Penda Learning Science Intervention: Logic Model and Research Foundation

Prepared by Steven L Miller, PhD, Elite Performance Solutions (May 2026) for Penda Learning (Learning 2020, Inc.)

Abstract: Penda Learning is a gamified, phenomenon-based digital science intervention platform designed for Grades 3–12 and aligned to the Next Generation Science Standards (NGSS). The platform operationalizes the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate) through scaffolded three-dimensional science activities, immediate screen-by-screen feedback, mastery-based retry loops, a Pacing Assistance Service that auto-assigns activities at the appropriate level, weekly Class Mastery Reports for teacher decision-making, and built-in equity supports, including read-aloud, 100+ language translation, and differentiated readability.

This report documents evidence supporting the alignment of Penda Learning's Science Intervention with the Every Student Succeeds Act (ESSA) evidence framework. Tier 4 (Demonstrates a Rationale) is established by a well-defined logic model, an articulated theory of change, and a peer-reviewed research base for each instructional strategy component. Tier 3 (Promising Evidence) is established by correlational dose-response and subgroup analyses, with statistical controls for selection bias, drawn from a sample of 18,738 students. Tier 2 (Moderate Evidence) is established by Miller (2025), a multi-site quasi-experimental study conducted across 46 Charter Schools USA sites in Florida.

The Miller (2025) study satisfies What Works Clearinghouse (WWC) standards for a well-designed, well-implemented quasi-experimental design with baseline equivalence, established via pre-test NWEA MAP Science scores entered as MANCOVA covariates. Penda Learning students demonstrated statistically significant gains over business-as-usual controls ($p < .001$), with an average effect size of Hedges' $g = 0.56$ (95% CI [0.53, 0.59]), corresponding to a 21% average performance gain and an approximate 20-percentage-point advantage in NWEA Level 3 proficiency per grade. Effects were statistically significant for every reported ethnic subgroup and for both genders, with no negative findings on any outcome. A monotonically increasing dose-response relationship was confirmed, with no ceiling effect observed at higher engagement levels.

These findings support classification of Penda Learning as an evidence-based intervention at the ESSA Tier 2 (Moderate Evidence) level, with concurrent qualification at Tiers 3 and 4, making it eligible for Title I, Section 1003 (School Improvement) funding as well as the broader suite of Title I–IV programs.

Document is Aligned to the U.S. Department of Education / IES Regional Educational Laboratory Framework (REL 2014–007 & REL 2014–025). Funding for the report was provided by Learning 2020, Inc.

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1. Introduction

Penda Learning (Learning 2020, Inc.) is the developer of a digital science intervention platform serving students in grades 3 through high school. Built on three core pillars: *proven pedagogies, gamified instruction,* and *automation to support teachers.* Penda's mission is to make science learning engaging and accessible for all students. The platform provides standards-aligned, phenomenon-based science activities and assessments hand-crafted to meet specific standards, including Next Generation Science Standards (NGSS), California NGSS, Texas Essential Knowledge and Skills (TEKS), Pennsylvania Science, Technology, & Engineering, Environmental Literacy and Sustainability (STEELS), Florida Science Academic Standards (FSASS), and other state science standards.

This report presents a formal Logic Model for the Penda Learning science intervention program. It grounds each design feature in peer-reviewed learning science research, maps the platform's design to the 5E Instructional Model (Bybee, 1997), maps program strategies to ESSA tiered evidence ratings, and provides a comprehensive reference list. The document is aligned with the U.S. Department of Education / Institute of Education Sciences (IES) Regional Educational Laboratory framework for logic model development (REL 2014–007; REL 2014–025) and follows the documentation conventions established in Johns Hopkins CRRE evidence reports for educational technology interventions (Reid & Neitzel, 2022).

1.1 Problem Statement

The United States is experiencing a systemic failure in K–12 science education at the precise moment when science proficiency has become one of the most important determinants of individual economic mobility and national economic competitiveness. National science assessments report that fewer than one in three American eighth-grade students demonstrates proficiency in science (NAEP, 2024), yet STEM occupations will require an additional 3.5 million workers by 2032 (Bureau of Labor Statistics, 2023). Without targeted, evidence-based science intervention, delivered equitably across all student populations, this gap will widen, foreclosing opportunity for millions of students and undermining the workforce foundation of the American economy.

The Science Proficiency Gap

National assessment data provide precise estimates of the scope of the crisis. According to the National Assessment of Educational Progress (NAEP, 2024), fewer than one in three eighth-grade students, 32 percent, perform at or above the proficient level in science. In twelfth grade, the proportion falls below 22 percent, meaning that fewer than one in four graduating seniors demonstrate the science proficiency required for postsecondary readiness. These values have remained essentially flat for more than a decade, signaling that standards revision alone, without high-quality, research-grounded

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instructional materials and targeted intervention, is insufficient to move achievement at scale.

The performance gap is not uniform. Among Black students, science proficiency at the eighth-grade level falls to approximately 14 percent; among Hispanic students to 18 percent; and among students from low-income households to 19 percent (NCES, 2024). Students with disabilities and English Language Learners demonstrate proficiency at rates well below their general education peers. These are not incidental disparities; they reflect structural inequities in access to qualified science teachers, functional laboratory facilities, rigorous standards-aligned instructional materials, and the data systems needed to identify and address learning gaps before they compound. Internationally, PISA 2022 placed the United States 13th in science among OECD nations, trailing Singapore, Japan, South Korea, Canada, and Finland, nations with which U.S. workers directly compete in advanced manufacturing, biotechnology, and clean energy (OECD, 2023).

The STEM Workforce Demand Crisis

The severity of this instructional failure is amplified by its temporal overlap with an unprecedented demand for STEM labor. The Bureau of Labor Statistics (2023) projects STEM occupations will grow at nearly twice the rate of non-STEM fields through 2032, requiring an estimated 3.5 million additional workers. Median annual wages for STEM workers stood at $97,430 in 2023, more than double the $48,060 median for non-STEM workers, reflecting both high demand and persistent supply constraints. The U.S. semiconductor industry alone projects a shortfall of 67,000 technicians and engineers by 2030 (Semiconductor Industry Association, 2023), even as the CHIPS and Science Act (2022) has catalyzed over $200 billion in new domestic investment. Korn Ferry estimates that skilled-labor shortages could cost the United States approximately $1.75 trillion in unrealized annual revenue by 2030, equivalent to roughly 6 percent of the U.S. economy (Korn Ferry, 2018). The connection to K–12 science instruction is direct: research consistently demonstrates that student orientation toward STEM careers is determined by middle and early high school science experiences (Tai et al., 2006; Wang, 2012). The K–12 instructional pipeline is the primary upstream determinant of the long-run supply of the STEM workforce.

Equity and Economic Mobility Imperative

The workforce demand crisis intersects with a demographic reality that amplifies both its urgency and its moral weight. Students of color now constitute more than 55 percent of K–12 public school enrollment nationally (NCES, 2024), yet Black and Hispanic students access science proficiency at rates less than half those of their white peers. Meanwhile, China awarded approximately 1.4 million STEM bachelor's degrees in 2022, more than four times the U.S. total, and now leads the world in science and engineering research publications (National Science Foundation, 2024). A nation that cannot develop the scientific potential of its fastest-growing demographic groups cannot sustain its STEM workforce, its innovation economy, or its global competitiveness. Hanushek and Woessmann (2015) demonstrated across 50 nations that raising cognitive skills in science by even half a standard deviation produces GDP gains equivalent to trillions of dollars over a 75-year horizon, gains that are only realizable if the entire population, not a

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privileged subset, reaches proficiency. STEM credentials provide among the most reliable pathways to economic mobility: STEM bachelor's degree holders earn a persistent wage premium of approximately 26 percent above comparable non-STEM graduates (Langdon et al., 2011; Noonan, 2017), with even larger premiums for workers from low-income backgrounds. Failing to build scientific proficiency among historically underserved students is not merely an educational inequity; it is a mechanism that reproduces intergenerational poverty.

The Instructional Infrastructure Gap

Underlying the performance and workforce data is a set of structural instructional failures that no single policy lever has yet to resolve at scale. The Learning Policy Institute estimated that U.S. schools would be short approximately 100,000 qualified teachers by 2017–18, a projection later confirmed by state workforce reports, and in the years since, more than 40 states have annually reported shortages of teachers in mathematics, science, and special education (Sutcher, Darling-Hammond, & Carver-Thomas, 2016; Darling-Hammond, 2022), shortages most severe in rural and high-poverty urban districts, the same communities where science proficiency gaps are widest. National survey data indicate that few teachers have extensive access to subject-area content expertise through their professional learning, even though such access strongly predicts whether teachers find professional learning beneficial to their teaching and student learning (Zuo, Doan, & Kaufman, 2023), meaning that even in states with rigorous standards, many classrooms have not seen the instructional transformation those standards require. Data systems capable of providing teachers with timely, standard-level mastery information remain unavailable in many districts, leaving educators without the diagnostic intelligence needed to differentiate instruction before gaps compound into persistent deficits.

Summary: The Case for Targeted Science Intervention

The convergence of chronically low science proficiency, surging demand for a STEM workforce, deep and persistent equity gaps, accelerating international competition, teacher shortages, and inadequate instructional data systems constitutes a systemic problem that standards reform alone cannot adequately address. What is required is a targeted, evidence-based science intervention: high-quality, standards-aligned instructional content delivered through research-grounded pedagogical systems, supported by actionable data reporting, differentiated to meet the full range of learner needs, and implemented with fidelity through well-prepared educators. The Penda Learning science intervention is designed precisely to address the conditions documented in this problem statement through the mechanisms articulated in the Logic Model that follows.

2. Program Description

2.1 Product Definition and Positioning

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Penda Learning is a technology-enabled, gamified science instruction and intervention system designed to improve engagement, mastery, and measurable achievement. It functions as a hybrid system combining:

- Curriculum supplement (standards-aligned interactive science content)
- Intervention platform (RTI/MTSS Tier 1, 2, and 3 support)
- Assessment and data system (diagnostic, formative, and summative assessments with automated reporting)
- Engagement engine (gamification mechanics grounded in motivation science)

The platform is built to align explicitly with standards-based accountability systems, RTI/MTSS frameworks, equity-driven district initiatives, and post-COVID remediation priorities.

2.2 Target Users

Primary Learners

Students in grades 3 through high school, with particular emphasis on:

- Struggling readers and below-grade-level science learners
- English Language Learners (ELL/ESOL)
- Students with disabilities (SPED/ESE)
- Title I and historically underserved populations

Penda Learning has research evidence supporting its position as both a universal Tier 1 instructional supplement and a targeted Tier 2/3 intervention tool.

Instructional Stakeholders

- Classroom science teachers
- Science coordinators and curriculum directors
- Building principals and assistant principals
- District administrators and federal programs supervisors

2.3 Problems the Platform Claims to Solve

Student-Level Problems

- Low engagement and motivation in science
- Weak reading ability inhibits science comprehension.
- Limited foundational science exposure, particularly at the elementary level
- Achievement gaps across racial, linguistic, and socioeconomic subgroups

Instructional Problems

- Out-of-field teachers lacking deep science content expertise
- Time constraints limit science instruction, especially in elementary grades.
- Difficulty differentiating instruction across wide performance ranges

System-Level Problems

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- Standards alignment complexity across NGSS, TEKS, and FSASS
- Lack of actionable, timely data for instructional decision-making
- Accountability pressure from state science assessments
- Post-pandemic learning loss in science

2.4 Core Platform Components

Pacing Assistance Service (PAS)

Penda's proprietary PAS automatically aligns all science activities and assessments to a district's specific scope-and-sequence calendar, then auto-assigns them to students weekly. This eliminates the planning burden on teachers while ensuring student practice is always synchronized with current classroom instruction.

Gamified Science Activities and Assessments

Penda's activities are grounded in real-world phenomena and built around the NGSS framework for three-dimensional learning, weaving together Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs) into each performance expectation. To meet students where they are, every standard is addressed through scaffolded difficulty levels (emerging to achieving), so instruction can be appropriately differentiated across the classroom. Within this environment, three embedded tools support hands-on, inquiry-based exploration, including 100+ PhET simulations for interactive physics and science modeling, Tuva for data manipulation and analysis, and TL-Draw for digital scientific modeling.

For classrooms seeking authentic laboratory experiences, Penda offers hands-on activities in its instructional guides and integrates with Vernier probes, allowing students to conduct real experiments and collect live data directly within the platform. This bridges the gap between digital simulation and genuine scientific investigation, giving teachers flexibility in how deeply they engage students in hands-on science.

Mastery-Based Progression and Revision Loops

Students must achieve mastery thresholds to advance. If not yet mastered, students revisit the content, improve their performance, and earn additional points and bonuses through retries. This iterative learning loop (attempt → feedback → retry → improvement) is grounded in mastery learning theory (Bloom), retrieval practice research, and gamified reinforcement principles.

Teacher Dashboard and Automated Reporting

The Penda Learning platform provides a real-time teacher dashboard that tracks student progress, standards mastery, and time on task, enabling both automated sequencing and manual, teacher-directed customization. Scores sync automatically to LMS grade books via LTI 1.3. Teachers can access reports showing each student's mastery status (i.e., not mastered, partially mastered, or mastered) for each standard and share them with administrators.

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Differentiated Readability and Multilingual Access

Content is available at differentiated reading levels to support struggling readers' access to grade-level science concepts. Read-aloud functionality and translation into 100+ languages ensure that English Language Learners can engage with all five phases of the learning cycle, understanding prompts (Engage), interpreting tasks (Explore), and articulating ideas (Explain), in their home language.

Teacher Professional Development

Penda provides a structured implementation and professional learning program aligned to the Learning Forward Standards for Professional Learning (Learning Forward, 2022). This is the field's most widely recognized framework for high-quality educator development. PD is content-rich, sustained over time, and tightly coupled to NGSS standards, data use and instructional decision-making, and integration into classroom workflows. Penda's Coaches Academy provides a train-the-trainer model that builds internal district capacity for job-embedded professional learning, differentiation, and data-driven instruction. This model directly reflects Joyce and Showers' (2002) research establishing that peer coaching within authentic instructional contexts produces transfer to practice at a rate more than ten times higher than traditional workshop delivery alone. PD is positioned as a prerequisite for implementation fidelity and for maximizing the effect sizes documented in efficacy research, particularly for the Engage, Explore, and Evaluate phases of the 5E instructional cycle.

Cosmos AI Instructional Assistant

Cosmos is an AI-powered instructional assistant built directly into the Penda student platform. Designed to advance learning and reduce frustration without providing students with answers, Cosmos delivers structured academic support through pre-set prompts with customized, content-specific responses. When students encounter difficulty, Cosmos prompting supports student re-engagement with activity content and scaffolds their thinking toward self-generated understanding. Cosmos operates within a closed, educator-controlled environment to ensure student safety and instructional focus. This design aligns with Zimmerman's (2002) model of self-regulated learning, in which students who develop metacognitive awareness, the ability to monitor their own understanding and regulate their effort, demonstrate significantly greater academic achievement than those who depend on external correction alone.

2.5 Theory of Change

Across its documented design features and value propositions, Penda advances the following integrated theory of change:

① Engagement Layer: Gamification → increased time-on-task → persistence

② Accessibility Layer: Language + reading supports → broader content access → equity gains

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③ Instruction Layer: Standards-aligned phenomena-based content + simulations → conceptual understanding ④ Practice & Mastery Layer: Repetition + iterative retry loops + adaptive difficulty → skill consolidation ⑤ Data Layer: Assessment + automated reporting → targeted intervention → instructional precision ⑥ Outcome: Improved standardized test performance→ narrowed achievement gaps→ science→STEM persistence

3. Logic Model

The IES logic model is the standard evaluation framework for the Institute of Education Sciences in federally funded education research and programs. It maps the chain from resources through to lasting impact, making it essential for helping stakeholders understand both implementation and expected outcomes.

Problem Statement:

The United States is experiencing a systemic failure in K–12 science education at the precise moment when science proficiency has become one of the most important determinants of individual economic mobility and national economic competitiveness. National science assessments report that fewer than one in three American eighth-grade students demonstrates proficiency in science (NAEP, 2024), yet STEM occupations will require an additional 3.5 million workers by 2032 (Bureau of Labor Statistics, 2023). Without targeted, evidence-based science intervention, delivered equitably across all student populations, this gap will widen, foreclosing opportunity for millions of students and undermining the workforce foundation of the American economy

Table 1: **Display of the Logic Model for the Penda Learning Science Intervention Program**. The table shows specific resources (inputs), strategies and activities (outputs), and short- and long-term program outcomes for teachers and students, consistent with the IES REL framework (Lawton et al., 2014). The model demonstrates the program's theory of change and provides the evidentiary chain that is frequently required for grant applications, curriculum committee reviews, and district adoption presentations. Note: Each strategy's empirical basis is documented in Table 3.

The resources, expertise, funding, and evidence base you invest before any activity	*The specific, deliberate program actions you deliver using your inputs. Activities must*	*Direct, countable products of your activities. Outputs confirm delivery, they show the*	*Early changes in knowledge, skills, attitudes, or behaviors that result from outputs.*	*Sustained, meaningful changes the program ultimately exists to produce the*

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begins. Inputs establish credibility and capacity.	*be replicable and measurable to satisfy reviewers.*	*program ran as designed, not yet that it worked.*	*Measurable within one to two school years.*	*impact claims that justify continued investment and scaling.*
Penda Learning — Science Intervention Examples	**Penda Learning — Science Intervention Examples**	**Penda Learning — Science Intervention Examples**	**Penda Learning — Science Intervention Examples**	**Penda Learning — Science Intervention Examples**
•NGSS and state curriculum aligned for grades 3–12 science curriculum content, developed with science educators •Prior efficacy research and evidence base is reviewed •Trained Penda teacher support and implementation team set session and duration expectations •Established partnerships with Title I schools and districts •IES, Title I, Title IV-A, or SBIR grant funding •Technology platform infrastructure and LMS	•Deliver self-paced science lessons aligned to grade-level standards •Administer embedded formative assessments after each learning sequence •Provide real-time teacher dashboards showing student mastery and gaps •Run structured professional development sessions on data-driven instruction •Align all content to NGSS and state science standards by grade band •Prioritize deployment in Title I and underserved school communities	•Number of science lessons completed per student per semester •Formative assessments administered per class per month •Teacher dashboard logins and data review sessions per week •Professional development hours completed by participating teachers •NGSS-aligned lessons published and available in the platform •Number of students from Title I / underserved schools served •Schools and districts actively	•Students demonstrate stronger science conceptual understanding on assessments •Teachers use formative data to target and address specific misconceptions •Increased teacher confidence in facilitating science inquiry lessons •Students develop observable science inquiry and reasoning skills •Reduced student science anxiety; higher reported engagement and motivation •Teachers shift from lecture-only to data-informed	•Sustained, measurable growth in student science achievement scores •Equitable science outcomes across student populations and school contexts •Higher pass rates on state science standardized assessments •Students better prepared to enter STEM coursework and career pathways •Improved college and career readiness in science-related fields •Teachers sustain data-driven instructional practices beyond the program period

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integration capability	adjust language and reading level as appropriate •Provide ongoing implementation coaching and technical support to teachers	implementing the program	differentiated instruction •Students apply scientific vocabulary and concepts in new contexts	
Resources invested	→Program actions	→Delivery evidence	→Early changes	→Lasting impact
Theory of change: If students have consistent access to adaptive, NGSS-aligned science content (activities) and teachers receive real-time formative data (outputs), then students will build conceptual understanding and inquiry skills (short-term), leading to sustained gains in science achievement and STEM readiness (long-term).	**Theory of change:** If students have consistent access to adaptive, NGSS-aligned science content (activities) and teachers receive real-time formative data (outputs), then students will build conceptual understanding and inquiry skills (short-term), leading to sustained gains in science achievement and STEM readiness (long-term).	**Theory of change:** If students have consistent access to adaptive, NGSS-aligned science content (activities) and teachers receive real-time formative data (outputs), then students will build conceptual understanding and inquiry skills (short-term), leading to sustained gains in science achievement and STEM readiness (long-term).	**Theory of change:** If students have consistent access to adaptive, NGSS-aligned science content (activities) and teachers receive real-time formative data (outputs), then students will build conceptual understanding and inquiry skills (short-term), leading to sustained gains in science achievement and STEM readiness (long-term).	**Theory of change:** If students have consistent access to adaptive, NGSS-aligned science content (activities) and teachers receive real-time formative data (outputs), then students will build conceptual understanding and inquiry skills (short-term), leading to sustained gains in science achievement and STEM readiness (long-term).
Key assumptions: Adaptive content increases engagement | Teacher data use improves instructional decisions | Formative	**Key assumptions:** Adaptive content increases engagement | Teacher data use improves instructional decisions | Formative	**Key assumptions:** Adaptive content increases engagement | Teacher data use improves instructional decisions | Formative	**Key assumptions:** Adaptive content increases engagement | Teacher data use improves instructional decisions | Formative	**Key assumptions:** Adaptive content increases engagement | Teacher data use improves instructional decisions | Formative

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feedback accelerates mastery | Implementation fidelity is maintained with ongoing coaching support	feedback accelerates mastery | Implementation fidelity is maintained with ongoing coaching support	feedback accelerates mastery | Implementation fidelity is maintained with ongoing coaching support	feedback accelerates mastery | Implementation fidelity is maintained with ongoing coaching support	feedback accelerates mastery | Implementation fidelity is maintained with ongoing coaching support
External factors: School technology infrastructure | Teacher adoption and coaching receptivity | District curriculum alignment | Student attendance and family support | State science policy environment	**External factors:** School technology infrastructure | Teacher adoption and coaching receptivity | District curriculum alignment | Student attendance and family support | State science policy environment	**External factors:** School technology infrastructure | Teacher adoption and coaching receptivity | District curriculum alignment | Student attendance and family support | State science policy environment	**External factors:** School technology infrastructure | Teacher adoption and coaching receptivity | District curriculum alignment | Student attendance and family support | State science policy environment	**External factors:** School technology infrastructure | Teacher adoption and coaching receptivity | District curriculum alignment | Student attendance and family support | State science policy environment
Aligned funding streams: IES SBIR/STTR | Title I (ESEA) | Title IV-A Student Support & Academic Enrichment | IDEA Part B | NSF SBIR | State science literacy grants	**Aligned funding streams:** IES SBIR/STTR | Title I (ESEA) | Title IV-A Student Support & Academic Enrichment | IDEA Part B | NSF SBIR | State science literacy grants	**Aligned funding streams:** IES SBIR/STTR | Title I (ESEA) | Title IV-A Student Support & Academic Enrichment | IDEA Part B | NSF SBIR | State science literacy grants	**Aligned funding streams:** IES SBIR/STTR | Title I (ESEA) | Title IV-A Student Support & Academic Enrichment | IDEA Part B | NSF SBIR | State science literacy grants	**Aligned funding streams:** IES SBIR/STTR | Title I (ESEA) | Title IV-A Student Support & Academic Enrichment | IDEA Part B | NSF SBIR | State science literacy grants

How to use this logic model: Read from left to right to follow the theory of change from investment to impact. Each column builds on the one before it. Outputs confirm the program is running as designed; outcomes confirm it is producing the intended effects. The problem statement and theory of change (in the bottom rows) provide the narrative framing required for IES proposals. Funders and district evaluators will use this model to assess program coherence, implementation fidelity, and the plausibility of the causal claim.

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4. Design Principles Grounded in Learning Science Research

The following sections describe the core design principles underlying the Penda Learning platform and their grounding in peer-reviewed learning science research. The framing of this section follows the structure recommended in the IES REL literature on evidence-based intervention documentation (Lawton et al., 2014).

4.1 The 5E Instructional Model as Penda's Pedagogical Framework

The 5E Instructional Model (Bybee, 1997) is a constructivist, inquiry-based learning cycle explicitly designed to place students at the center of learning, emphasize inquiry and evidence, and structure instruction over coherent learning sequences rather than isolated lessons. The five phases are **Engage → Explore → Explain → Elaborate → Evaluate**. The model is intentionally sequenced; order matters for effectiveness, and it aligns directly with NGSS three-dimensional learning and constructivist learning theory (Piaget, 1954; Vygotsky, 1978).

Penda Learning operationalizes the 5E model digitally across its platform architecture. Table 2 below maps each 5E phase to the corresponding Penda features, evidence basis, and assessed alignment strength.

Table 2. Penda Learning Alignment to the 5E Instructional Model (Bybee, 1997)

Engage	Gamification, curiosity, motivation; phenomena-based prompts surfacing prior knowledge	Gamification activates curiosity and sustained attention; phenomena-based scenarios surface misconceptions (Malone & Lepper, 1987; Bybee, 1997)	**Very Strong**
Explore	PhET simulations, structured inquiry tasks, interactive digital investigations. Instructions for hands on activities as well as Vernier probe integrations are provided.	Structured digital exploration approximates inquiry; PhET simulations support hypothesis testing within a guided framework (NRC, 2012; Krajcik & Shin, 2014)	**Moderate**
Explain	Standard-aligned instructional content, immediate corrective feedback, scaffolded explanations	Platform delivers formal concept introduction post-exploration; corrective feedback explicitly addresses misconceptions (Shute, 2008; Bybee, 1997)	**Strong**

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Elaborate	Multi-level practice activities, retry loops, and application to new contexts for bonus points	Mastery-based retry loops and escalating activity levels extend conceptual understanding; Bloom's higher-order application stages (Bloom & Krathwohl, 1956; Dweck, 2006)	**Strong**
Evaluate	Embedded diagnostics, formative assessments, teacher dashboards	Continuous, multi-level assessment system aligned with ongoing evaluation; standards-level reporting supports data-driven instructional decisions (Hamilton et al., 2009; Fuchs & Fuchs, 2001)	**Very Strong**

Note. 5E model phases sourced from Bybee (1997) and Ballone Duran & Duran (2004). Alignment strength is assessed based on the degree of structural correspondence between Penda features and the pedagogical intent of each phase. "Structured Exploration" is the appropriate descriptor for Penda's Explore phase, which approximates but does not fully replicate open-ended, authentic inquiry.

Critical Note on the Explore Phase

It is important to distinguish between *structured exploration* and *authentic open-ended inquiry*. The Explore phase of the 5E model ideally requires open-ended investigation, physical or authentic student-designed experimentation, and student-led hypothesis testing. Penda addresses this phase through three complementary mechanisms: PhET simulations for conceptual model-building, Tuva data analysis tools for authentic data interpretation, and optional Vernier probe integration that enables students to conduct real-time laboratory experiments and collect empirical data directly within the platform. The digital simulation and structured inquiry components operate as “structured exploration” within a defined problem space; however, the Vernier probe integration represents a meaningful step toward fully authentic inquiry by enabling genuine hands-on data collection. Districts without access to Vernier should, wherever possible, complement Penda’s digital Explore experience with physical laboratory investigations, see Penda Learning’s Instructor’s Guide, to fully realize the 5E cycle.

4.2 Gamification and Engagement

Penda’s gamification architecture is grounded in Eccles’ *Expectancy-Value Theory* (Eccles, 1987; Wigfield & Eccles, 2000), which holds that motivation is a function of a student’s expectation of success and their perceived value of the task. Scaffolded activities and mastery-based retry directly boost students’ expectancy of success, the primary lever available to an instructional platform.

Malone and Lepper (1987) identified challenge, curiosity, control, and fantasy as the four intrinsic motivators most effectively activated by game-based learning environments. Penda activates all four: activities are calibrated to the student’s current level (challenge),

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phenomenon-based scenarios spark curiosity, students control avatar customization and peer competition selections (control), and SpaceCRAFT narrative provides fantasy. Plass, Homer, and Kinzer (2015) further establish that game mechanics, when grounded in cognitive and motivational theory, significantly improve both engagement and learning outcomes. Research also shows that competition elements, such as leaderboards, enhance effort and self-efficacy when properly calibrated (Bandura, Adams, & Beyer, 1977; Schunk, 1982).

A systematic review by Hamari, Koivisto, and Sarsa (2014), examining 24 empirical studies of gamification across educational and workplace contexts, found that gamification produces positive effects on motivation, engagement, and behavioral outcomes in the majority of cases, with the strongest effects observed when game mechanics are tightly aligned with the learning task rather than applied superficially. This finding directly supports Penda's design philosophy of grounding game elements, points, leaderboards, avatars, and the SpaceCRAFT narrative in the cognitive and motivational logic of science mastery, rather than treating gamification as an external reward layer. The review further notes that perceived meaningfulness of the game context is a key moderator of effect size, consistent with Penda's use of real-world science phenomena as the content anchor for all game-embedded activities.

4.3 Phenomenon-Based, Three-Dimensional Science Learning

Penda's instructional content is built around *A Framework for K–12 Science Education* (National Research Council, 2012) and the NGSS performance expectations, which call for students to engage simultaneously with Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs). Consistent with NGSS evidence statements, each activity is anchored in a real-world phenomenon.

Research on learning progressions suggests that science content is learned most effectively when it is sequenced by increasing rigor—following NGSS and state-specific standards—so that students build new understanding on simpler, prior concepts (Corcoran, Mosher, & Rogat, 2009; Duncan & Hmelo-Silver, 2009). Penda operationalizes this principle through two scaffolded activity levels per standard, *Emerging* and *Achieving*, which reflect Bloom's Taxonomy (Bloom et al., 1956; Anderson & Krathwohl, 2001) and Webb's Depth of Knowledge (Webb, 1997).

Both levels present students with the same rigorous content; the levels differ in readability. Emerging activities are written at or below grade level, and Achieving activities are at or above grade level. Within either level, questions increase in complexity and rigor as a student progresses through an activity. The "Remember It!" and "Review It!" segments revisit content from earlier grade bands, preparing students to access grade-level material. Every activity concludes with a "Communicate It!" screen, where students construct explanations, argue from evidence, and/or obtain, evaluate, and communicate information.

Penda's phenomenon-based instructional approach is further supported by the foundational cognitive science synthesis in Bransford, Brown, and Cocking (2000), How

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People Learn, which established that prior knowledge activation is the single strongest predictor of new learning. When students encounter a real-world phenomenon before receiving formal instruction, they bring their existing conceptual frameworks to the surface, enabling teachers and instructional systems to identify and address misconceptions directly. This is precisely the cognitive function of the 5E Engage phase, and it is what distinguishes phenomenon-based instruction from traditional content-delivery models. Bransford and colleagues further established that transfer of learning, the ability to apply knowledge to novel contexts, requires deep conceptual understanding rather than surface memorization, a finding that supports Penda's emphasis on three-dimensional sense-making over isolated recall.

Penda operationalizes Bloom's Taxonomy and Webb's Depth of Knowledge by embedding a named taxonomy of slide types in every activity. Lower-order recall and comprehension (DOK 1–2 / Bloom's Remember and Understand) are addressed through Remember It! and Learn It! slides. Application and analysis (DOK 2–3 / Bloom's Apply and Analyze) appear in Practice It!, Analyze It!, Predict It!, and Test It! slides. Higher-order synthesis and creation (DOK 3–4 / Bloom's Evaluate and Create) are engaged through Design It!, Model It!, Synthesize It!, and Communicate It! slides. This explicit cognitive architecture ensures that every Penda activity moves students through a deliberate progression from recall to reasoning, a design principle directly auditable against Bloom and Krathwohl (1956), Anderson, Krathwohl, and Bloom (2001), and Webb (1997).

Penda's three-dimensional learning progressions are operationalized using the NSTA Atlas of the Three Dimensions (Willard, 2022), a comprehensive mapping tool that diagrams how Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas connect within and across grade bands. This tool integrates the theoretical learning progression research of Duncan and Hmelo-Silver (2009) and Corcoran, Mosher, and Rogat (2009) from the academic literature into practical curriculum architecture, providing Penda's content designers with an auditable, standards-based blueprint for vertical alignment decisions. Content can be organized by domain (earth-space, life, physical) or by conceptual progressions aligned to NGSS Appendix K, depending on district preference, ensuring coherence across the full K–12 science continuum.

4.4 Immediate Feedback and Mastery-Based Progression

Penda provides immediate, screen-by-screen feedback on every student response. Incorrect answers are accompanied by detailed explanations, and students may reattempt the activity until mastery is achieved. Shute's (2008) comprehensive review established that timely, specific feedback on errors is a key element of quality formative assessment. Kornell, Hays, and Bjork (2009) demonstrated that even unsuccessful retrieval attempts, when followed by corrective feedback, enhance subsequent learning more than passive re-study.

The platform's mastery-based scoring system, which always keeps mastery attainable and rewards re-attempts with bonus points, reflects Dweck's (2006) growth mindset theory: the belief that intelligence is malleable and that effort leads to achievement. By designing

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out ceiling mastery and rewarding persistence, Penda fosters a growth mindset from a learner's first use.

The broader feedback literature further underscores the significance of this design. In their landmark synthesis of feedback research, Hattie and Timperley (2007) reported an average effect size of d = 0.73, placing feedback among the highest-leverage influences on student achievement. They identified the most effective feedback as addressing three questions: *Where am I going?* (feed-up), *How am I going?* (feed-back), and where *to next?* (feed-forward). Penda's screen-by-screen corrective feedback, standards-level mastery tracking, and activity progression collectively address all three for students, while the Weekly Class Mastery Report delivers feedback and feed-forward information to teachers. This dual-level feedback architecture, operating simultaneously at the student and teacher levels, is a distinctive design strength with robust empirical support.

The Cosmos AI instructional assistant extends Penda's feedback architecture by delivering on-demand, personalized scaffolding when students encounter difficulty. This design is grounded in Zimmerman's (2002) self-regulated learning framework, which identifies self-monitoring, goal-setting, and strategic resource use as metacognitive processes predictive of academic achievement. By prompting students to articulate what they know, what is confusing them, and what strategy they might try next, Cosmos builds these habits within the context of science learning. Critically, Cosmos operates within a closed, educator-controlled environment: students receive only pre-approved, curriculum-aligned support, ensuring that the instructional integrity of the activity and the safety of the digital environment are maintained.

4.5 Data-Driven Instruction and RTI/MTSS Support

Hattie (2009), in his synthesis of over 800 meta-analyses, found that feedback to *teachers* about what students know and do not know is among the highest-leverage interventions available. Penda's automated weekly and monthly reporting system operationalizes this finding at scale: every Monday, teachers receive a standards-level mastery report for every student without any data collection effort.

Hamilton and colleagues (2009) recommend that data be actionable, timely, and presented at the standard level, all three of which characterize Penda's reporting design. Fuchs and Fuchs (2001) established the research foundation for progress monitoring within RTI frameworks. Gersten and colleagues (2009) recommend screening all students for risk and monitoring progress as core RTI practices. Penda's integration with RTI/MTSS, through intervention group formation, targeted activity assignment, and ongoing mastery reporting, aligns directly with these evidence-based recommendations.

The economic stakes of effective data use in science instruction deserve emphasis here. U.S. Department of Commerce analyses document that STEM workers earn a wage premium of 26 percent above comparable non-STEM workers (Langdon et al., 2011), a premium that had grown to 29 percent by 2015 (Noonan, 2017). Georgetown University

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Center on Education and the Workforce research further identifies workforce credentials as among the most reliable pathways to economic mobility for workers from low-income backgrounds (Carnevale, Garcia, Ridley, & Quinn, 2020). When data-driven instruction enables earlier identification of science learning gaps and more targeted interventions, the downstream effect is a larger, more economically diverse STEM pipeline. Penda's automated mastery reporting system thus functions not only as an instructional tool but as an equity mechanism, ensuring that struggling students in every classroom receive targeted attention before small gaps become permanent tracking decisions that foreclose STEM opportunity.

4.6 Equity and Multilingual Access

Penda's built-in read-aloud, 100-language translation, and differentiated readability levels align with the principles of *Universal Design for Learning* (CAST, 2018), which call for multiple means of representation, engagement, and action as foundational to equitable instruction. Gersten and colleagues (2007) provide IES practice guide recommendations for ELL instruction, including explicit vocabulary and visual representations, both core Penda design features. The National Academies (2021) emphasize that equitable science education requires culturally responsive, linguistically accessible, and cognitively scaffolded experiences for historically underserved populations.

Within the 5E model, multilingual access is particularly critical at the Engage, Explore, and Explain phases, where students must understand phenomenon-based prompts, interpret investigation tasks, and articulate their emerging scientific understanding. Penda's translation and read-aloud features remove language as a barrier to participation in all five phases of the inquiry cycle. Penda's platform is further designed to meet WCAG 2.1/2.2 accessibility standards, providing the technical compliance framework that gives legal and programmatic weight to its UDL-based equity commitments. For districts operating under Section 508, ADA accessibility requirements, or state-level digital accessibility mandates, WCAG compliance ensures that Penda's inclusive design extends from pedagogical intent to technical implementation.

The equity imperative for access to science education is reinforced by the United States' demographic trajectory. Students of color now represent more than 55 percent of K–12 public school enrollment nationally (NCES, 2024), yet Black and Hispanic students score at the proficient level in science at rates of 14 and 18 percent, respectively, less than half the rate of their white peers. Ladson-Billings (1995) established that culturally relevant pedagogy, instruction that connects academic content to students' cultural backgrounds, lived experiences, and community contexts, significantly improves academic engagement and achievement among historically underserved learners. Penda's phenomenon-based activity design, which anchors science concepts in observable real-world events, is broadly consistent with this principle and provides teachers with an entry point to extend content into locally relevant contexts. Districts implementing Penda should consider supplementing the platform's universal equity tools with professional development in culturally responsive science pedagogy to maximize student engagement across diverse backgrounds. The national imperative is clear: a country that fails to develop the

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scientific potential of its fastest-growing demographic groups cannot sustain its STEM workforce, its research enterprise, or its long-term economic competitiveness.

4.7 High-Yield Instructional Strategies (Marzano Framework)

Penda's activity design and support structures are aligned with the high-yield instructional strategies identified by Marzano, Pickering, and Pollock (2001) in Classroom Instruction That Works, a synthesis of more than 100 studies identifying the nine categories of instructional strategy with the greatest average effect sizes on student achievement. Several of Marzano's highest-leverage strategies are directly embedded in Penda's instructional architecture: setting objectives and providing feedback (manifested through standards-based mastery targets and immediate screen-by-screen feedback); cues, questions, and advance organizers (manifested through Think About It! and Remember It! prompts that activate prior knowledge and establish a learning purpose); identifying similarities and differences (manifested through Crosscutting Concepts that require students to recognize patterns and cause-and-effect relationships across phenomena); and reinforcing effort and providing recognition (manifested through Penda's mastery-based scoring and gamification reward system). This alignment to Marzano's framework provides an additional evidence anchor for curriculum adoption committees, connecting Penda's design to one of the most widely recognized and practitioner-accessible instructional research syntheses in the K–12 field.

5. Tiered Evidence for ESSA

Evidence-based interventions are practices or programs supported by evidence demonstrating that they are effective at producing results and improving outcomes when implemented. The evidence described in ESSA is produced through formal studies and research, and ESSA recognizes four tiers, or levels, of evidence. The Penda Learning intervention provides evidence that we posit satisfies the evidence requirements of multiple ESSA tiers, with the highest applicable designation being Tier 2 (Moderate Evidence). The remainder of Section 5 documents that evidence in ascending order of rigor. Tier 4 (Demonstrates a Rationale) is established by Penda's well-defined logic model (Section 3), its articulated theory of change (Section 2.5), and the peer-reviewed research base supporting each component strategy (Table 3, below). Tier 3 (Promising Evidence) is established by the correlational dose-response and subgroup analyses (with statistical controls for selection bias) embedded within the Miller (2025) study (Section 5.2). Tier 2 (Moderate Evidence) is established by Miller (2025), a well-designed,well-implemented, multi-site quasi-experimental study that demonstrates baseline equivalence between treatment and comparison groups, statistically significant positive effects on a nationally normed outcome measure, and no negative findings (Section 5.3)

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5.1 Evidence Supporting ESSA Tiers

Per ESSA, an intervention qualifies for Tier 4 (Demonstrates a Rationale) when (a) it has a well-defined logic model or theory of action, (b) it is supported by research suggesting it is likely to improve student outcomes, and (c) there is an effort underway by a state, district, or research organization to determine its effectiveness. Penda Learning satisfies all three conditions. The logic model is presented in Section 3, and the theory of change in Section 2.5; the peer-reviewed research base supporting each component strategy is documented in Table 3 below; and a formal evaluation effort culminated in the Miller (2025) multi-site quasi-experimental study described in Section 5.3. Table 3 maps each strategy in the Penda Learning Logic Model to its underlying research base. The "evidence base" column references the peer-reviewed literature that grounds each strategy; the tier labels in the right-hand column reflect the strength of the research supporting that individual strategy and are not, in themselves, the ESSA tier designation of the Penda intervention as a whole. The intervention-level Tier 2 and Tier 3 designations are established by the empirical findings reported in Sections 5.2 and 5.3.

Table 3. Tiered Evidence for the Strategies in the Penda Learning Logic Model

Gamified, phenomenon-based science activities auto-assigned weekly (PAS)	Gamification and engagement theory (Malone & Lepper, 1987; Eccles, 1987); game-based learning (Plass, Homer, & Kinzer, 2015); motivation and self-efficacy (Bandura et al., 1977)	**Tier 3 – Promising Evidence**
Immediate screen-by-screen feedback; mastery-based retry until 100% achieved	Formative feedback (Shute, 2008); retrieval practice (Kornell, Hays, & Bjork, 2009); growth mindset (Dweck, 2006)	**Tier 1 – Strong Evidence**
Scaffolded 3D science activities sequenced by complexity (5E + Bloom's + Webb's DOK)	Learning progressions (Duncan & Hmelo-Silver, 2009); Bloom's Taxonomy (Bloom & Krathwohl, 1956; Anderson et al., 2001); Webb's Depth of Knowledge (Webb, 1997); 5E Model (Bybee, 1997)	**Tier 1 – Strong Evidence**
5E Explore phase: PhET simulations and structured inquiry tasks	Inquiry-based science instruction (NRC, 2000, 2012); simulation-based learning (Krajcik & Shin, 2014); 5E instructional model (Bybee, 1997; Ballone Duran & Duran, 2004); data analysis in science learning (Konold & Higgins, 2003); hands-on laboratory investigation (NRC, 2006)	**Tier 2 – Moderate Evidence**
Weekly Class Mastery Reports; data-driven differentiated instruction	Data-driven decision making (Hamilton et al., 2009; Al Otaiba et al., 2011; Connor et al., 2011); progress monitoring (Fuchs & Fuchs, 2001; Gersten et al., 2009)	**Tier 3 – Promising Evidence**

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RTI/MTSS intervention groups; Tier 2/3 targeted activity assignment based on mastery data	Small group / individual intervention for at-risk students (Gersten et al., 2009; Neitzel et al., 2022; Pellegrini et al., 2021); explicit systematic instruction (Kirschner, Sweller, & Clark, 2006)	**Tier 1 – Strong Evidence**
Student agency: avatar selection, peer challenges, personal mastery dashboard, retry-for-bonus	Active learning and student ownership (Grabinger & Dunlap, 1995; Tullis et al., 2018); Zone of Proximal Development (Vygotsky, 1978); Expectancy-Value Theory (Eccles, 1987; Wigfield & Eccles, 2000)	**Tier 2 – Moderate Evidence**
Equity access: read-aloud, 100+ language translation, differentiated readability levels	Universal Design for Learning (CAST, 2018); ELL science instruction (Gersten et al., 2007); equity in science education (National Academies, 2021)	**Tier 3 – Promising Evidence**
Teacher PD aligned to NGSS, data use, and 5E instructional facilitation	Implementation of fidelity and professional development (Gersten et al., 2009); 5E instructional support (Bybee, 1997; Ballone Duran & Duran, 2004); Standards for Professional Learning (Learning Forward, 2022); job-embedded coaching and transfer to practice (Joyce & Showers, 2002)	**Tier 3 – Promising Evidence**

5.2 Promising Evidence: Dose-Response, Mastery, and Correlational Findings

ESSA Tier 3 (Promising Evidence) requires at least one well-designed and well-implemented correlational study with statistical controls for selection bias. The analyses presented in the following Sections 5.2.1 through 5.3 satisfy this requirement. Within the Miller (2025) study, mastery counts and platform engagement levels were correlated with NWEA MAP Science growth using regression-based models that controlled for pre-test achievement, grade level, ethnicity, and gender as covariates—the statistical controls for selection bias that ESSA Tier 3 requires. The dose-response analysis (Section 5.2.1) showed a monotonic increase in post-test gains with activity mastery, with no ceiling effect at the 75th percentile of usage. The subgroup analyses (Section 5.3.1) showed statistically significant positive correlations between Penda use and outcome gains across all reported ethnic subgroups and among female students, with no negative findings. Reviewers should treat the findings below as a Tier 3 evidence layer that is independent of, and additive to, the Tier 2 designation established by the overall QED contrast in Section 5.3.

5.2.1 Recommended Usage (Dosage)

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In the Miller (2025) study, the recommended use of Penda Learning was at least 30 minutes of active platform engagement per week throughout the school year. This equates to approximately 3 sessions per week of 15-20 minutes, or 2 sessions of 20–30 minutes. Teachers were instructed to integrate Penda activities at least three times per week for 20–30 minutes per session.

Dose-response finding: The results from the Miller (2025) study confirmed a clear dose-response relationship; the more activities mastered, the greater the academic growth on the NWEA MAP Science assessment. There was no evidence of a ceiling effect at higher engagement levels; performance continued to increase even among students in the 75th percentile of platform usage. This finding underscores the importance of consistent, sustained engagement rather than sporadic high-intensity use.

5.2.2 Annual Mastery Expectation

Students are expected to demonstrate mastery of at least 15 science standards per school year. Mastery is defined as achieving 80% or higher on the embedded formative assessments associated with each standard. This threshold is consistent with Miller's (2025) study definition and with Penda's internal mastery-based progression design.

- Students completing 15–25 mastered activities (25th percentile of users) showed statistically significant and moderate effect-size growth gains (p,.01).
- Students completing 26–50 mastery activities (50th percentile) showed statistically significant and substantial effect-size growth (p,.01).
- Students completing 51+ mastered activities (75th+ percentile) showed statistically significant and the largest effect-size MAP Science growth gains (p,.01).
- Multiple regression analysis showed that the dose-response curve (mastery levels of the content) showed no flattening; higher mastery consistently predicted higher growth on standardized science measures (NWEA MAP Science) (p,<.01).

Implementation note: Teachers should monitor cumulative mastery counts on the teacher dashboard and intervene for students who are tracking below 15 standards at the mid-year checkpoint. The Pacing Assistance Service (PAS) auto-assigns activities at the correct pace, but teacher monitoring and re-engagement of low-usage students are essential for achieving the dose-response benefits documented in the research.

5.3 Well-Designed Research Evidence

Miller (2025) conducted a multi-site two-group quasi-experimental study (QED) across 46 Charter Schools USA sites in Florida, involving 18,738 students in Grades 3–8. The study employed an active business-as-usual comparison condition and used pre-test NWEA MAP Science scores as a covariate in a MANCOVA framework, satisfying the What Works Clearinghouse (WWC) requirement for baseline equivalence between the Penda treatment group and the comparison group at pre-test. This design meets ESSA Tier 2 (Moderate Evidence) criteria for a well-designed, well-implemented quasi-experimental study with a matched comparison group. Results showed statistically

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significant gains in science achievement among Penda Learning students relative to controls ($p < .001$). The average effect size (Hedges' g) was 0.56 (95% CI [0.53, 0.59]), a magnitude the WWC characterizes as substantively important and corresponding to a 21% average performance gain. Penda Learning students outperformed comparison students in proficiency (NWEA Level 3) by approximately 20 percentage points per grade. Effects were statistically significant across all reported ethnic subgroups and both genders, and no negative findings were observed for any outcome or subgroup. A dose-response relationship was confirmed: greater activity-level mastery predicted greater MAP Science growth, with no ceiling effect observed. Together, these features—baseline equivalence, statistically significant positive effects on an independent, nationally normed outcome measure, a real-world multi-site implementation, and the absence of negative findings—satisfy ESSA Tier 2 (Moderate Evidence) requirements as articulated in ESSA Section 8101(21)(A)(i)(II) and operationalized in the WWC Standards Handbook.

Table 4. Study Design with Suggested Institute of Education Evidence Tiers

Study Feature	Penda Learning vs Controls	Strength of Feature
Study design	Quasi-Experimental Design (QED) with pre-post assessment	Tier 2
Comparison group	Active controls (12,597 students in Grades 3–8 received business-as-usual instruction)	Tier 2
Causal inference	Yes, pre-test NWEA MAP Science used as MANCOVA covariate to assess treatment effects	Tier 1
Statistical significance	$p<.001$ overall; $p<.05$ for all subgroups (Gender, Ethnicity)	Tier 1
Sample size & setting	18,738 total students; 46 schools; real-world charter network implementation	Tier 1
Outcome measure	NWEA MAP Science (nationally normed, computer-adaptive, validated)	Tier 1
Effect size (Hedges' g)	0.56 overall (95% CI [0.53, 0.59]); range 0.36–0.82 by grade	Tier 1
Dose-response	Confirmed: more activities mastered the greater NWEA MAP science growth; no ceiling effect	Tier 1

Source: Miller, S.L. (2025). Science achievement gains from a computer-based learning platform: A multi-site quasi-experimental study. Elite Performance Solutions. Funded by Learning 2020, Inc.

5.3.1 Subgroup Impact — Equity Evidence

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The Miller (2025) study provides unusually comprehensive subgroup evidence. Statistically significant gains were observed for every ethnic subgroup reported compared to 'business-as-usual" control students ($p<.05$ for Group × Ethnicity interaction). While both male and female students using Penda Learning significantly outperformed the control subjects. The female students benefited significantly more than the male students (Group × Gender $F(1,28)=3.98$, $p<.05$). These findings indicate that Penda Learning reduced rather than widened equity gaps in science achievement:

- Black/African American students: The Penda group outperformed the control group peers at both pre-test and post-test, with gains exceeding those of the controls
- Hispanic/Latino students: Significant post-test gains over the control group; the Penda group outperformed at all measured time points
- American Indian/Alaska Native, Asian, Multi-ethnic, and White students: All showed significant post-test superiority for the Penda group vs. controls
- Female students: Benefited significantly more from Penda Learning than female controls ($p<.05$); middle school is identified as a critical inflection point where Penda's gains are especially valuable for sustaining girls' STEM interest

6. Conclusion

On the basis of the evidence presented in this report, Penda Learning satisfies the evidence requirements of ESSA Tier 4 (Demonstrates a Rationale), Tier 3 (Promising Evidence), and Tier 2 (Moderate Evidence). The Tier 4 threshold is met by a well-defined logic model (Section 3), an articulated theory of change (Section 2.5), a comprehensive research base for each component strategy (Section 4 and Table 3), and an active program of formal evaluation. The Tier 3 threshold is met by correlational dose-response and subgroup analyses with statistical controls for selection bias, drawn from a sample of 18,738 students across 46 schools (Section 5.2). The Tier 2 threshold is met by Miller (2025), a well-designed and well-implemented multi-site quasi-experimental study with baseline equivalence, statistically significant positive effects (Hedges' $g = 0.56$, $p<.001$) on the nationally normed NWEA MAP Science assessment, and no negative findings (Section 5.3).

Critically, Penda's architecture can be understood as a *digitally scaffolded implementation of the 5E instructional model* (Bybee, 1997). The platform delivers strong alignment across the Engage, Explain, Elaborate, and Evaluate phases, with a structured approximation of Explore through PhET simulations and guided inquiry tasks. This framing positions Penda not merely as a content-delivery tool but as a coherent pedagogical system grounded in constructivist learning theory and NGSS three-dimensional science education.

The Logic Model presented in Table 1 articulates a clear and coherent theory of change: when Penda is implemented with fidelity (Miller, 2025), the platform produces measurable short-term gains in engagement, vocabulary, and mastery monitoring; these

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gains compound into mid-term improvements in differentiated instruction and equitable access; and they ultimately drive long-term gains in student performance on independent, nationally normed science assessments, as documented in Miller (2025). Because Title I, Section 1003 (School Improvement) requires interventions supported by strong, moderate, or promising evidence (Tiers 1–3), and because all other programs under Titles I–IV may rely on Tiers 1–4, Penda Learning is eligible for funding consideration under both School Improvement and the broader Title I–IV programs. On the strength of the Miller (2025) quasi-experimental findings, state educational agencies, local educational agencies, and schools may classify Penda Learning as an evidence-based intervention at the ESSA Tier 2 (Moderate Evidence) level for science achievement in Grades 3–8, with concurrent qualification at Tiers 3 and 4.

7. References

Al Otaiba, S., Connor, C. M., Folsom, J. S., Greulich, L., Meadows, J., & Li, Z. (2011). Assessment data–informed guidance to individualize kindergarten reading instruction. The Elementary School Journal, 111 (4), 535–560.

Anderson, L. W., & Krathwohl, D. R. (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* Longman.

Ballone Duran, L., & Duran, E. (2004). The 5E instructional model: A learning cycle approach for inquiry-based science teaching. The Science Education Review, 3 (2), 49–58.

Bandura, A., Adams, N. E., & Beyer, J. (1977). Cognitive processes mediating behavioral change. Journal of Personality and Social Psychology, 35 (3), 125–139.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain.* David McKay.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). How people learn: Brain, mind, experience, and school (Expanded ed.). Washington, DC: National Academy Press.

Bureau of Labor Statistics. (2023). Occupational outlook handbook: STEM occupations, past, present, and future. Washington, DC: U.S. Department of Labor. Retrieved from https://www.bls.gov/ooh/architecture-and-engineering/home.htm

Bybee, R. W. (1997). Achieving scientific literacy: From purposes to practices. Portsmouth, NH: Heinemann.

Carnevale, A. P., Garcia, T. I., Ridley, N., & Quinn, M. C. (2020). The overlooked value of certificates and associate's degrees. Washington, DC: Georgetown University Center on Education and the Workforce.

CAST. (2018). Universal Design for Learning guidelines version 2.2. Wakefield, MA: Author. Retrieved from http://udlguidelines.cast.org

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Connor, C. M., Morrison, F. J., Schatschneider, C., Toste, J. R., Lundblom, E., Crowe, E. C., & Fishman, B. (2011). Effective classroom instruction: Implications of child characteristics by reading instruction interactions on first graders' word reading achievement. Journal of Research on Educational Effectiveness, 4 (3), 173–207.

Corcoran, T., Mosher, F. A., & Rogat, A. (2009). Learning progressions in science: An evidence-based approach to reform. Philadelphia, PA: Consortium for Policy Research in Education.

Darling-Hammond, L. (2022). Breaking the legacy of teacher shortages. Educational Leadership, 80(2), 14–20.

Duncan, R. G., & Hmelo-Silver, C. E. (2009). Learning progressions: Aligning curriculum, instruction, and assessment. Journal of Research in Science Teaching, 46(6), 606–609.

Dweck, C. (2006). Mindset. New York, NY: Random House.

Eccles, J. S. (1987). Gender roles and women's achievement-related decisions. *Psychology of Women Quarterly, 11*(2), 135–172.

Fuchs, L. S., & Fuchs, D. (2001). What is scientifically-based research on progress monitoring? National Center on Student Progress Monitoring.

Gersten, R., Baker, S. K., Shanahan, T., Linan-Thompson, S., Collins, P., & Scarcella, R. (2007). Effective literacy and English language instruction for English learners in the elementary grades (NCEE 2007-4011). Washington, DC: U.S. Department of Education, IES.

Gersten, R., Compton, D., Connor, C. M., Dimino, J., Santoro, L., Linan-Thompson, S., & Tilly, W. D. (2009). Assisting students struggling with reading: Response to Intervention (RtI) and multi-tier intervention in the primary grades (NCEE 2009-4045). Washington, DC: U.S. Department of Education, IES.

Grabinger, R. S., & Dunlap, J. C. (1995). Rich environments for active learning: A definition. Research in Learning Technology, 3 (2), 5–34.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does gamification work? A literature review of empirical studies on gamification.Proceedings of the 47th Hawaii International Conference on System Sciences (HICSS), 3025–3034.

Hamilton, L., Halverson, R., Jackson, S. S., Mandinach, E., Supovitz, J. A., & Wayman, J. C. (2009). Using student achievement data to support instructional decision making (NCEE 2009-4067). Washington, DC: U.S. Department of Education, IES.

Hanushek, E. A., & Woessmann, L. (2015).The knowledge capital of nations: Education and the economics of growth. Cambridge, MA: MIT Press.

Hattie, J., & Timperley, H. (2007). The power of feedback.Review of Educational Research, 77 (1), 81–112.

Hattie, J. A. C. (2009). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. New York, NY: Routledge.

©2026, Steven L Miller, all rights reserved.

Joyce, B., & Showers, B. (2002).Student achievement through staff development (3rd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work. Educational Psychologist, 41(2), 75–86.

Konold, C., & Higgins, T. L. (2003). Reasoning about data. In J. Kilpatrick, W. G. Martin, & D. Schifter (Eds.),A research companion to Principles and Standards for School Mathematics (pp. 193–215). Reston, VA: National Council of Teachers of Mathematics.

Korn Ferry. (2018). Future of work: The global talent crunch. Los Angeles, CA: Korn Ferry Institute. Retrieved from https://www.kornferry.com/insights/this-week-in-leadership/talent-crunch-future-of-work

Kornell, N., Hays, M. J., & Bjork, R. A. (2009). Unsuccessful retrieval attempts enhance subsequent learning. Journal of Experimental Psychology: Learning, Memory, & Cognition, 35(4), 989–998.

Kraft, M. A. (2020). Interpreting effect sizes of education interventions. Educational Researcher, 49(4), 241–253.

Krajcik, J. S., & Shin, N. (2014). Project-based learning. In R. K. Sawyer (Ed.), The Cambridge handbook of the learning sciences (2nd ed., pp. 275–297). Cambridge: Cambridge University Press.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. American Educational Research Journal, 32 (3), 465–491.

Langdon, D., McKittrick, G., Beede, D., Khan, B., & Doms, M. (2011). STEM: Good jobs now and for the future. Washington, DC: U.S. Department of Commerce, Economics and Statistics Administration, ESA Issue Brief #03-11. Retrieved from www.esa.doc.gov

Lawton, B., Brandon, P. R., Cicchinelli, L., & Kekahio, W. (2014). Logic models: A tool for designing and monitoring program evaluations (REL 2014–007). Washington, DC: U.S. Department of Education, IES, NCEE, Regional Educational Laboratory Pacific.

Learning Forward. (2022). Standards for professional learning. Oxford, OH: Author. Retrieved from https://learningforward.org/standards/

Malone, T. W., & Lepper, M. R. (1987). Making learning fun: A taxonomy of intrinsic motivations for learning. In R. E. Snow & M. J. Farr (Eds.), Aptitude, learning, and instruction: Vol. 3 (pp. 223–253). Hillsdale, NJ: Erlbaum.

Marzano, R. J., Pickering, D. J., & Pollock, J. E. (2001). Classroom instruction that works: Research-based strategies for increasing student achievement. Alexandria, VA: Association for Supervision and Curriculum Development.

Miller, S. L. (2025). Science achievement gains from a computer-based learning platform: A multi-site quasi-experimental study. IEEE Education Society, The 10th International STEM Education Conference Proceedings, pp. 1-6. DOI: 10.13140/RG.2.2.36799.88484

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National Academies of Sciences, Engineering, and Medicine. (2021). Call to action for science education: Building opportunity for the future. Washington, DC: The National Academies Press.

National Research Council. (1996). National science education standards. Washington, DC: National Academy Press.

National Research Council. (2000). Inquiry and the national science education standards. Washington, DC: National Academy Press.

National Research Council. (2006). America's lab report: Investigations in high school science. Washington, DC: The National Academies Press.

National Research Council. (2012). A framework for K–12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

National Center for Education Statistics. (2024).NAEP science: 2024 results. Washington, DC: U.S. Department of Education, Institute of Education Sciences. Retrieved from https://nces.ed.gov/nationsreportcard/

National Science Foundation. (2024). Science and Engineering Indicators 2024. Alexandria, VA: National Center for Science and Engineering Statistics. Retrieved from https://ncses.nsf.gov/indicators

Neitzel, A. J., Lake, C., Pellegrini, M., & Slavin, R. E. (2022). A synthesis of quantitative research on programs for struggling readers in elementary schools. Reading Research Quarterly, 57 (1), 149–179.

Noonan, Ryan. Office of the Chief Economist, Economics and Statistics Administration, U.S. Department of Commerce. (March 30, 2017). STEM Jobs: 2017 Update (ESA Issue Brief # 02-17). Retrieved from https://www.commerce.gov/sites/default/files/migrated/reports/stem-jobs-2017-update.pdf

NWEA. (2024). MAP Growth: Precisely measure student growth and performance. Portland, OR: NWEA. Retrieved from https://www.nwea.org/map-growth/

OECD. (2023). PISA 2022 results (Volume I): The state of learning and equity in education. Paris: OECD Publishing. https://doi.org/10.1787/53f23881-en

Pellegrini, M., Lake, C., Neitzel, A., & Slavin, R. E. (2021). Effective programs in elementary mathematics: A meta-analysis. AERA Open, 7 (1), 1–29.

Perie, M., Marion, S., & Gong, B. (2009). Moving toward a comprehensive assessment system: A framework for considering interim assessments. Educational Measurement: Issues and Practice, 28 (3), 5–13.

Piaget, J. (1954). The construction of reality in the child. New York, NY: Basic Books.

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of game-based learning. Educational Psychologist, 50 (4), 258–283.

©2026, Steven L Miller, all rights reserved.

Reid, A. J., & Neitzel, A. (2022). Exact Path with Standards Mastery: A report for tiered evidence for ESSA and logic model. Baltimore, MD: Johns Hopkins University, Center for Research and Reform in Education.

Schunk, D. H. (1982). Effects of effort attributional feedback on children perceived self-efficacy and achievement. Journal of Educational Psychology, 74(4), 548–556.

Semiconductor Industry Association & Oxford Economics. (2023). Chipping away: Assessing and addressing the labor market gap facing the U.S. semiconductor industry. Washington, DC: Semiconductor Industry Association.

Shakman, K., & Rodriguez, S. M. (2015). Logic models for program design, implementation, and evaluation: Workshop toolkit (REL 2015–057). Washington, DC: U.S. Department of Education, IES, NCEE, Regional Educational Laboratory Northeast & Islands.

Shute, V. J. (2008). Focus on formative feedback. Review of Educational Research, 78 (1), 153–189.

Sutcher, L., Darling-Hammond, L., & Carver-Thomas, D. (2016). A coming crisis in teaching? Teacher supply, demand, and shortages in the United States. Palo Alto, CA: Learning Policy Institute.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. Science, 312(5777), 1143–1144.

Tullis, J. G., Fiechter, J. L., & Benjamin, A. S. (2018). The efficacy of learners' testing choices. Journal of Experimental Psychology: Learning, Memory, & Cognition, 44(4), 540–552.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Wang, M.-T. (2012). Educational and career interests in math: A longitudinal examination of the links between classroom environment, motivational beliefs, and interests. Developmental Psychology, 48(6), 1643–1657.

Webb, N. L. (1997). Criteria for alignment expectations and assessments in mathematics and science education (Research Monograph No. 6). Madison, WI: University of Wisconsin–Madison, WCER.

Wigfield, A., & Eccles, J. S. (2000). Expectancy-value theory of achievement motivation. Contemporary Educational Psychology, 25 (1), 68–81.

Willard, T. (Ed.). (2022). NSTA Atlas of the Three Dimensions. Arlington, VA: NSTA Press.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. Theory Into Practice, 41 (2), 64–71.

Zuo, G., Doan, S., & Kaufman, J. H. (2023). How do teachers spend professional learning time, and does it connect to classroom practice? Findings from the 2022 American Instructional Resources Survey (RR-A134-18). Santa Monica, CA: RAND Corporation.

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8. Glossary of Key Terms

The following glossary defines key terms, acronyms, and theoretical frameworks used throughout this report. Terms are organized alphabetically. Where a term has a commonly used abbreviation, it is noted in *italics* beneath the term name. Inline citations identify the primary source for each definition where applicable.

A	A
Adaptive Learning	An instructional approach in which the system dynamically adjusts content, difficulty, sequencing, or support based on individual learner performance data. Adaptive systems may use algorithms, diagnostic data, or teacher-directed groupings to personalize the learning path. Penda operationalizes adaptive learning through the Pacing Assistance Service (PAS), differentiated activity levels, and teacher-directed RTI/MTSS intervention groupings. (*Neitzel et al., 2022*)
AI Instructional Assistant	A software-based pedagogical tool that uses artificial intelligence to provide personalized academic support, scaffolding, and guidance within a digital learning environment. Cosmos is Penda's AI instructional assistant, operating within a closed educator-controlled environment. See also: Cosmos AI Instructional Assistant.
Assessment, Diagnostic	An assessment administered before or at the start of instruction to identify students' prior knowledge, skill gaps, and readiness levels. Diagnostic assessment informs initial placement and instructional planning. In Penda, diagnostic assessments place students into appropriate scaffolded activity levels and inform RTI/MTSS tier assignment.
Assessment, Formative	Ongoing assessment conducted during instruction to monitor student progress, provide feedback, and adjust teaching in real time. Formative assessment is distinguished from summative assessment in that it is used to improve learning rather than to certify it. Penda's embedded activity-level feedback, mastery tracking, and weekly Class Mastery Reports function as formative assessments. (*Perie, Marion, & Gong, 2009; Shute, 2008*)
Assessment, Summative	Assessment conducted at the end of a unit, course, or program to measure the degree of student learning against established standards. Summative assessments are used for accountability and reporting purposes. In the context of this report, state science assessments (e.g., FCAT, STAAR, PSSA) serve as the primary long-term summative outcome measures for Penda efficacy.

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B	**B**
Bloom's Taxonomy	A hierarchical framework for classifying educational goals and cognitive tasks, organized from lower-order thinking skills (remembering, understanding, applying) to higher-order thinking skills (analyzing, evaluating, creating). Originally developed by Benjamin Bloom and colleagues in 1956 and revised by Anderson, Krathwohl, and Bloom in 2001. Penda's two-level scaffold per standard (Emerging and Achieving) reflects Bloom's progression from knowledge recall to application and analysis. (*Bloom & Krathwohl, 1956; Anderson, Krathwohl, & Bloom, 2001*)
Business-as-Usual Controls	The comparison condition in Miller (2025) study. Students in the control group (n=12,597, Gr 3–8, across 46 schools) received standard science instruction without access to the Penda Learning platform. This is characterized as an "active control" because students received regular instruction rather than a no-treatment condition.
C	**C**
Coaches Academy	Penda Learning's train-the-trainer professional development model in which district instructional coaches are trained to facilitate ongoing job-embedded professional learning, differentiation coaching, and data-driven instruction support within their own school community. Grounded in Joyce and Showers (2002).
Comprehending Score	In reading/miscue analysis: the proportion of errors that preserve meaning or are self-corrected. In Penda context: analogous concept applied to tracking whether student errors on science activities reflect conceptual understanding gaps.
Constructivism	A learning theory, grounded in the work of Piaget and Vygotsky, holding that learners actively construct knowledge through experience, reflection, and interaction with their environment, rather than passively receiving information. The 5E Instructional Model is explicitly grounded in constructivist principles. Penda's iterative mastery loops, student-driven exploration, and inquiry-based activities reflect constructivist design. (*Vygotsky, 1978; Bybee, 1997*)

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Cosmos AI Instructional Assistant	An AI-powered instructional assistant built directly into the Penda student platform. Cosmos delivers structured academic support through pre-set, content-specific prompts. It guides students through productive struggle by asking clarifying questions and scaffolding thinking without providing direct answers. Operates in a closed, educator-controlled environment. Grounded in Zimmerman's (2002) self-regulated learning framework. See Section 3.
Crosscutting Concepts (CCCs)	One of the three dimensions of the Next Generation Science Standards (NGSS) Framework. CCCs are overarching scientific concepts that apply across all domains of science and engineering, including patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. Penda activities integrate CCCs alongside Science and Engineering Practices and Disciplinary Core Ideas. (*National Research Council, 2012*)
D	**D**
Data-Driven Instruction (DDI)	An instructional approach in which teachers systematically analyze student performance data to inform decisions about what to teach, how to teach it, and which students need additional support. Penda supports DDI through automated weekly Class Mastery Reports, monthly Grade-Level Mastery Reports, and a real-time teacher dashboard tracking standards-level mastery by student. (*Hamilton et al., 2009*)
Depth of Knowledge (Webb's DOK) *DOK*	A framework developed by Norman Webb that classifies cognitive tasks by their level of complexity and the context in which the knowledge is applied, ranging from Level 1 (recall) to Level 4 (extended thinking requiring complex reasoning and synthesis). Unlike Bloom's Taxonomy, DOK emphasizes the complexity of the task context rather than the nature of the cognitive operation. Penda's scaffolded activity levels are aligned with DOK progressions. (*Webb, 1997*)
Differentiated Instruction	An instructional approach in which teachers adjust content, process, product, or learning environment based on individual student readiness, interests, or learning profiles. Penda supports differentiated instruction through teacher-assigned intervention groups, differentiated activity scaffolding levels (developing, achieving, exceeding), and standards-level mastery data that enables targeted reassignment.

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Disciplinary Core Ideas (DCIs)	One of the three dimensions of the NGSS Framework. DCIs are the fundamental scientific ideas in each of the four science domains, physical sciences, life sciences, earth and space sciences, and engineering, that have broad importance within or across disciplines and provide a key tool for understanding complex ideas. Penda activities are designed to develop students' understanding of DCIs in integration with SEPs and CCCs. (*National Research Council, 2012*)
Dose-Response Relationship	A causal or correlational pattern in which increasing levels of an intervention (the dose) are associated with increasing levels of an outcome (the response). Miller (2025) confirmed a dose-response relationship for Penda: more activities mastered = greater MAP Science growth, with no ceiling effect. This finding strengthens causal inference regarding Penda's impact.
E	**E**
Effect Size (Hedges' g) *g*	A standardized measure of the magnitude of an intervention's impact, expressed in standard deviation units. Hedges' g is the effect size statistic used in the Miller (2025) study, calculated under a fixed-effects model. Average g=0.56 for Penda (95% CI [0.53, 0.59]) indicates more than half a standard deviation of growth within a single academic year. Effect sizes of 0.20–0.25+ are considered educationally meaningful (Kraft, 2020). Penda's range of 0.36–0.82 by grade exceeds this threshold.
Elaborate (5E Phase)	The fourth phase of the 5E Instructional Model. In this phase, students apply their newly acquired conceptual understanding to new contexts, extend their thinking, and deepen mastery beyond the initial learning experience. Penda aligns to this phase through multi-level practice activities, retry-for-bonus-points loops, and escalating difficulty levels that require students to transfer knowledge to increasingly complex applications. (*Bybee, 1997*)
Engage (5E Phase)	The first phase of the 5E Instructional Model. This phase activates prior knowledge, surfaces misconceptions, and builds curiosity and problem framing by connecting students to a real-world phenomenon. Penda's phenomenon-based activity framing, gamification mechanics (points, avatars, leaderboards), and SpaceCRAFT narrative mission provide strong alignment to the Engage phase by activating curiosity, motivation, and sustained attention from first interaction. (*Bybee, 1997; Malone & Lepper, 1987*)
Equitable Science Education	An approach to science instruction that ensures all students, regardless of race, language, socioeconomic status, disability

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	status, or prior achievement, have meaningful access to rigorous, high-quality science content and experiences. Penda addresses equity through read-aloud functionality, 100+ language translations, differentiated readability levels, and scaffolded activities designed for ELL, SPED, and Title I student populations. (*National Academies, 2021; CAST, 2018*)
ESSA Tiered Evidence *ESSA*	A four-tier framework established by the Every Student Succeeds Act (2015) for classifying the strength of evidence supporting educational interventions. Tier 1 (Strong Evidence) requires at least one well-designed randomized controlled trial; Tier 2 (Moderate Evidence) requires at least one quasi-experimental study; Tier 3 (Promising Evidence) requires at least one correlational study with statistical controls; Tier 4 (Demonstrates a Rationale) requires a logic model supported by research. ESSA tiers inform federal program funding decisions.
Evaluate (5E Phase)	The fifth and final phase of the 5E Instructional Model. Evaluation is ongoing throughout the learning cycle (not just terminal) and includes both student self-assessment and teacher assessment of student understanding. Penda demonstrates very strong alignment to this phase through its embedded diagnostic and formative assessments, standards-based mastery tracking, Weekly Class Mastery Reports, Monthly Grade-Level Mastery Reports, and real-time teacher dashboard. (*Bybee, 1997; Hamilton et al., 2009*)
Expectancy-Value Theory	A motivational framework developed by Jacquelynne Eccles and colleagues holding that student motivation is a function of two factors: (1) the student's expectation of success on a task, and (2) the student's perceived value of achieving that task. Students are most motivated when both expectancy and value are high. Penda boosts expectancy through scaffolded activities and mastery-based retry (success is always attainable) and builds value through phenomena-based, real-world science contexts. (*Eccles, 1987; Wigfield & Eccles, 2000*)
Explain (5E Phase)	The third phase of the 5E Instructional Model. After exploration, students articulate their emerging understanding and teachers introduce formal scientific concepts, vocabulary, and explanations to address any remaining misconceptions. Penda aligns to this phase through standards-aligned instructional content, immediate corrective feedback with explanations following incorrect responses, and vocabulary scaffolding with visuals and definitions. (*Bybee, 1997; Shute, 2008*)

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Explore (5E Phase)	The second phase of the 5E Instructional Model. Students engage in hands-on, inquiry-driven investigation, testing hypotheses, collecting data, and collaborating, before receiving formal instruction. Penda provides structured digital exploration through 100+ PhET interactive simulations and guided inquiry tasks. This is characterized as "structured exploration" rather than fully open-ended authentic inquiry, as Penda's tasks operate within defined digital problem spaces. See also: PhET Simulations. (*Bybee, 1997; Krajcik & Shin, 2014*)
F	**F**
Fidelity of Implementation	The degree to which a program is implemented as intended by its designers, including adherence to the prescribed dosage, delivery methods, content, and support structures. Fidelity is a prerequisite for realizing the effect sizes documented in efficacy research. For Penda, fidelity means students completing 2–3 activities per week and teachers regularly reviewing and acting on weekly mastery data.
G	**G**
Gamification	The application of game design mechanics and motivational principles to non-game contexts, including education, to increase engagement, motivation, and persistence. Common elements include points, leaderboards, badges, rewards, levels, and narrative progression. Penda's gamification architecture, encompassing avatars, leaderboards, SpaceCRAFT missions, retry bonuses, and 14 virtual worlds, is grounded in the four intrinsic motivators identified by Malone and Lepper (1987): challenge, curiosity, control, and fantasy. (*Malone & Lepper, 1987; Plass, Homer, & Kinzer, 2015; Eccles, 1987*)
Growth Mindset	A concept developed by Carol Dweck (2006) referring to the belief that intelligence and ability are malleable, that is, they can be developed through effort and effective strategies, as opposed to a fixed mindset, which views intelligence as innate and unchangeable. Penda's mastery-based scoring (where 100% is always attainable), retry-for-bonus-points architecture, and forgiving feedback system are explicitly designed to instill a growth mindset orientation in learners. (*Dweck, 2006*)
Guaranteed and Viable Curriculum (GVC) *GVC*	An educational model (Marzano et al.) emphasizing evidence-based instructional strategies and alignment with state standards, ensuring all students access the same high-quality, standards-

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	aligned content. The GVC framework was the instructional context for the Miller (2025) study at Charter Schools USA sites.
H	**H**
Hedges' g *g*	See Effect Size (Hedges' g).
I	**I**
IES Logic Model	A standard evaluation framework required by the Institute of Education Sciences for federally funded education research and programs. Maps the chain from resources (inputs) through program delivery (activities, outputs) to educational impact (short-term and long-term outcomes). The framework used to structure this document. (Lawton et al., 2014; Shakman & Rodriguez, 2015)
Implementation Fidelity	See: Fidelity of Implementation.
Inquiry-Based Learning	An instructional approach in which students construct knowledge through question-driven exploration, investigation, and evidence-based reasoning, rather than through passive reception of teacher-delivered content. The 5E model is fundamentally an inquiry cycle. Penda supports inquiry through phenomenon-based activity framing, PhET simulation-based exploration, and student-driven interaction characterized as structured digital inquiry. (*National Research Council, 2000; Bybee, 1997*)
L	**L**
Learning Management System (LMS) *LMS*	A software platform used by schools and districts to deliver, manage, and track educational content, assignments, and student progress. Common LMS platforms in K–12 education includes Canvas, Schoology, and Google Classroom. Penda integrates with Canvas and Schoology via LTI 1.3 Advantage protocols, enabling automatic grade sync and seamless access without leaving the LMS environment.
Learning Progressions	A research-based approach to curriculum design in which academic content is organized into coherent sequences of increasing rigor and complexity. Each stage in the progression builds on prior knowledge, allowing students to advance toward higher achievement levels incrementally. Penda's two-level scaffold per standard (Emerging and Achieving) directly

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	operationalizes learning progressions theory. (*Duncan & Hmelo-Silver, 2009; Corcoran, Mosher, & Rogat, 2009*)
Learning Tools Interoperability (LTI) *LTI*	An industry standard developed by IMS Global (now 1EdTech) that enables seamless, secure integration between a learning application and a Learning Management System. LTI 1.3 Advantage is the current standard and supports features including grade passback, deep linking, and roster sync. Penda supports LTI 1.3 integration with Canvas and Schoology, enabling automatic grade book synchronization.
Logic Model	A graphical representation that describes the theory of action underlying a program or intervention by mapping the relationships between inputs (resources), activities, outputs, and short-, mid-, and long-term outcomes. Logic models are required or strongly encouraged by the U.S. Department of Education for programs seeking federal funding and serve as the foundation for program evaluation design. (*Lawton, Brandon, Cicchinelli, & Kekahio, 2014; REL 2014–007*)
M	**M**
MANCOVA	Multivariate Analysis of Covariance. A statistical procedure used in the Miller (2025) study to test group differences (Penda vs. control) on multiple dependent variables (Spring NWEA MAP by grade, gender, and ethnicity) while controlling pre-existing differences using the Fall pre-test as a covariate. The primary analysis revealed $F(1,28)=41.2$, $p<.001$.
Mastery-Based Progression	An instructional design approach in which students must demonstrate a specified level of competence (mastery threshold) before advancing to more complex content. Penda requires 80%+ on embedded assessments for mastery. Students who do not meet the threshold revisit content, retry, and earn bonus points for improvement, reflecting Bloom's mastery learning theory.
Mastery Learning	An instructional model, developed by Benjamin Bloom, in which students are required to demonstrate proficiency on a learning objective before advancing to the next one. Students who do not initially meet the mastery threshold receive corrective instruction and additional practice opportunities. Penda's retry-until-mastery architecture, bonus points for re-attempts, and three-level activity scaffolding directly operationalize mastery learning principles. (*Bloom & Krathwohl, 1956*)
Multi-Tiered System of Supports (MTSS) *MTSS*	A schoolwide framework for providing graduated levels of support to all students based on assessed need, integrating academic instruction, behavioral support, and social-emotional learning. MTSS typically comprises three tiers: Tier 1 (universal

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	instruction for all students), Tier 2 (targeted small-group intervention), and Tier 3 (intensive individualized intervention). Penda is designed to serve students at all three tiers simultaneously, with PAS-driven auto-assignment supporting Tier 1 and teacher-directed intervention groups supporting Tiers 2 and 3.
N	**N**
Next Generation Science Standards (NGSS) *NGSS*	A set of K–12 science content standards developed through a state-led process and released in 2013, based on the Framework for K–12 Science Education (NRC, 2012). NGSS define what students should know and be able to do in science by the end of each grade band. Each performance expectation integrates three dimensions: Disciplinary Core Ideas (DCIs), Science and Engineering Practices (SEPs), and Crosscutting Concepts (CCCs). Penda's content library is hand-crafted to NGSS performance expectations for grades 3 through high school. (*National Research Council, 2012*)
NWEA MAP Growth Science *MAP*	Measures of Academic Progress (MAP) Growth Science Assessment. A nationally normed, computer-adaptive assessment measuring science achievement and growth over time with strong psychometric properties. Used as the primary independent outcome measure in the Miller (2025) efficacy study. Level 3 on MAP is considered proficient for science accountability purposes. (NWEA, 2024)
P	**P**
Pacing Assistance Service (PAS) *PAS*	Penda Learning's proprietary automated sequencing service that aligns the Penda science activity library to a district's specific scope and sequence calendar, then auto-assigns standards-aligned activities to students on a weekly basis. PAS eliminates teacher planning burden, ensures student practice is synchronized with current classroom instruction, and enables fidelity of implementation at scale.
Phenomenon-Based Learning	An instructional approach, central to NGSS-aligned science education, in which instruction is anchored in observable, real-world phenomena that students are motivated to explain. The phenomenon serves as the context for all three dimensions of three-dimensional learning (SEPs, CCCs, DCIs). Every Penda activity is phenomenon-based, ensuring that students engage with science as a sense-making practice rather than as a collection of isolated facts. (*National Research Council, 2012*)

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PhET Interactive Simulations	Free, research-based interactive science and mathematics simulations developed by the University of Colorado Boulder. PhET simulations allow students to explore scientific phenomena, test hypotheses, visualize abstract concepts, and engage in data collection within a virtual environment. Penda has integrated 100+ PhET simulations into its platform to strengthen alignment to the Explore phase of the 5E model and to provide authentic inquiry-based digital learning experiences. (*Krajcik & Shin, 2014*)
Professional Learning Community (PLC) *PLC*	A collaborative group of educators who meet regularly to examine student data, share instructional strategies, and collectively improve their practice. Penda's implementation protocol includes monthly PLC sessions facilitated by Penda coaches or Coaches Academy-trained internal coaches. (Learning Forward, 2022; Joyce & Showers, 2002)
Progress Monitoring	A systematic process of regularly measuring student performance on key skills or standards to evaluate whether students are making adequate progress and to identify those who need additional intervention. Progress monitoring is a core practice in both RTI and MTSS frameworks. Penda's weekly and monthly mastery reports serve as automated progress monitoring tools for both teachers and administrators. (*Fuchs & Fuchs, 2001*)
Productive Struggle	A pedagogical approach in which students are supported to work through challenging problems independently, developing cognitive resilience and metacognitive skills, rather than receiving immediate corrective assistance. Cosmos AI is specifically designed to support productive struggle without resolving it prematurely.
R	**R**
RIT (Rasch Unit) *RIT*	The scale unit used by NWEA MAP Growth assessments. RIT scores are equal-interval, enabling comparison of growth across grade levels and time points. The Miller (2025) study reports gains in RIT units for Penda Learning vs. control groups.
Response to Intervention (RTI) *RTI*	A multi-tier framework for early identification of and support for students with learning and behavioral needs, in which the intensity of intervention is matched to assessed student need across three tiers. RTI relies on universal screening, frequent progress monitoring, and evidence-based interventions delivered with fidelity. Penda's assessment and reporting infrastructure is purpose-built to support RTI implementation, with intervention group formation, targeted activity assignment, and ongoing

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	mastery reporting across all three tiers. (*Gersten et al., 2009; Fuchs & Fuchs, 2001*)
Retrieval Practice	A learning strategy in which students actively reconstruct knowledge from memory rather than re-reading or passively reviewing material. Research consistently shows that retrieval practice produces stronger, more durable long-term retention than passive study, even when initial retrieval attempts are unsuccessful, as the effort of retrieval itself enhances subsequent learning. Penda's activity-based practice, retry loops, and mastery-based re-attempts leverage retrieval practice principles. (*Kornell, Hays, & Bjork, 2009*)
S	**S**
FL-SASS (Florida Science Academic Standards) *SASS*	Florida's state-adopted science standards that define what students should know and be able to do in science at each grade level. Penda has hand-crafted three differentiated scaffolded activity levels for every Florida SASS standard from grades 3 through high school biology, making it one of the most comprehensively aligned science platforms for Florida districts.
Scaffolding	A temporary instructional support structure that helps students engage with content or tasks that are beyond their current independent capability, with the goal of gradually fading support as proficiency develops. Scaffolding is grounded in Vygotsky's concept of the Zone of Proximal Development. In Penda, scaffolding takes the form of two activity levels per standard (Emerging and Achieving), differentiated readability, read-aloud support, visual representations, and immediate corrective feedback. (*Vygotsky, 1978*)
Science and Engineering Practices (SEPs) *SEPs*	One of the three dimensions of the NGSS Framework. SEPs describe the eight key practices that scientists and engineers use to investigate the natural world and design solutions to problems, including asking questions, developing models, planning investigations, analyzing data, constructing explanations, engaging in argument from evidence, and communicating information. Penda activities integrate SEPs alongside CCCs and DCIs in every three-dimensional learning experience. (*National Research Council, 2012*)
Self-Efficacy	An individual's belief in their own capacity to successfully perform a task or achieve a goal. High self-efficacy is associated with increased effort, persistence, and academic achievement. Penda's mastery-based scoring (where success is always attainable), retry-for-bonus-points design, and scaffolded activity

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	levels are explicitly designed to build student self-efficacy in science. (*Bandura, Adams, & Beyer, 1977; Schunk, 1982*)
Self-Regulated Learning	A model of learning (Zimmerman, 2002) in which students actively monitor their own understanding, set learning goals, and deploy cognitive strategies purposefully. Students high in self-regulation show significantly greater academic achievement. Cosmos AI is designed to build self-regulatory habits, monitoring, goal-setting, and strategic resource use, through structured scaffolding.
Single Sign-On (SSO) *SSO*	An authentication method that allows users to log in once and gain access to multiple systems without re-entering credentials. Penda supports SSO integration through Clever and ClassLink, enabling students and teachers to access Penda directly through their existing school login credentials, reducing friction and supporting consistent platform usage.
SpaceCRAFT	Penda Learning's narrative gamification framework, a science mission storyline spanning 14 virtual worlds that provides the fantasy motivation element identified by Malone and Lepper (1987) as a core intrinsic motivator for game-based learning. Students earn points, unlock worlds, and progress through the SpaceCRAFT narrative as they master science standards.
T	**T**
TEKS (Texas Essential Knowledge and Skills) *TEKS*	Texas' state-adopted curriculum standards, including for science, that define the knowledge and skills students are expected to master at each grade level. Penda has hand-crafted activities and assessments aligned to the science TEKS for grades 3 through Biology, making it one of the most comprehensively aligned science platforms for Texas districts.
Theory of Change	A systematic and cumulative description of how and why a program is expected to produce its intended outcomes, linking inputs and activities to short-, mid-, and long-term results through a chain of causal logic. The Theory of Change differs from a Logic Model in that it makes the underlying causal assumptions explicit. Penda's Theory of Change operates across six sequential layers: Engagement → Accessibility → Instruction → Practice & Mastery → Data → Improved Science Outcomes.
Three-Dimensional Learning	The instructional approach at the heart of the NGSS Framework, requiring that students simultaneously engage with all three dimensions of science: Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), and Disciplinary Core Ideas (DCIs). Three-dimensional learning represents a fundamental shift from traditional science instruction focused on content memorization toward science as a practice of sense-making.

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	Every Penda activity integrates all three dimensions. (*National Research Council, 2012*)
Tier 1 Instruction	Within RTI/MTSS frameworks, Tier 1 refers to high-quality, evidence-based core instruction delivered to all students in the general education classroom. Tier 1 is universal and should be sufficient to meet the needs of approximately 80% of the student population. Penda is explicitly designed to function as a Tier 1 supplemental instructional resource through PAS-driven weekly auto-assignment for all students.
Tier 2 Intervention	Within RTI/MTSS frameworks, Tier 2 refers to targeted, supplemental intervention provided to students who have not responded sufficiently to Tier 1 instruction, typically delivered in small groups. Tier 2 should serve approximately 10–15% of the student population. Penda supports Tier 2 through teacher-formed intervention groups and targeted activity assignment based on weekly mastery data.
Tier 3 Intervention	Within RTI/MTSS frameworks, Tier 3 refers to intensive, individualized intervention for students with significant learning needs who have not responded to Tier 1 and Tier 2 supports, typically delivered one-on-one or in very small groups. Tier 3 should serve approximately 3–5% of the student population. Penda supports Tier 3 through individualized activity assignment, diagnostic assessment data, and integration with teacher-provided small-group instruction.
U	**U**
Universal Design for Learning (UDL) *UDL*	A research-based framework developed by CAST (2018) for designing flexible learning experiences that are accessible and effective for all learners from the outset. UDL calls for multiple means of representation (how content is presented), action and expression (how students demonstrate learning), and engagement (what motivates students). Penda's read-aloud, multilingual translation, differentiated readability levels, and varied gamification mechanics reflect UDL principles. (*CAST, 2018*)
W	W
WCAG 2.1/2.2 *WCAG*	Web Content Accessibility Guidelines, the international technical standard for digital accessibility. Penda Learning's platform meets WCAG 2.1/2.2 standards, ensuring compliance with Section 508, ADA accessibility requirements, and state-level digital accessibility mandates. This extends Penda's UDL-based equity commitments from pedagogical intent to technical implementation.

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Z	Z
Zone of Proximal Development (ZPD) *ZPD*	A concept developed by Lev Vygotsky (1978) defining the gap between what a learner can do independently and what they can accomplish with appropriate guidance or scaffolding from a more knowledgeable other. The ZPD represents the optimal instructional target: challenging enough to promote growth, but not so difficult as to cause frustration. Penda addresses the ZPD through scaffolded activity levels, teacher-directed intervention groupings based on mastery data, and adaptive assignment that targets each student's current proficiency level. (*Vygotsky, 1978*)

Note. All theoretical frameworks cited in this glossary are referenced in full in the References section of this report. Definitions of NGSS dimensions (SEPs, CCCs, DCIs) are sourced from the National Research Council (2012) Framework for K–12 Science Education. ESSA tier definitions are sourced from the U.S. Department of Education Every Student Succeeds Act (2015). RTI and MTSS tier definitions are adapted from Gersten and colleagues (2009). *Logic model structure adapted from Lawton, Brandon, Cicchinelli, & Kekahio (2014) and Shakman & Rodriguez (2015), consistent with U.S. Department of Education IES REL Pacific (REL 2014-007) and REL Northeast & Islands (REL 2015-057) frameworks.* Evidence data from Miller, S.L. (2025).

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