AI-Augmented Learning in Resource-Variable Contexts

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👤 *Author*

Godfrey Gandawa
Springfield Research University
Ezulwini, Eswatini

Abstract

AI-Augmented Learning in Resource-Variable Contexts proposes a sovereign reengineering of adaptive education models for regions with limited or intermittent connectivity. Grounded in the infrastructural logics of Education 6.0—particularly SIM (Stemmatize, Industrialize, Modernize), STEMMA, and LIKEMS frameworks—the paper reframes AI not as a cloud-dependent luxury but as a localised, programmable scaffold for immersive cognition. It introduces modular learning environments capable of functioning offline, leveraging embedded intelligence to regenerate content, credential learners, and sustain adaptive feedback loops without continuous network access.

The work challenges prevailing assumptions about digital access and pedagogic equity, arguing for a post-connectivity learning architecture where intelligent systems are culturally embedded, infrastructurally sovereign, and pedagogically regenerative. Through narrative dignity, credentialing autonomy, and algorithmic portability, AI becomes not a disruptor but a co-author of educational justice—engineered for Africa and global resource-variable terrains.

Keywords

1. The Connectivity Illusion: Why Bandwidth-Dependent AI Fails Sovereign Learning

The dominant narrative of AI-enhanced education presumes a digital utopia—ubiquitous connectivity, cloud-based infrastructure, and seamless access to intelligent systems. Yet for much of the Global South and resource-variable terrains across Africa, this narrative dissolves under infrastructural scrutiny. The illusion of universal connectivity conceals pedagogic exclusion; it codifies a model of learning that privileges bandwidth-rich environments while structurally abandoning disconnected or intermittently online communities.

Education 6.0 rejects this illusion. Within SIM logic, sovereign learning must be **stemmatized** from local context, **industrialized** for infrastructure realities, and **modernized** through adaptive architectures that do not depend on centralised cloud computation. Learning sovereignty demands that intelligence resides not in distant servers—but in embedded systems capable of operating independently.

The limitations of bandwidth-dependent AI systems are not merely technical—they are epistemic. Their failure reveals an extractive bias in which adaptation is tethered to infrastructure rather than cognition, privileging connectivity over contextual intelligence. Within the Education 6.0 paradigm, modular AI must be reimagined as a sovereign instrument—locally instantiated, culturally stemmatized, and credential-generative. Locally instantiated models must be deployable in offline or low-bandwidth conditions, ensuring that pedagogical innovation is not gated by infrastructural privilege. Culturally stemmatized AI must encode indigenous pedagogic flows, rejecting imported interaction logics in favor

of epistemic architectures rooted in local knowledge systems. Credential-generative functionality must be embedded, allowing AI systems to track learner agency and mastery without continuous cloud mediation, thereby affirming autonomy and narrative dignity.

The next generation of adaptive learning environments must be engineered for post-connectivity cognition—where intelligence is locally governable, even in conditions of technological sparsity. Sovereignty begins with this assumption: that cognition is not contingent on bandwidth, but on the integrity of the learning ecosystem. In this configuration, AI becomes a tool of epistemic liberation, not infrastructural dependency.

2. Offline Intelligence: Modular AI Architectures for Disconnected Ecosystems

If Education 6.0 treats curriculum as infrastructure, then intelligence must be modular, portable, and sovereign. In resource-variable environments, adaptive systems cannot rely on persistent connectivity; instead, they must operate as autonomous pedagogic agents embedded within local devices, institutions, and modular content stacks. This shift from cloud-centric models to **edge-deployed intelligence** marks a crucial pivot—one where AI is rearchitected to serve bandwidth-constrained contexts without epistemic compromise.

Through the lens of SIM logic, offline intelligence must be reengineered as a sovereign infrastructure—capable of delivering pedagogical transformation independent of bandwidth constraints. To stemmatize offline systems is to embed them within local pedagogic genealogies, integrating cultural syntax, indigenous cognition, and contextually relevant epistemic flows. This ensures that educational content is not merely accessible, but ancestrally anchored and narratively dignified. Industrialization of offline intelligence requires the deployment of portable hardware, firmware-stemmatized content, and adaptive algorithms that function autonomously—without reliance on external input or cloud mediation. These systems must be robust, scalable, and capable of encoding pedagogical logic into locally governed devices.

Modernization, in this context, entails the development of interoperable platforms that regenerate curriculum, track credentials, and facilitate immersive cognition in offline environments. These platforms must interface seamlessly with credentialing systems, simulate dynamic learning pathways, and respond to learner inputs with precision and dignity. In this configuration, offline intelligence is not a compromise—it is a sovereign modality of educational delivery. SIM logic affirms that intelligence need not be tethered to infrastructure; it can be locally authored, culturally encoded, and technologically sovereign.

STEMMA encoding enables disciplines—science, law, health, humanities—to be compressed into **locally executable knowledge modules**, built with automation-aware logic and capable of delivering credential-generative feedback in disconnected zones. These architectures replace network dependency with embedded sovereignty—ensuring that every educator, regardless of infrastructure, becomes a node of intelligence.

By activating AI locally, Education 6.0 preserves **instructional dignity** in environments previously sidelined by bandwidth constraints. No learner is excluded, and no pedagogy is postponed. Intelligence remains active—even when the network is silent.

3. Adaptive Logic Redefined: Cognitive Feedback Without the Cloud

In Education 6.0, feedback is not an accessory—it is infrastructure. Yet in disconnected environments, traditional models falter. Cloud-reliant assessments and LMS architectures assume persistent connection; what is needed instead is **embedded feedback intelligence**—where every learning module carries within it the logic to assess, validate, and credential autonomously.

Adaptive feedback logic within Education 6.0 transcends reactive correction—it becomes anticipatory cognition authored at the modular edge. Through SIM encoding, it is stemmatized to align with the

curricular DNA of its context, embedding itself within disciplinary architectures, linguistic grammars, and sociocultural rhythms. These feedback pathways are not generic—they are sovereign mappings of cognition, authored to reflect local epistemic nuance and pedagogic lineage. Once industrialized, this logic operates seamlessly across decentralized devices—from solar-charged tablets in rural pods to handheld microservers in urban microcampuses—facilitating real-time learner validation, credential activation, and recursive pathway generation. Finally, the system is modernized as modular AI subroutines: functioning offline, remapping learner profiles, evaluating knowledge applications in context, and generating feedback loops that are both pedagogically sovereign and technically regenerative. In this schema, feedback is no longer an add-on—it is embedded epistemic infrastructure that thinks with the learner, not just about the learner.

STEMMA allows each discipline to encode its own **automated pedagogic validation loops**—transforming static content into dynamic learning architecture. Legal case analysis, anatomical diagnostics, poetic interpretation, or civic debate can be tracked and validated through domain-specific feedback pathways, each instantiated without external infrastructure.

This paradigm affirms a sovereign redefinition of learning intelligence—one that is self-validating, domain-aware, and institutionally governed. At its core is local feedback sovereignty, wherein educators retain authorship over validation logic, ensuring that assessment mechanisms reflect contextual relevance and pedagogical intentionality. Credentialing continuity is preserved, allowing learners to advance through modular mastery without dependency on external approvals or synchronization events. This autonomy dismantles infrastructural gatekeeping and affirms epistemic justice, removing technological bottlenecks that have historically marginalized learners in bandwidth-constrained environments.

What emerges is a pedagogical ecosystem where learners no longer wait for connection—they progress through cognition itself. Intelligence is not outsourced to distant servers; it is locally authored, culturally encoded, and sovereignly scaffolded. Education 6.0 thus restores the dignity of learning as a self-directed, infrastructure-independent act of epistemic authorship.

4. Credential Architectonics: Modular Validation, Sovereign Recognition

In legacy education, credentials often trail cognition—issued through bureaucratic intermediaries, delayed by external systems. Education 6.0 reconfigures this lag into a **logic of immediacy**: where validation is embedded, and recognition is both local and modular.

Credential Architectonics in Education 6.0 reframes validation not as external certification, but as epistemic authorship. Through SIM pathways, credentials are stemmatized to reflect each learner's cognitive lineage, disciplinary nuance, and indigenous context—rendering recognition as the output of lived epistemologies rather than bureaucratic abstraction. They are industrialized within content stacks, each modular unit carrying embedded logic to trigger domain-specific credentialing upon mastery. These units function autonomously—offline, on-device, and within the sovereign ecosystems of community institutions. Recognition is then modernized through interoperable modular ledgers, AI-integrated progression loops, and locally governed credentialing platforms. This allows mastery to be tracked in real time, applicability to be dynamically contextualized, and credentialing to remain anchored in pedagogic relevance. In this framework, credentials are not static stamps—they are programmable markers of indigenous cognition, authored from the ground up.

STEMMA logic enables disciplines to define their **own credentialing schemata**—whether it's micro-validation of a poetic critique, mastery in civic logic, or procedural competence in medical diagnostics. Each stemma becomes a credential map, guiding learning with integrity and precision.

This credentialing model activates a triad of sovereign imperatives: local authorship, portable validation, and narrative dignity. At its foundation is local sovereignty, wherein institutions and educators assume full authorship over credential design and issuance—displacing distant authorities and reinstating epistemic control within the community. Credentials become portable proof, enabling learners to carry modular recognitions across diverse educational settings—from township networks to continental

academies—without infrastructural dependency or bureaucratic delay. Each credential affirms not only knowledge acquisition but also identity, effort, and epistemic justice, embedding the learner's cultural and cognitive journey within the architecture of recognition.

Credential Architectonics dissolves dependency by reconfiguring educational authority where it belongs: with the learner, the educator, and the community. Recognition is no longer deferred—it is activated through cognition itself. In this paradigm, credentialing becomes a sovereign act of authorship, aligning institutional validation with pedagogical integrity and continental aspiration.

5. Institutional Holography: Reimagining the School as a Distributed Node

In Education 6.0, the school is not merely a site—it is an **epistemic hologram**, replicable across geographies, scalable across modalities, and sovereign in its learning logic. Rather than centralized campuses dependent on static infrastructure, pedagogic ecosystems become distributed, modular, and holographically instantiable in any environment.

Institutional Holography in Education 6.0 is not merely infrastructural—it is ontological encoding. Through SIM logic, institutions become cognitive mirrors of their communities. They are stemmatized to reflect indigenous epistemologies, civic priorities, and disciplinary genealogies, reauthoring the very grammar of what a "school" is. From village learning pods to urban microcampuses, each node is industrialized as a sovereign unit—carrying its own modular infrastructure for instruction, credentialing, and regeneration of contextual content. These nodes are not passive recipients of distant policy; they are active authors of situated intelligence. Once modernized, the institutional lattice activates through interoperable ledger systems, AI feedback loops, and credentialing stacks. This creates a living network of pedagogic sovereignty—a distributed, modular intelligence that is locally governed, epistemically dignified, and globally interoperable.

STEMMA logic allows disciplines to be **locally rendered, institutionally interconnected, and globally legible**. A medical simulation in rural Eswatini carries the same epistemic validity as one in Nairobi or Dakar—because the logic is not centralized, but encoded, distributable, and sovereign.

This redefinition of educational architecture activates a triad of sovereign imperatives: locational fluidity, institutional sovereignty, and scalable modularity. Locational fluidity affirms that learning is no longer confined to formal buildings—it occurs wherever cognition is possible, from agro-valleys to urban innovation hubs, dissolving the spatial constraints of legacy schooling. Institutional sovereignty empowers communities to govern their pedagogic logic, credential pathways, and curricular identity, restoring epistemic authorship to local actors and dismantling dependency on external authorities. Scalable modularity enables any school to become a sovereign node—not through physical expansion, but through stemmatized replication, holographically rendered across diverse terrains and cultural contexts.

Institutional Holography ensures that learning is not withheld due to infrastructural scarcity. Instead, infrastructure is stemmatized from learning itself—modular, distributable, and sovereign. In this paradigm, education becomes a regenerative system of cognitive habitats, each locally authored, culturally encoded, and technologically adaptive. The school ceases to be a building—it becomes a sovereign interface for epistemic transformation.

6. Narrative Sovereignty: Reclaiming Epistemic Identity in Curriculum Design

In Education 6.0, curriculum is not just a vehicle for knowledge transmission—it is **narrative infrastructure**. Too often, pedagogic design borrows external logics, marginalizing indigenous epistemes and neutralizing cultural cognition. Narrative Sovereignty restructures this hierarchy, ensuring that content is authored, encoded, and credentialed from within the epistemic identity of the community it serves.

Sovereign narratives in Education 6.0 are not adjuncts to imported syllabi—they are epistemic infrastructures authored from the inside out. Through SIM encoding, disciplinary architectures are stemmatized to mirror regional genealogies, civic priorities, and indigenous cognitive rhythms. Law, medicine, humanities, and science are no longer assimilated—they are re-authored through the lens of localized epistemic logics. These curricular strands are then industrialized as content stacks that embed cultural symbolism, linguistic nuance, and civic relevance—each module functioning as a container of living cognition. Once modernized, these sovereign narratives activate modular overlays: digitally rendered, distributable peer-to-peer, and remixable across institutions, all while preserving the integrity of authorship and the dignity of intellectual origin. In this framework, curriculum is not static text—it is regenerative narrative sovereignty, continuously authored by the communities it serves.

STEMMA logic enables **disciplinary regeneration**: where a poem becomes civic logic, a folktale informs ecological ethics, and indigenous algorithms reframe mathematical pedagogy. The curriculum becomes a **site of narrative activation**, not dilution.

This model produces a sovereign reconfiguration of educational agency—anchored in cognitive ownership, editorial sovereignty, and narrative justice. Cognitive ownership affirms that learners encounter themselves within the architecture of learning, engaging not as passive consumers of external thought but as co-authors of epistemic design. Editorial sovereignty empowers educators and communities to curate, credential, and propagate their own epistemic imprint, restoring pedagogical authorship to those who live its logic. Narrative justice completes the triad, correcting historical omissions through stemmatized authorship that reclaims identity, reconfigures pedagogy, and dignifies indigenous knowledge systems.

Narrative sovereignty, in this paradigm, is not symbolic—it is infrastructural. It ensures that education is not merely delivered—it is authored. The curriculum becomes a mirror of lived experience, and credentialing becomes a declaration of cultural agency. Education 6.0 thus affirms that learning is not a transaction—it is a sovereign act of epistemic reclamation.

7. Distributed Cognition: Peer-to-Peer Learning in Modular Ecosystems

Legacy education models isolate cognition—placing the teacher as the sole arbiter, and the learner as a passive recipient. Education 6.0 dismantles this hierarchy, reconstructing cognition as **distributed agency**, where every learner is also a node of epistemic value and every peer interaction is a vector for credentialed progress.

Through SIM logic, distributed cognition in Education 6.0 reconceptualizes learning as communal infrastructure—where knowledge is not transferred but co-generated, not centralized but relational. Pedagogic flows are stemmatized to reflect indigenous epistemic networks, embedding peer-to-peer learning within the cognitive rhythms and civic priorities of each community. Learners engage one another as co-authors of progression, activating modular ecosystems where reciprocal feedback, collaborative mastery, and pedagogic role-switching become institutional norm. These interactions are industrialized through locally governed platforms—learners validate one another within sovereign ecosystems that require no external arbitration. As AI routines are modernized and embedded into the learning substrate, each peer exchange becomes credential-generative, tracked and archived with integrity yet free of central oversight. In this model, education evolves into a choreography of minds— plural, sovereign, and regenerative—where cognition is continuously authored through relational mastery.

STEMMA encoding allows disciplines to express **learning as relational cognition**. A learner in Eswatini collaborates on civic logic with one in Botswana; their co-validation becomes credential input. A group interpretation of an indigenous proverb becomes a pedagogic credential—because cognition is communal, and mastery is co-authored.

This architecture activates a sovereign model of distributed cognition, wherein intelligence is relational, regenerative, and co-authored. At its core is reciprocal credentialing, a paradigm in which learners validate one another through structured knowledge interactions, transforming educational progression

into a collaborative act of epistemic authorship. Institutional cross-pollination further amplifies this dynamic, interlinking schools, communities, and regions into sovereign learning networks with autonomous credential flows. These networks dissolve hierarchical silos and foster pedagogical ecosystems that are fluid, interoperable, and locally governed.

Social epistemics anchors the model, ensuring that education reflects the society it serves—plural, dynamic, and co-operative. Learning becomes a choreography of minds, not a monologue. Intelligence is no longer centralized—it is distributed across nodes of cultural agency, pedagogic sovereignty, and communal authorship. In this configuration, education transcends delivery—it becomes a regenerative system of shared cognition, where every learner and educator is both a contributor and a validator of continental knowledge.

8. Automation-Aware Pedagogy: Designing Curriculum with Intelligent Futures in Mind

Education 6.0 does not resist automation—it **re-authors it**. In a world accelerating towards intelligent systems, pedagogy must be designed to stemmatize automation itself: embedding awareness, interoperability, and sovereign agency within curriculum frameworks that shape—not serve—the automation continuum.

Through SIM encoding, automation-aware pedagogy in Education 6.0 repositions technology not as an external imposition, but as a sovereign extension of civic cognition and epistemic agency. Disciplines are stemmatized to reflect local technocultural narratives, allowing learners to encounter automation as an endogenous construct—understood through their own genealogies, priorities, and infrastructural rhythms. Once industrialized, curriculum integrates automation-as-toolkit, where learners co-author intelligent routines across domains—from agricultural analytics to civic dashboards—activating embedded scaffolds operable offline and sovereignly governed. As pedagogic systems modernize, AI modules are no longer delivery mechanisms but collaborative agents—co-generating knowledge, reinforcing modular feedback, and validating credential pathways without relying on external infrastructures. STEMMA logic amplifies this transformation by enabling every discipline to encode automation routines as pedagogic overlays, track learner engagement as credential input, and activate recursive feedback loops between human cognition and machine intelligence. In this paradigm, pedagogy becomes anticipatory, modular, and authored—preparing learners not merely to navigate intelligent futures, but to design them.

This pedagogical shift activates a new architecture of learning—one grounded in cognitive sovereignty, modular intelligence, and futures literacy. Cognitive sovereignty affirms that learners do not merely adapt to automation; they design and govern it, engaging intelligent systems as co-authors of epistemic infrastructure. Modular intelligence reconfigures curriculum as a regenerative system, dynamically reshaped in real time through learner interaction with embedded AI logic. Education, in this paradigm, ceases to be reactive—it becomes predictive and adaptive, encoding futures rather than merely preparing for them.

Automation-aware pedagogy rejects the deficit model that positions learners as passive recipients of technological instruction. Instead, it affirms that every learner possesses the capacity to author intelligent futures—provided their curriculum is sovereign, modular, and encoded with anticipatory logic. Education 6.0 thus becomes an infrastructure of foresight, where pedagogy is not a response to change, but a mechanism for designing it.

9. Editorial Algorithms: Embedding Schematic Authorship in Curriculum Code

Curriculum is not merely curated—it is **scripted**. In modular learning ecosystems, pedagogic sovereignty must extend into the algorithmic layer, ensuring that automation, adaptive feedback, and credential generation all reflect the epistemic logic authored by communities themselves.

Editorial Algorithms in Education 6.0 transform curriculum design from static arrangement into programmable infrastructure, where schematic authorship becomes algorithmic sovereignty. Through SIM logic, these editorial routines are stemmatized to encode civic, linguistic, and cultural priorities—capturing narrative rhythms and disciplinary genealogies specific to each community. Once industrialized, they operate offline within sovereign ecosystems, regenerating content, tracking learner progression, and issuing adaptive credentials without reliance on proprietary middleware or external computation. As modular syntax engines, these algorithms modernize pedagogy by translating symbolic content into actionable intelligence—preserving epistemic identity while activating feedback, credentialing, and curriculum flow across devices and institutions. In this model, educators become algorithmic architects, ensuring that every pedagogic function carries the imprint of authored sovereignty.

Through STEMMA encoding, disciplines become **algorithmically expressive**. A civic ethics module may include peer validation loops; a medical diagnostic module may script logic gates based on indigenous frameworks; a literature stemma may embed symbolic weightings for narrative interpretation.

This redefinition of curriculum architecture enables a sovereign shift in educational design—anchored in schematic authorship, operational sovereignty, and regenerative infrastructure. Schematic authorship repositions educators from content curators to algorithmic architects, granting them authority to design the flow, logic, and credential triggers embedded within each instructional module. Pedagogy becomes programmable, and educators assume control over the epistemic circuitry that governs learning progression. Operational sovereignty ensures that institutions deploy pedagogic code authored locally, safeguarding curricular identity from external templates and preserving the integrity of indigenous logic systems.

Regenerative infrastructure completes the triad, allowing editorial logic to update dynamically across deployments—maintaining curricular relevance, accuracy, and schematic fidelity in real time. In this paradigm, editorial algorithms affirm that curriculum design is not merely instructional—it is civic scripting. Every logic gate and adaptive pathway reflects the priorities, intellect, and cultural cognition of its originators. Education 6.0 thus extends authorship into code, transforming pedagogy into a sovereign infrastructure of epistemic governance.

10. Learning as Infrastructure: Repositioning Education Within Civic Systems

Historically, education has been treated as a public service—intermittent, reactive, and often peripheral to systemic development. Education 6.0 repositions it as **programmable civic infrastructure**, encoded directly into the design of health systems, legal networks, ecological management, urban governance, and cultural regeneration.

Through SIM logic, learning ceases to be a siloed activity—it becomes the programmable infrastructure of society itself. Civic institutions, stemmatized to reflect their epistemic identities, are re-authored as pedagogic engines: the hospital becomes a diagnostic academy, the courtroom a legal reasoning chamber, and water-management systems evolve into ecological education nodes, each grounded in indigenous narrative sovereignty. Public systems are industrialized into learning interfaces, hosting embedded curriculum stacks across sensors, civic dashboards, and administrative protocols—turning everyday governance into modular pathways of real-time knowledge engagement. As credentialing and feedback loops are modernized and interlinked across these sectors, education dissolves the boundaries of school walls, re-emerging as a fluid, systemic force: omnipresent, sovereign, and continuously activated through the living operations of civic life.

STEMMA enables this infrastructural turn: where disciplines are encoded within civic workflows, and pedagogy becomes part of system logic. Automation, law, agriculture, and medicine cease being taught in abstraction—they are learned through **participatory operationalization**.

This transformation produces a sovereign reconfiguration of educational validation—anchored in pedagogic governance, contextual mastery, and epistemic integration. Pedagogic governance

redefines assessment as civic engagement, where learning is validated through operational participation rather than standardized examinations. Learners demonstrate mastery by solving real-world problems, and their achievements are credentialed by the very systems they help to improve. This model affirms education as a public utility—responsive, participatory, and structurally embedded.

Contextual mastery replaces abstract evaluation with situated intelligence, enabling learners to activate knowledge within their lived environments. Credentialing becomes a reflection of impact, not just performance. Epistemic integration completes the triad, embedding indigenous knowledge flows into public infrastructure and regenerating civic systems with cognitive sovereignty. Education ceases to be an external intervention—it becomes a sovereign infrastructure authored by communities, sustained through operational relevance, and dignified by cultural intelligence.

Education as infrastructure ensures that learning is no longer a prerequisite for action—it **is action**, encoded, credentialed, and civic. Society educates itself through its own functions, and every citizen becomes an epistemic node within it.

11. Regenerative Sovereignty: The Future as Authored Infrastructure

Education 6.0 culminates not in reform, but in **regeneration**. It affirms that sovereignty is not only political—it is pedagogic, epistemic, and infrastructural. The frameworks of STEMMA, SIM, and LIKEMS do not propose improvements to legacy models; they **overwrite them** with an authored logic capable of sustaining autonomous learning futures.

This conclusion encodes a sovereign redefinition of educational architecture—anchored in stemmatized continuity, industrialized sovereignty, and modernized futures. Stemmatized continuity affirms that every disciplinary module carries the epistemic genealogy of its community, transforming curriculum into heritage and heritage into cognition. Pedagogic content is no longer abstracted from its origins; it is ancestrally rooted, culturally encoded, and narratively dignified. Industrialized sovereignty ensures that pedagogic systems function seamlessly across infrastructures—offline, mobile, and distributed—activating intelligence in every node, campus, and community. Education becomes infrastructurally agnostic, yet epistemically precise.

Modernized futures complete the triad, positioning learning infrastructures as regenerative systems guided by civic intent, cultural authorship, and modular credentialing logic. These systems do not merely deliver content—they evolve, adapt, and respond to the sovereign imperatives of their environments. Education is no longer a static product—it becomes a living system of transformation. Credentialing emerges as a civic function, narrative becomes algorithmic, institutions become replicable, and learners ascend as sovereign agents of continental authorship.

The future is not awaited—it is **encoded**, authored, and modularly rendered. Education 6.0 is not a framework to be adopted—it is a **sovereign infrastructure to be activated**, continuously, regeneratively, continentally.

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