verified. Design cautions include time effects and cluster correlation; not a power guarantee.

[R13] Brantly Callaway; Pedro H. C. Sant'Anna (2021). Difference-in-Differences with multiple time periods. Journal of Econometrics, 225(2), 200-230.

DOI: https://doi.org/10.1016/j.jeconom.2020.12.001

Source: https://doi.org/10.1016/j.jeconom.2020.12.001

Verified 2026-10-16. Publisher abstract and author-maintained software references verified. Conditional parallel trends and varying treatment timing; fallback comparative study, not magical removal of selection bias.

[R14] Don Husereau; Michael Drummond; Federico Augustovski; Esther de Bekker-Grob; Andrew H. Briggs; Chris Carswell; Lisa Caulley; Nathorn Chaiyakunapruk; Dan Greenberg; Elizabeth Loder; Josephine Mauskopf; C. Daniel Mullins; Stavros Petrou; Raoh-Fang Pwu; Sophie Staniszewska; CHEERS 2022 ISPOR Good Research Practices Task Force (2022). Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) statement: updated reporting guidance for health economic evaluations. BMJ, 376, e067975.

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Verified 2026-10-16. Publisher and PubMed complete author group, title, DOI/date verified. Reporting guidance originated in health; adapted transparently, no claim of educational instrument validation.

[R15] CAST (2024). Universal Design for Learning Guidelines version 3.0. CAST.

Source: https://udlguidelines.cast.org/

Verified 2026-10-16. Official guidelines site identifies version 3.0 released 30 July 2024; recommendations not treated as causal validation of this curriculum.

[R16] U.S. Department of Education, Office of Educational Technology (2024). A Call to Action for Closing the Digital Access, Design, and Use Divides: 2024 National Educational Technology Plan. U.S. Department of Education.

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Verified 2026-10-16. Official Government Publishing Office record and ERIC ED641164 verify institutional author, title, January 2024 and access/design/use framework.

Source and authorship notes

Original analysis and proposed research design; no completed fieldwork, empirical effect, systematic search, accepted protocol registration, ethics approval or independent human peer review is claimed.

Source selection is purposive and claim-specific. References verified against publisher, official standards, government, UNESCO, CAST or author-maintained method records on 16 October 2026. Citation does not imply endorsement by any source institution.

No stale global out-of-school count or numerical access prevalence is asserted. Historic research is dated and contextualized.

The proposed service obligation and exit protections are normative institutional/contractual recommendations, not a statutory interpretation or legal-compliance certificate.

The randomized intervention is an enhancement above an essential-service floor; urgent accessibility and access remediation is not withheld.

AI-assisted research, drafting and source checking require author accountability and independent human editorial assessment. Newly prepared article has no documented independent human review report.

Editorial methods audit resolved the initial multi-term/cohort ambiguity: final design is a one-term matched-pair randomized delayed-start comparison with a closed baseline cohort, aligned assessments, one pre-endpoint module, and no post-crossover confirmatory contrast.

Participation uses five common curricular milestones with identical goals, timing and minimum evidence requirements across arms; extra enhancement events do not inflate the denominator. Entry-to-feedback access task and baseline research-cohort denominator are common across policies. Consent/assent and baseline measurement occur before allocation.