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From Infrastructure Automation to Clinical Pedagogy: The Origin and Evolution of Curriculum-as-Code (2018–2026)

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Canonical Definition — Curriculum-as-Code (CaC): Curriculum-as-Code is an instructional engineering discipline that treats syllabi, readings, clinical simulations, competency rubrics, and accessibility governance as plain-text, Git-versioned source code compiled through automated Continuous Integration (CI/CD) verification gates into Learning Management Systems (LMS) and open-access educational datasets.

Abstract

This whitepaper establishes the historical genealogy and paradigmatic evolution of **Curriculum-as-Code (CaC)** from 2018 network reliability engineering (`NetOps`) to 2026 neuro-symbolic higher-education pedagogy. In November 2018, the NRE Labs community (`nre-learning/nrelabs-curriculum` and the Antidote engine) coined *Curriculum-as-Code* to orchestrate Kubernetes virtual routers and browser terminals via declarative YAML (`syringe.yaml`). Because Generation 1 coupled learning content permanently to heavy container clusters, NRE Labs ultimately shut down under infrastructure overhead. Generation 2 (`2021–2026`) decoupled prose into plain-text Git repositories—demonstrated early by Alan Pruitt's August 2021 NADO Aliceann Wohlbruck Impact Award for compiling a regional CEDS manual via an open-source GitHub AI Co-Pilot, and echoed later by 2026 STEM LaTeX/Beamer slide pipelines (`arXiv:2608.07364`)—yet flat document pipelines remained blind to semantic pedagogy, LMS accessibility checkers, and cryptographic lineage. Generation 3 (**Sovereign Neuro-Symbolic Curriculum-as-Code**, `S-A-R v2.2`) closes those gaps across a live 5-course, 11-shell higher-education fleet (`EXW 101, 150, 210, 245, 265` / `KIN & HLTH` dual-namespace OER) by uniting **The Clinical Framing Protocol (`Pattern / Rule / Solve`)**, federal Single Sources of Truth (**PAGA 2018, DGA 2025–2030, ACSM 12th Ed., NASM OPT, U.S. DOL ETA TEN No. 07-25**), automated **ADA Title II / WCAG 2.2 AA (`9:1` Double-Contrast Guard) & WCAG 3.0** CI/CD linters, a `3,265`**-node DOM GraphRAG** knowledge graph, **W3C PROV-O** SHA-256 provenance receipts, **W3C SKOS** Norteño-Spanish clinical ontologies, and air-gapped Apple Silicon Edge AI (**Google Gemini Carbon 4** & **Gemma 4**).

1. Historical Roots: Three Generations of Curriculum-as-Code (2018–2026)

1.1 Generation 1 (2018): NetOps Container Emulation at NRE Labs

In late 2018, network reliability engineers introduced **Curriculum-as-Code** via NRE Labs and the archived `github.com/nre-learning/nrelabs-curriculum` repository. Borrowing from *Infrastructure-as-Code*, NRE Labs stored guides (`guide.md`) and network topologies (`syringe.yaml`) in Git. Yet the "code" was infrastructural: every lesson provisioned live Docker containers and Kubernetes (`Minikube`) pods to emulate routers and firewalls. When cluster hosting costs and container orchestration fragility outgrew volunteer maintenance, NRE Labs shut down—proving that coupling curriculum to heavy container runtimes creates an operational single point of failure.

1.2 Generation 2 (2021–2026): Plain-Text SSoTs, GitHub AI Co-Pilots & Slide Pipelines

Generation 2 decoupled written content from container runtimes by establishing plain-text Git repositories as the Single Source of Truth (SSoT). In August 2021—five years before 2026 STEM LaTeX/Beamer slide preprints (`arXiv:2608.07364`)—Alan Pruitt earned the **2021 NADO Aliceann Wohlbruck Impact Award** for engineering a regional Comprehensive Economic Development Strategy (`CEDS`) manual using an early-stage open-source AI Co-Pilot model from a GitHub repository. While flat Markdown and LaTeX pipelines solved vendor portability, they lacked typed pedagogical graphs, deterministic LMS accessibility gates, bilingual borderland ontologies, and FERPA-sovereign local inference.

1.3 Generation 3 (2026): Sovereign Neuro-Symbolic Curriculum-as-Code (S-A-R v2.2)

Battle-tested across live Canvas LMS cohorts at Arizona Western College—an HSI serving a **77% Latino** and **62% first-generation** student body where *"challenge is everywhere"* (AWC President Dr. Reetika Dhawan, as quoted in *The Yuma Sun*, Nov. 11, 2026)—and R1 Edge AI incubation at The University of Arizona, **Generation 3 (`S-A-R v2.2` — Scalable / Auditable / Repeatable)** compiles semantic HTML, GraphQL LMS mutations, bilingual W3C SKOS ontologies, 4-Tier `Schema.org/Dataset` OER packages, and cryptographic SHA-256 audit receipts without fragile container runtimes or textbook paywalls.

2. Three-Generation Comparative Paradigm Matrix

Evolution of Curriculum-as-Code Across Generation 1 (2018), Generation 2 (2021–2026), and Generation 3 (S-A-R v2.2, 2026)

Dimension	Gen 1: NetOps Infrastructure (NRE Labs, 2018)	Gen 2: Flat Docs & Slide Pipelines (2021–2026)	Gen 3: Sovereign Neuro-Symbolic CaC (S-A-R v2.2, 2026)
Primary Domain	NetOps CLI automation, packet routing, virtual switches.	Regional strategy manuals (`2021 CEDS`), software docs, STEM LaTeX/Beamer slides (`arXiv:2608.07364`).	Higher-ed kinesiology, clinical nutrition, special populations & AI literacy (`EXW / KIN / HLTH`).
Runtime & Delivery	Kubernetes (`Minikube`), Docker pods, `syringe.yaml` proxies (platform defunct).	Git plain-text compiled to static PDFs, slide decks, or flat reference sites.	Markdown SSoT + Hugo SSG + **Canvas GraphQL (`/api/graphql`)** 3-Stage Pipeline + `exwtoolkit.com` PWAs.
Taxonomy & Pedagogy	`Course → Lesson → Stage` (procedural CLI tasks).	Linear chapters/slides without machine-typed competency edges.	**The Centaur Protocol** & **The Clinical Framing Protocol (`Pattern / Rule / Solve`)** + `10–7–0` Mastery.
Governing SSoT	Network CLI syntax and API state checks.	Instructor prompt templates and mathematical typesetting scripts.	**PAGA 2018**, **DGA 2025–2030**, **ACSM 12th Ed.**, **NASM OPT**, & **U.S. DOL TEN No. 07-25**.
Accessibility CI/CD	Browser terminal UI; no cognitive or contrast mandates.	Manual downstream PDF/slide checks; LMS parity drift.	Automated **8 Canvas Checker rules**, **`9:1` Double-Contrast Guard**, & **WCAG 3.0** bilingual scaffolding.
Graph & Sovereignty	Imperative container checks; pre-LLM.	Flat text chunks + cloud LLM APIs.	**`3,265`-node DOM GraphRAG** + **W3C PROV-O** + **W3C SKOS** Norteño-Spanish + air-gapped **Gemini Carbon 4 / Gemma 4**.

3. Six Core Architectural Pillars of S-A-R v2.2

1. **Federal Single Source of Truth (SSoT) Binding:** Eliminates commercial textbook paywalls across all 5 fleet courses (`EXW 101 / KIN–101` , `EXW 150 / HLTH–150` , `EXW 210 / KIN–210` , `EXW 245 / KIN–245` , `EXW 265 / KIN–265`) by grounding every claim in PAGA 2018 (2nd Ed.), 2025–2030 DGA ("Real Food" Focus), ACSM 12th Ed. (2025), NASM OPT, and U.S. DOL ETA TEN No. 07-25.
2. **The Centaur Protocol & Clinical Framing Protocol (`Pattern / Rule / Solve`):** Trains students as Clinical Problem Framers using P-T-C-F prompts, triple-hash (`###`) case-data delimiters, tactile `exwtoolkit.com` calibration, 150-word SSoT audits, and 150-word verbatim Active Verification defenses on the `10–7–0` Mastery Scale (`allowed_attempts = –1`).
3. **Born-Accessible Compliance-as-Code (ADA Title II & `9:1` Guard):** Pre-push Python gates (`remediate_canvas_accessibility_checker_exw101.py` , `pour_audit.py` , `achieve_oer_linter.py`) enforce `0 Open Issues` in Canvas Accessibility Checker, paired hex `9:1` contrast for `100,000+ lux` desert readability, and bespoke *In Plain English / En Palabras Sencillas* callouts.
4. **Neuro-Symbolic DOM GraphRAG, W3C PROV-O & W3C SKOS:** Connects `3,265` DOM nodes to CLOs, rubrics, and Norteño-Spanish clinical expressions while issuing SHA-256 cryptographic provenance receipts.
5. **GraphQL-First LMS Sync & 21/21 Achieve OER Dataset Syndication:** Pushes zero-drift updates across 11 Canvas shells via `POST /api/graphql` while compiling `467/467` dual-namespace OER Markdown modules verified at `21/21 (100.0%)` on Achieve OER Rubrics + 4-Tier `Schema.org/Dataset` JSON-LD.
6. **Air-Gapped Edge AI & Non-Competing 50-State NSF AI-Ready Enablement:** Executes local **Google Gemini Carbon 4** and **Gemma 4** inference on Apple Silicon (`M1/M2`) for 100% FERPA privacy, positioning Webcognita LLC (`SDVOSB`) as a non-competing 50-state technical partner for **NSF TechAccess: AI-Ready America** Hubs.

4. Academic Citation & Sovereign IP Attribution

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Disclaimer: The Curriculum-as-Code architecture, S-A-R Standard, Clinical Framing Protocol, and open-source software tools described in this whitepaper represent independent faculty engineering and research through Webcognita LLC and do not represent official policy or endorsement by Arizona Western College or The University of Arizona.