Magpie Literacy

From Community-centered Research to Scalable Products

Six Years of Research and Development at Magpie Literacy



Table of Contents

Introduction

Research and Development Framework

Technology Requirements for Effective Digital Literacy Instruction

1. **Translating Research-based Instruction into Technology**
   - Speech Recognition for Oral Reading
   - Translating Classroom Instructional Routines
   - Key Design Principles
2. **Integrated Literacy Learning Systems**
   - Assessment as a Commitment to Efficacy
   - Formative Evidence in Service of Instruction
   - Designing Data to Drive Educator Action
   - Building a Unified Learner Model
   - Key Design Principles
3. **Designing for Scale**
   - Making Implementation Invisible
   - Designing for Real Classrooms
   - Implementation as Instructional Support
   - Key Design Principles

Looking Ahead

Introduction

Technology has become an increasingly important part of literacy instruction, yet relatively little has been written about the technical requirements for faithfully translating evidence-based reading instruction into digital learning experiences. While decades of research have identified instructional practices that improve student outcomes, far less attention has been given to the engineering, product design, and implementation decisions necessary to deliver those practices effectively at scale. Over the past six years, Magpie Literacy partnered with researchers, educators, engineers, and school communities to investigate this challenge through an iterative research and development process focused on building evidence-based literacy technology.

This paper synthesizes the technological lessons that emerged from that work. Rather than documenting the development of a single product, it identifies a set of broader design principles that may inform the next generation of educational technology. These findings are organized around three interconnected challenges: translating research-based instructional practices into technology, integrating assessment and instruction into coherent learning systems, and designing technology that can be implemented reliably and equitably at scale. Together, these lessons offer a practical framework for developing educational technologies that are not only engaging and scalable, but demonstrably effective for the students they are intended to serve.

Research and Development Framework

Each technology capability described in this paper was evaluated using a common phased research and development framework. Promising solutions progressed through successive stages of investigation before advancing to increasingly rigorous evaluations of implementation and instructional efficacy. This framework enabled technology decisions to be informed by evidence at each stage of development while ensuring that instructional quality, user experience, privacy, and scalability were considered throughout the research and development process.

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Stage	Exploration & Discovery	Usability Validation	Technical Feasibility	Implementation & Early Efficacy	Rigorous Efficacy Evaluation
Key Question	Should this technology exist?	Can kids, teachers, and caregivers use it?	Can it reliably work in authentic settings?	Does it improve instruction and learning?	Does it produce measurable learning gains?
Primary Activities	■ Literature review ■ Needs assessment ■ Market scan for aligned solutions ■ Privacy & security review ■ Solution selection (build, buy, or license)	■ UX research ■ Mockups ■ Interactive designs ■ Early-stage prototypes ■ Controlled usability studies	■ Proof of concept ■ MVP development ■ Short implementations in classroom, home, and/or tutoring settings ■ QA & performance testing	■ Quasi-experimental implementation studies ■ Classroom observations to understand how technology solutions facilitate/hinder implementation, instruction, and overall efficacy ■ Educator interviews ■ Continuous product refinement	■ Randomized controlled trials ■ Student group analyses ■ Independent evaluation ■ Long-term validation
Evidence Generated	■ Technology requirements and challenges ■ Design principles	■ Evidence of usability and user experience	■ Evidence that the technology is technically and operationally viable	■ Evidence that implementation supports intended instructional practices and shows early impact	■ Strong evidence of efficacy and conditions for scale
Typical Output	Technology strategy	Tested prototype	Classroom-ready MVP	Production-ready product	Validated technology solution

Technology Requirements for Effective Digital Literacy Instruction

The phased research and development framework described above generated a growing body of evidence about the technological capabilities required to deliver evidence-based literacy instruction through digital platforms. While individual investigations focused on specific technologies—from speech recognition and adaptive feedback to educator dashboards and authentication systems—common themes emerged across these efforts. Together, these findings illustrate that building effective literacy technology depends not on any single innovation, but on a coordinated set of technical, instructional, and implementation capabilities that reinforce one another.

The findings presented in this section are organized into three broad categories. The first examines the **requirements for translating research-based instructional practices into technology** while preserving instructional fidelity. The second explores **how instruction, assessment, learner data, and the broader learning experience can be integrated into a coherent system** that supports both students and educators. The third focuses on the **technical and operational considerations required to scale these experiences** across diverse educational settings while maintaining quality, privacy, security, and ease of implementation.

Although these categories are presented separately for clarity, they are deeply interconnected. Decisions made in one area frequently shaped possibilities in another, and many technology solutions addressed multiple requirements simultaneously. Collectively, these findings represent a practical framework for understanding the technological foundations necessary to build, implement, and scale effective digital literacy tools.





1 Translating Research-based Instruction into Technology

How research-based literacy practices can be faithfully implemented in digital learning environments.

One of the central findings to emerge from this research is that effective literacy technology cannot simply digitize classroom materials or instructional activities—it must faithfully translate the instructional expertise that makes those activities effective. Evidence-based literacy instruction depends on hundreds of subtle instructional decisions made by educators: when to provide feedback, how to scaffold a student's thinking, which errors require intervention, how to represent language visually and auditorily, and how to adjust instruction based on student responses. These decisions are often invisible to learners but are fundamental to effective reading instruction. Successfully translating literacy instruction into technology therefore requires preserving instructional intent, not merely instructional format.

This distinction shaped nearly every aspect of Magpie Literacy's research and development process. Technologies developed for general consumer applications frequently proved insufficient when evaluated against the demands of evidence-based literacy instruction. Speech recognition systems optimized for conversational language lacked the phonetic precision required for decoding instruction. Conventional digital handwriting applications often failed to account for developmental variability in young children's motor skills. Many educational products provided simple right-or-wrong feedback without capturing the instructional reasoning educators use to help students understand and correct their mistakes. Rather than adapting instructional practices to fit existing technologies, this work instead identified the technical capabilities necessary to faithfully support established literacy research.

Across multiple investigations, two themes consistently emerged. First, some instructional practices require entirely new technological capabilities because existing tools were designed to solve different problems. Second, faithfully translating classroom instruction requires technology that increasingly encodes instructional expertise—supporting not

only what students do, but how they think through increasingly sophisticated literacy tasks. The following findings illustrate these principles through two representative areas of investigation: speech recognition for oral reading and the translation of research-based classroom instructional routines into digital learning experiences.

Speech Recognition for Oral Reading

Automatic speech recognition (ASR) illustrates how the technical requirements of literacy instruction differ fundamentally from those of general-purpose speech technologies. Most commercial ASR systems are designed to determine what a speaker intended to communicate. Virtual assistants, transcription services, and voice interfaces prioritize semantic understanding, often relying on predictive language models to infer meaning from context. Reading instruction, however, demands a different type of precision. When supporting beginning readers, the objective is not simply to recognize words, but to determine whether each phoneme has been produced accurately and to identify the specific decoding errors that require instructional support.

Early investigations demonstrated that conventional ASR technologies were not well suited to this task. Small-scale evaluations of multiple commercial providers revealed substantial reductions in recognition accuracy for students from historically underrepresented linguistic backgrounds, consistent with concerns about bias arising from training datasets that inadequately represent diverse dialects and language varieties. These findings reinforced a broader conclusion: technologies intended for educational use must be evaluated against the diversity of learners they are expected to serve, rather than assuming that performance in consumer applications will generalize to classroom settings.

The research also highlighted that instructional and assessment uses of speech recognition should not necessarily be treated as the same technical problem. Emerging evidence suggests that some aspects of reading assessment may be accomplished through alternative approaches that do not rely on speech recognition, reducing both technical complexity and potential linguistic bias. By contrast, delivering individualized instructional feedback during decoding practice still appears to require highly accurate, phoneme-level analysis of student speech. This distinction substantially changed the role envisioned for ASR within the broader literacy platform and redirected development toward instructional applications where speech recognition provides the greatest educational value.

Finally, this work demonstrated that designing speech recognition for literacy extends well beyond model accuracy. Classroom background noise, speaker identification, latency, privacy, internet connectivity, and deployment architecture all influence whether speech recognition can function reliably in authentic educational settings. Decisions about on-device versus cloud processing, vendor dependency, and data privacy became instructional decisions as much as engineering decisions because each directly affected the feasibility



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of delivering timely, trustworthy feedback to students. Collectively, these findings suggest that speech recognition for literacy instruction should be understood not as a straightforward application of existing AI technologies, but as a distinct educational challenge requiring specialized technical solutions.

Translating Classroom Instructional Routines

While speech recognition illustrates the need for specialized technical capabilities, a broader challenge emerged across nearly every aspect of product development: faithfully translating classroom instructional routines into digital learning experiences. Effective literacy instruction relies on carefully designed routines that combine physical materials, verbal interaction, visual supports, and educator judgment to help students construct increasingly sophisticated understandings of written language. Simply recreating these activities on a screen is insufficient. Instead, technology must preserve the instructional purpose behind each routine while adapting it to a digital environment.

This challenge became particularly evident when developing technology-based alternatives to common classroom tools such as Elkonin boxes, decodable texts, handwriting instruction, and multisensory learning activities. Each of these instructional routines contains design decisions that have been refined through decades of literacy research. Digital versions therefore required more than visual replication—they required careful consideration of how learners interact with technology, how feedback is delivered, and how instructional scaffolds can be embedded into self-directed experiences without reducing instructional rigor.

The development of Starwriter, Magpie's digital handwriting platform, illustrates this principle well. Early iterations demonstrated that conventional handwriting applications often evaluated children's writing against standards that failed to account for normal developmental variability. Young learners naturally exhibit inconsistent motor control, evolving pencil grips, and imperfect letter formation. Technology that interpreted these developmental characteristics as errors risked discouraging learners while providing misleading information about their progress. Rather than optimizing for geometric precision alone, the design process emphasized instructional appropriateness by calibrating recognition systems to distinguish between meaningful instructional errors and age-appropriate variation. In this case, faithfully translating handwriting instruction required encoding principles of child development alongside the mechanics of handwriting itself.

As our overall product development expanded into grades 3–8, the nature of the translation challenge evolved. Rather than reproducing relatively concrete instructional activities, the technology increasingly needed to support sophisticated cognitive routines. Students were expected to decode multisyllabic words while simultaneously considering morphology, vocabulary, syntax, and meaning. These are instructional decisions that experienced educators often model dynamically in response to student thinking. Translating these interactions into technology required decomposing expert instructional practice into discrete decision pathways that could be delivered consistently through digital experiences. The resulting products therefore encode not only instructional content, but aspects of instructional expertise itself.

Taken together, these investigations suggest that successful educational technology should not be evaluated by how closely it resembles classroom materials, but by how faithfully it reproduces the instructional reasoning those materials support. The objective is not to replicate or replace the role of the educator. Technology can provide students with individualized opportunities for practice and feedback at scale, creating more time for educators to focus on the forms of instruction that depend most on human expertise—such as facilitating discussion, responding to complex student thinking, and building relationships. Effective translation requires preserving the learning processes that make classroom instruction successful while leveraging the unique affordances of technology to increase consistency, accessibility, and opportunities for integrated and applied practice.

Key Design Principles

Educational technologies should be designed around instructional intent rather than interface design. Decisions about user experience, artificial intelligence, feedback, and interaction should be driven by established instructional research rather than by the capabilities of existing technologies.

Technologies developed for general consumer applications should not be assumed to satisfy educational requirements. Literacy instruction often demands greater precision, stronger protections against bias, and more transparent decision-making than technologies designed for communication, productivity, or entertainment.

Translating effective instruction requires making expert teaching decisions explicit. Many classroom routines rely upon professional judgment that experienced educators apply intuitively. Successfully implementing these routines digitally often requires identifying those decision points and designing systems capable of responding appropriately to student learning.

Technology is most valuable when it faithfully extends evidence-based instructional practices, provides additional opportunities for high-quality practice, and enables consistent implementation at scale without compromising instructional integrity.



2 Integrated Literacy Learning Systems

How instruction, assessment, learner data, educator supports, and learning contexts function as a unified system.

Rather than viewing assessment, instruction, educator supports, and personalization as independent product components, this research found that they function most effectively when designed as parts of a unified learning system. Each component generates information that strengthens the others: assessment informs instruction, instructional interactions generate new evidence about learning, learner models synthesize those signals into increasingly accurate representations of student understanding, and educator tools translate that information into instructional action. When these components operate independently, opportunities for personalization and instructional coherence are lost. When they operate as an integrated system, technology becomes capable of supporting continuous learning rather than isolated educational experiences.

One of the most significant findings to emerge from this work is that integration is not primarily a technical challenge—it is an instructional one. The question is not simply how to connect software systems, but how to ensure that every interaction with the platform contributes to a coherent understanding of what a student knows, what they are ready to learn next, and how the digital product and educators can best support that learning. This perspective shaped research across four interconnected areas: assessment, educator decision-making, learner modeling, and instructional coherence. Together, these investigations demonstrate how integrated learning systems can move beyond static educational products toward continuously improving instructional environments.

Assessment as a Commitment to Efficacy

One of the defining principles that emerged from this work is that validated assessment should first serve as evidence of instructional effectiveness. Rather than embedding assessment because schools expect a screener or because assessment represents a marketable product, the decision to integrate a validated assessment reflected a broader commitment: educational technology should be able to demonstrate whether students are actually learning.

This perspective fundamentally changes the role of assessment within a literacy platform. A validated benchmark assessment does not just tell the technology what to teach next. Instead, it answers a more foundational question: *Is the instructional experience working?* It provides an external measure of learning that holds developers accountable for outcomes and creates a shared standard against which instructional improvements can be evaluated. In this sense, assessment becomes a manifestation of organizational values—a commitment to efficacy rather than simply a product feature.

Formative Evidence in Service of Instruction

While validated assessments provide trustworthy evidence of learning, they often are not designed to support moment-to-moment instructional decision-making. Throughout this work, it became increasingly clear that educators need a different kind of information while students are actively learning. Rather than periodic benchmark scores alone, effective instruction depends on continuous evidence about how students are approaching individual literacy tasks, where misconceptions arise, and what support should be provided next.

This realization motivated the development of embedded knowledge checks and a broader learner model capable of capturing instructional signals throughout the learning experience. Unlike benchmark assessments, these interactions are not intended to validate efficacy. Their purpose is to inform instruction. By observing student responses as learning unfolds, the system can identify misconceptions, reinforce prerequisite skills, and guide increasingly personalized instructional pathways. Together, validated assessments and embedded formative evidence serve complementary purposes: one demonstrates whether learning is occurring, while the other helps make learning more effective.

Designing Data to Drive Educator Action

Research also demonstrated that educator dashboards are most valuable when they support decision-making rather than simply displaying information. Many educational dashboards emphasize comprehensive reporting, presenting large volumes of data without clarifying which information deserves attention or what educators should do in response. This approach often increases cognitive load while providing limited instructional value.

Instead, dashboard design was guided by a different principle: every data element should support a specific instructional or implementation decision. Early findings suggested, for example, that ensuring students spend sufficient time engaging with high-quality instructional experiences may be one of the most influential educator behaviors affecting outcomes. Dashboards therefore prioritized clear indicators of student usage, implementation fidelity, and assessment performance rather than exhaustive activity logs. The objective was not to provide more information, but to increase educator confidence and make high-leverage actions immediately apparent.



Validated assessments and embedded formative evidence serve complementary purposes: one demonstrates whether learning is occurring, while the other helps make learning more effective.

This work suggests that dashboards should be understood less as reporting tools and more as instructional support systems. Effective dashboards reduce the time required to interpret data, highlight meaningful patterns, and make actionable insights easier for educators to identify and apply.

Building a Unified Learner Model

Perhaps the most significant long-term finding from this research is that personalization depends on integrating information across the entire learning experience. Assessment results, instructional performance, gameplay interactions, and educator observations each provide partial evidence about student understanding. Considered independently, these signals offer limited insight. Integrated within a shared learner model, however, they create a richer representation of student learning that can guide increasingly precise instructional decisions.

This realization motivated development of a knowledge graph capable of representing relationships among literacy skills, instructional sequences, prerequisite concepts, and student performance. Rather than simply storing assessment scores, the learner model is designed to reason about why students struggle, which prerequisite skills may require reinforcement, and what instructional experiences should follow. As this architecture continues to mature, it provides the foundation for adaptive systems that remain grounded in evidence-based literacy instruction while responding dynamically to individual learner needs.

More broadly, the research suggests that effective personalization depends less on sophisticated algorithms than on thoughtfully designed representations of learning itself. Artificial intelligence can only personalize instruction to the extent that it possesses an accurate and instructionally meaningful model of student knowledge and skills.

Assessment becomes a manifestation of organizational values—a commitment to efficacy rather than simply a product feature.



Key Design Principles

Assessment should demonstrate efficacy. Validated assessments play a critical role in establishing whether students are learning. Assessments have to center trustworthy evidence that instructional experiences are producing meaningful outcomes. Embedding validated assessment reflects a commitment to accountability for learning, not simply a product feature.

Instruction requires continuous formative evidence. While benchmark assessments answer whether learning is occurring, effective instruction depends on richer, ongoing information about how students are learning. Embedded knowledge checks and other instructional signals should provide moment-to-moment evidence that helps personalize instruction and support learners as they progress.

Learning systems should connect evidence across experiences. No single assessment or interaction provides a complete picture of student learning. The greatest value comes from integrating validated assessments, formative evidence, instructional interactions, and learner data into a coherent model that supports increasingly informed instructional decisions over time.

Data should change behavior, not simply describe performance. Information presented to educators should exist to support clear instructional or implementation decisions. Dashboards are most valuable when they reduce cognitive burden, highlight high-leverage actions, build educator confidence, and maximize the time teachers spend engaging directly with students.

Technology should be organized around learning, not features. Assessment, instruction, personalization, and educator supports should not function as isolated product components. They are most effective when designed as interconnected elements of a unified learning system, where each component strengthens the others in service of improved student outcomes.



3 Designing for Scale

The technical, operational, and implementation requirements necessary to deliver effective literacy instruction to millions of learners.

Scaling educational technology is often described as a technical challenge: supporting more users, larger datasets, and increasingly complex infrastructure. This research suggests that technical capacity alone is not enough. For literacy technology to scale successfully, technical architecture, implementation design, and instructional quality must be developed in coordination. Investments in the right technical capabilities—made at the right time and in the right sequence—can reduce implementation friction, increase instructional dosage, and ultimately improve learning outcomes.

As product development progressed, it became increasingly clear that many of the greatest barriers to impact existed at the intersection of technology and implementation. Students struggled with login procedures, schools varied dramatically in their devices and internet connectivity, educators lacked time for extensive onboarding, and implementation challenges often reduced the amount of meaningful instructional time students spent using the product. Addressing these challenges required coordinated decisions across engineering, product, and implementation—not simply stronger instructional content. When instructional time is lost to technology or implementation barriers, the effectiveness of even the highest-quality instructional design is diminished.

This work therefore approached scale as the integration of instructional design, technical development, and implementation strategy rather than treating each as an independent workstream. Decisions about authentication, infrastructure, educator supports, and instructional experiences were evaluated according to a common question: *Does this remove barriers that prevent students from engaging consistently with effective instruction?* Across multiple investigations, three themes consistently emerged: implementation should become nearly invisible, technology must be resilient to the realities of diverse school environments, and implementation supports

should enable educator success rather than create additional work. Together, these findings suggest that scalable literacy technology depends not on excellence in any one area, but on the careful coordination of instructional, technical, and implementation design.

Making Implementation Invisible

One of the clearest findings from this work is that implementation should become as invisible as possible. While authentication, rostering, and account management are often viewed as administrative concerns, they directly affect the amount of instructional time available to students. This challenge is particularly acute for beginning readers, who may spend a substantial portion of a short instructional session entering usernames and passwords or waiting for technical assistance. In these contexts, implementation decisions become instructional decisions because every minute spent accessing technology is a minute unavailable for learning.

As development progressed, increasingly automated approaches—including QR code authentication, district rostering systems, and single sign-on integrations—proved valuable not simply because they improved convenience, but because they reduced instructional friction while strengthening security and data integrity. At scale, implementation systems must accomplish multiple objectives simultaneously: protecting student data, aligning with district technology standards, minimizing educator workload, and allowing students to begin learning with as little interruption as possible. The long-term objective is not merely easier implementation, but implementation that becomes nearly invisible within the instructional experience.

Designing for Real Classrooms

Successful literacy technology must function reliably within the realities of classrooms rather than ideal technical environments. Schools vary widely in device quality, operating systems, broadband availability, classroom noise, and physical learning environments. These conditions are especially pronounced in historically under-resourced communities, where aging hardware and inconsistent connectivity can become significant barriers to implementation. Designing for scale therefore requires planning for variability rather than assuming uniform technical conditions.

This research demonstrated that resilience must be designed into every stage of development. Compatibility testing across diverse devices, proactive monitoring systems, low-bandwidth optimization, and implementation planning with partner schools all became essential components of product development rather than post-launch support activities. By anticipating the realities of authentic classroom environments—including microphone failures, unstable internet connections, and heterogeneous device ecosystems—the platform became better positioned to deliver consistent instructional experiences regardless of local infrastructure constraints.

Implementation as Instructional Support

Perhaps the most significant finding from this work is that implementation should be understood as an extension of instructional



Validated assessments and embedded formative evidence serve complementary purposes: one demonstrates whether learning is occurring, while the other helps make learning more effective.

design rather than as a post-deployment service. Traditional implementation efforts often focus on training educators to use technology after a product has been built. This research suggests a different approach: implementation considerations should shape product development from the outset because they directly influence whether students receive sufficient access to effective instruction.

This perspective influenced decisions throughout the development process. Classroom onboarding procedures were simplified to minimize educator workload, login systems were redesigned to support independent use by young learners, and implementation planning increasingly incorporated conversations about school infrastructure, device availability, and local technology constraints before deployment began. Rather than assuming every school could adapt to the product, the product increasingly adapted to the realities of schools. These investments recognized that successful implementation depends as much on understanding classroom contexts as on developing high-quality instructional experiences.

These findings also reinforce a broader principle: technology cannot be considered effective if only a small proportion of students are able to use it consistently. Every implementation decision, from authentication workflows to onboarding materials and technical support, either increases or decreases students' opportunity to engage with instruction. Designing for scale therefore means designing systems that reduce demands on educators, increase student independence, and enable evidence-based instruction to become a routine part of classroom learning rather than an additional burden. Successful implementation is not separate from instructional efficacy; it is one of the conditions that makes efficacy possible.

Scalable literacy technology depends not on excellence in any one area, but on the careful coordination of instructional, technical, and implementation design.



Key Design Principles

Scale should be measured by instructional access, not technical capacity. Supporting millions of learners requires removing the barriers that prevent students and educators from consistently engaging with high-quality digital products.

Implementation should become invisible. Authentication, rostering, onboarding, and account management should minimize instructional disruption while maintaining security, privacy, and interoperability with school systems.

Technology should be resilient to real-world conditions. Effective educational products must be designed for diverse devices, inconsistent connectivity, varying classroom environments, and the operational realities of schools rather than ideal technical settings.

Implementation is part of instructional design. Professional learning, onboarding, educator supports, and implementation planning should be viewed as essential components of effective instruction rather than post-deployment services.

Reducing friction improves learning. Every technical decision that saves educator time, increases student independence, or removes barriers to consistent usage strengthens the likelihood that evidence-based instruction will produce meaningful learning outcomes.

Looking Ahead

The rapid advancement of artificial intelligence and educational technology presents an opportunity to rethink what digital learning experiences can become. Much of the current conversation focuses on increasingly capable algorithms, larger language models, or more sophisticated personalization engines. While these technologies undoubtedly expand what is technically possible, this work suggests that the greatest opportunity may lie elsewhere: in more faithfully representing the science of learning itself.

Imagine literacy technologies that understand not only *what* a student answered, but *why* they struggled. Systems that recognize when a child is ready for greater challenge, when additional scaffolding is needed, or when an instructional routine should unfold differently because of what has been learned about that individual over time. Platforms that integrate assessment, instruction, educator expertise, and implementation into a coherent learning ecosystem rather than a collection of disconnected tools. And technologies that are designed from the outset to function reliably in every classroom, not only those with ideal infrastructure or abundant resources.

Achieving this vision will require more than advances in artificial intelligence or software engineering. It will require deeper collaboration among educators, learning scientists, engineers, designers, and implementation researchers. It will require treating instructional expertise as something that can be systematically represented, tested, and continuously improved. Most importantly, it will require evaluating educational technology not by the sophistication of its features, but by its ability to faithfully deliver evidence-based instruction and measurably improve learning outcomes for all students.

If this work contributes anything beyond the development of a single literacy platform, it is the suggestion that educational technology can aspire to something more ambitious than digital content delivery. By grounding product development in evidence, integrating learning systems around student understanding, and designing implementation with the same care as instruction itself, the next generation of educational technology has the potential to become not simply more engaging or more intelligent, but meaningfully more effective.





Magpie Literacy

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