Age of Learning®

My Math Academy®

My Reading Academy®

Research-Driven Design Approaches to Personalized Learning for Young Children

Age of Learning® developed *My Math Academy* and *My Reading Academy*—two game-based adaptive learning systems—using a collaborative, child-centered process involving experts in learning sciences, curriculum research, user/design research, efficacy research, data science, assessment, and professional game design and development.

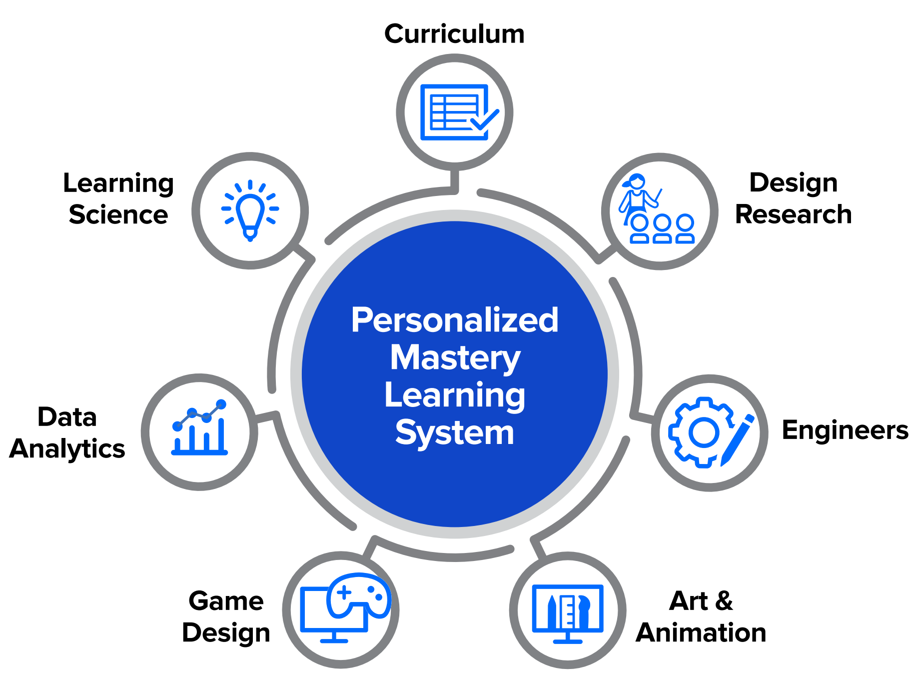


FIGURE 1. Age of Learning's experts collaborate across multiple disciplines to ensure an effective, engaging learning experience for children in *My Math Academy*

Our goal is to create a highly effective, engaging, and personalized learning experience to help all children build a strong foundation in early mathematics and literacy skills while developing a lifelong love of learning.

What is My Math Academy?

Our *My Math Academy* game-based adaptive learning system features 32 games with 320+ activities designed to help young learners build mastery of fundamental number sense and operations from pre-K to 2nd grade. Each game has a clear Learning Objective, learning task, and evidence of learning, and each Learning Objective is supported by an interactive instruction level and several layers of scaffolding and feedback. The narrative, mechanics, and system design provide playful learning experiences tailored to students' ages. Based on each learner's performance, the adaptive system provides support and feedback and recommends games at the appropriate difficulty level using a predetermined map of Learning Objectives and their prerequisite relationships. *My Math Academy* also includes resources for parents and teachers who play key roles in creating an effective system for learning.

FIGURE 2. A snapshot of selected games within the *My Math Academy* system

What is My Reading Academy?

Our *My Reading Academy* game-based adaptive learning system features Learning Games, reading experiences, and instructional videos designed to help pre-K through 2nd grade learners build mastery of fundamental literacy skills. *My Reading Academy* is grounded in science of reading and cognitive-development research and introduces students to concepts of print, phonemic awareness, phonics, sight words, vocabulary, fluency, and comprehension. Teaching videos provide explicit instruction and modeling with engaging, aspirational characters. Learning Games provide structured, repeated practice and corrective feedback, leading to accuracy and automaticity with phonemic awareness and phonics skills. Reading experiences provide targeted instruction in fluency, vocabulary, and comprehension. Each of these activities has a clear, singular Learning Objective stating something that the learner will be able to do or something that the learner will know (e.g., “Learner understands that spoken words are composed of individual phonemes. Learner can identify a single phoneme within a spoken word.”). Based on each learner’s performance with an objective, the adaptive system adjusts individual learning trajectories dynamically to provide additional instructional support, practice, or scaffolding where necessary or sometimes skips activities if a learner demonstrates mastery. *My Reading Academy* also includes resources for parents and teachers who play key roles in creating an effective system for learning.

FIGURE 3. A snapshot of selected activities and their corresponding skills in *My Reading Academy*

Our Learning Engineering Approach

We integrate research into every phase of developing both *My Math Academy* and *My Reading Academy*. From product conception through curriculum and product design and into program implementation, research guides our decisions about what to create, iterate, and refine.[1]

We adopt a Learning Engineering approach to creating products that support learners and their development.[2] We apply the research on how children learn to inform our pedagogy, design for playful engagement, and use human-centered research and analytics to create and iteratively improve upon those learning experiences.[3]

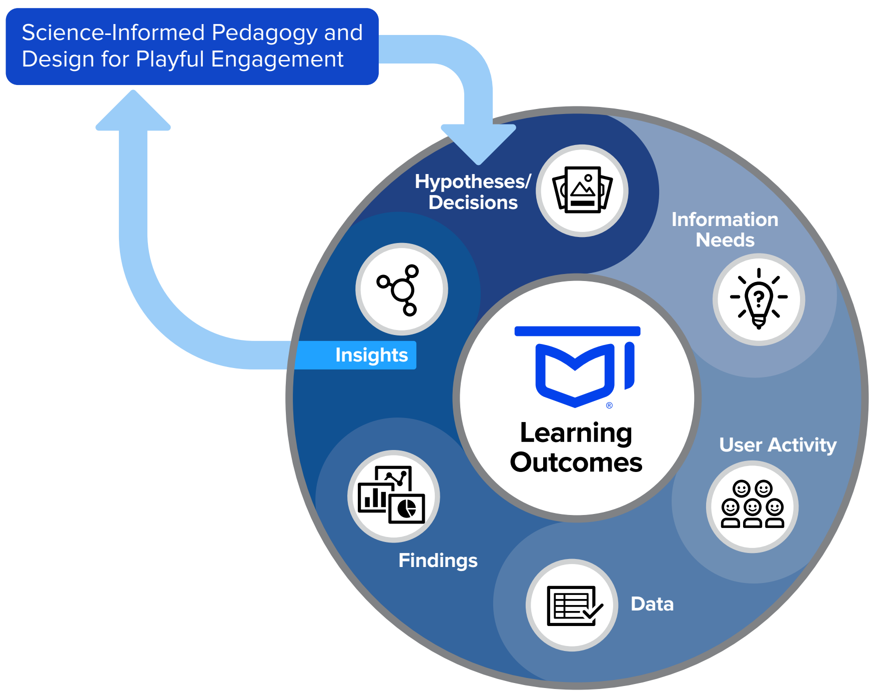


FIGURE 4. Age of Learning's Learning Engineering Framework

Our process includes three phases: (1) Curriculum Research, (2) Research-Based Design and Iterations, and (3) Implementation Research & Analyses.

1 Bang, H. J., & Li, L. (2020). *My Math Academy* Significantly Accelerates Early Elementary Children's Math Skills and Fosters Greater Engagement in Math: A Replication of a Randomized Control Trial. Research Brief. Age of Learning, Inc. https://www.ageoflearning.com/My_Math_Academy_Research_Brief_2020.pdf; Thai, K. P., Li, L., & Schachner, A. (2018). *My Math Academy* Significantly Accelerates Early Mathematics Learning. Research Brief. Age of Learning, Inc. https://www.ageoflearning.com/My_Math_Academy_Research_Brief_2018.pdf

2 IEEE Industry Connection Industry Consortium on Learning Engineering (ICICLE). (2019, December). https://www.ieeeicicle.org

3 Willcox, K. E., Sarma, S., & Lippel, P. H. (2016). Online education: A catalyst for higher education reforms. MIT Online Education Policy Initiative, 1–56.

PHASE 1: CURRICULUM RESEARCH

Each child is different, with different strengths, skills, and background knowledge. Therefore, each learner has an individual "trajectory" or pathway through the content. This idea of individual learning trajectories has roots in the constructivist work of such educational theorists as Lev Vygotsky, as well as more current research on hypothetical learning trajectories conducted by Martin Simon and the learning trajectories approach for early mathematics by Douglas Clements and Julie Sarama.[4]

Since all learners are different, instruction is best individualized, which requires clear definitions of granular Learning Objectives. However, there is no national pre-K math or reading curriculum, and kindergarten math and reading curricula are too coarse to effectively tailor instruction. Thus, our curriculum experts spent two years analyzing and synthesizing state and national standards frameworks (e.g., Common Core State Standards, NCTM's Standards, and Principles for School Mathematics) and the literature on mathematics and reading interventions, including the internationally recognized Math Recovery program, the highly researched Building Blocks early math curriculum,[5] and the Big Five for literacy.[6] This research helped us map what children need to know; how they build on what they know; the most problematic and challenging areas of early math and reading; and the hidden concepts, principles, and skills that often cause children's misunderstandings. Based on our findings, we developed a Knowledge Map of fine-grained, measurable Learning Objectives and pathways toward early number sense development for math and language and comprehension for reading. These Knowledge Maps served as the foundation for the next development phases of both products.

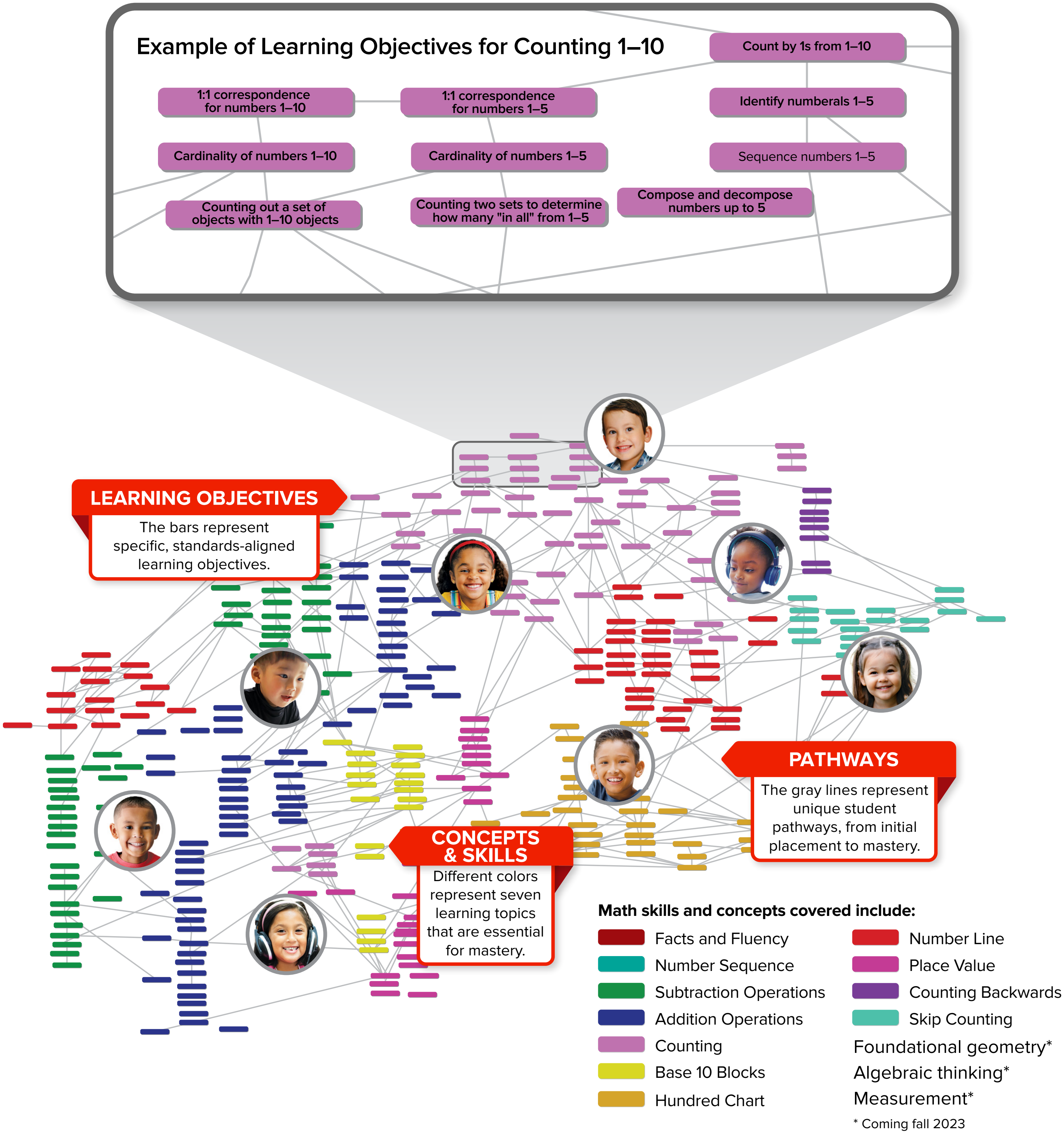
---

4 Vygotsky, L. S. (1978). Mind in Society: the Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press; Simon, M. (1995). Reconstructing Mathematics Pedagogy from a Constructivist Perspective. *Journal for Research in Mathematics Education, 26*(2), 11–145

5 https://www.mathrecovery.org/; Clements, D. H., & Sarama, J. (2004). Learning Trajectories in *Mathematics Education. Mathematical Thinking and Learning, 6*(2), 81-89. https://doi:10.1207/s15327833mtl0602_1; Clements, D. H., & Sarama, J. (2014). *Learning and teaching early math: The learning trajectories approach*. Routledge.

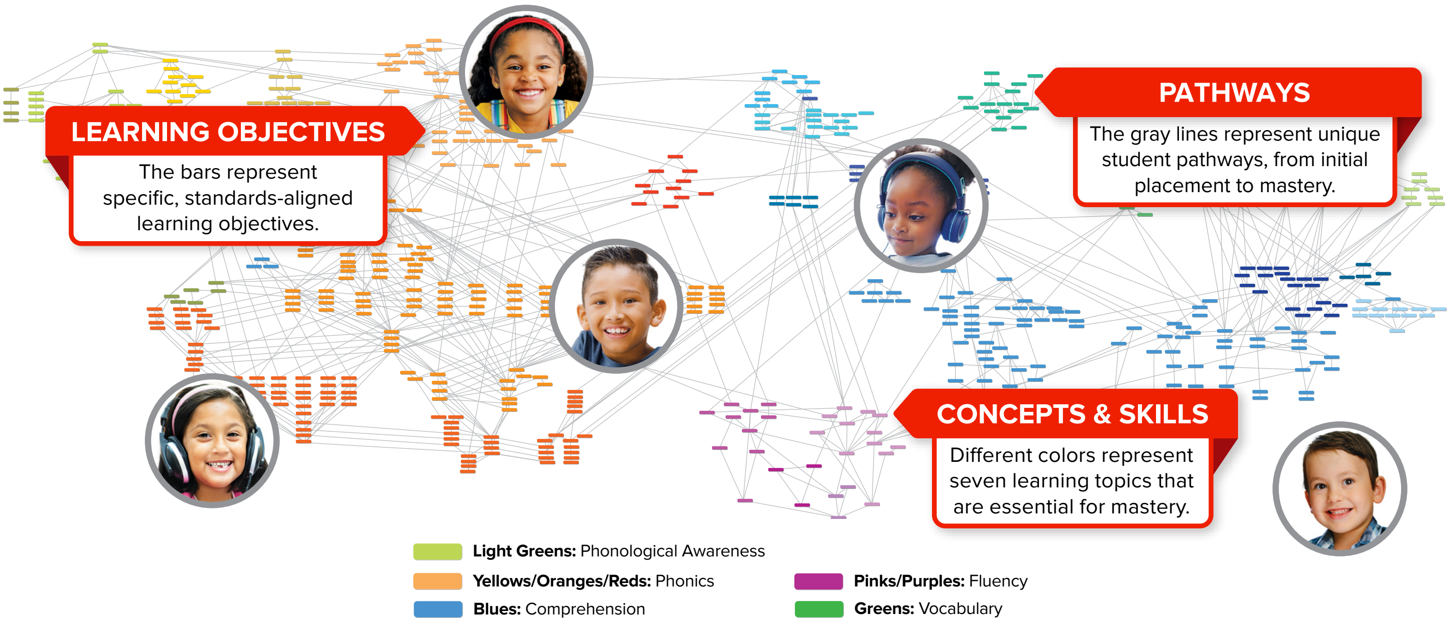
6 National Institute of Child Health and Development (NICHD). (2000). Report of the National Reading Panel: Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction (NIH Publication No. 00- 4769). Washington, DC: U.S. Government Printing Office. Available at https://www.nichd.nih.gov/publications/pubs/nrp/pages/smallbook.aspx

My Math Academy Knowledge Map Overview



Age of Learning®

My Reading Academy Knowledge Map Overview



PHASE 2: RESEARCH-BASED DESIGN & ITERATIONS

a. Mastery-Based Personalization

Children learn best when they receive individualized instruction with appropriate feedback that allows them to master each topic before moving on.[7] The Personalized Mastery Learning System™[8] in *My Math Academy* and *My Reading Academy* uses initial diagnostic assessments to place each child onto the Knowledge Map and provides different levels of scaffolding, feedback, and content based on the learner's performance. Each Learning Activity starts with a teaching portion, a game overview, the problem scenario, and instructions on the mathematics or reading content that are necessary for completing the task. A child may pass, stay, or go back to an easier level in a game, and the various adaptivity and scaffolding mechanisms are tailored to their level and learning pace, as shown in FIGURE 5, which illustrates the different pathways that students may take through the same content in *My Math Academy* or *My Reading Academy*. The lines represent each child's learning trajectories; time to completion shows the different lengths of times each child took to master the content (4 hours and 20 minutes; 2 hours and 19 minutes; 22 minutes). It would be challenging, if not impossible, for a teacher in a traditional classroom to personalize instruction in this way for 30 students, each with his or her own unique learning trajectory.

---

7 Bloom, B. (1968). Learning for mastery. In J. H. Block (Ed.), *Mastery learning: Theory and practice* (pp.47–63. New York, NY: Holt, Rinehart, & Winston.

8 Dohring, D., Hendry, D., Gunderia, S., Hughes, D., Owen, V. E., Jacobs, D. E., Betts, A., & Salak, W. (2019). U.S. Patent No. 20190236967 A1. Washington, DC: U.S. Patent and Trademark Office.

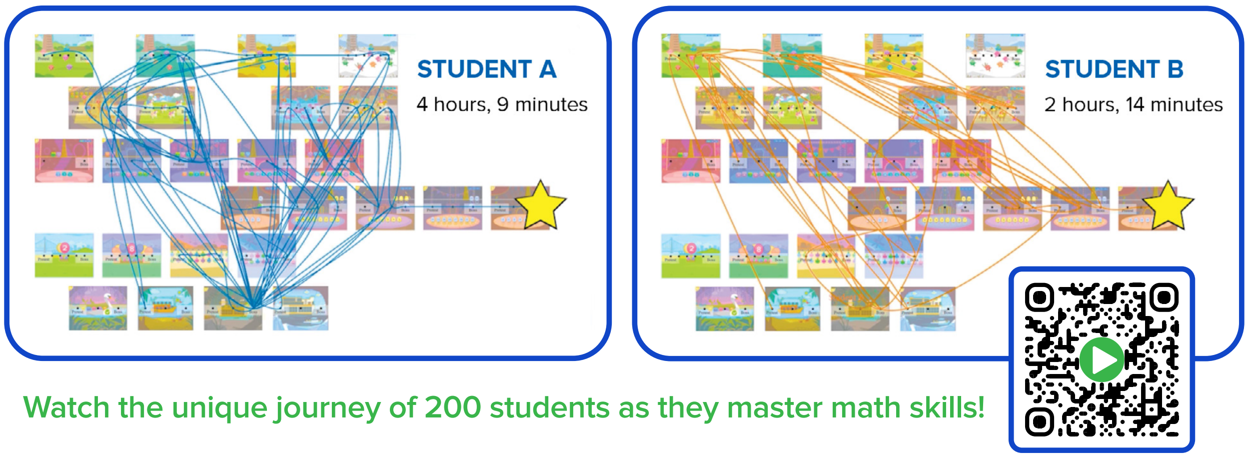
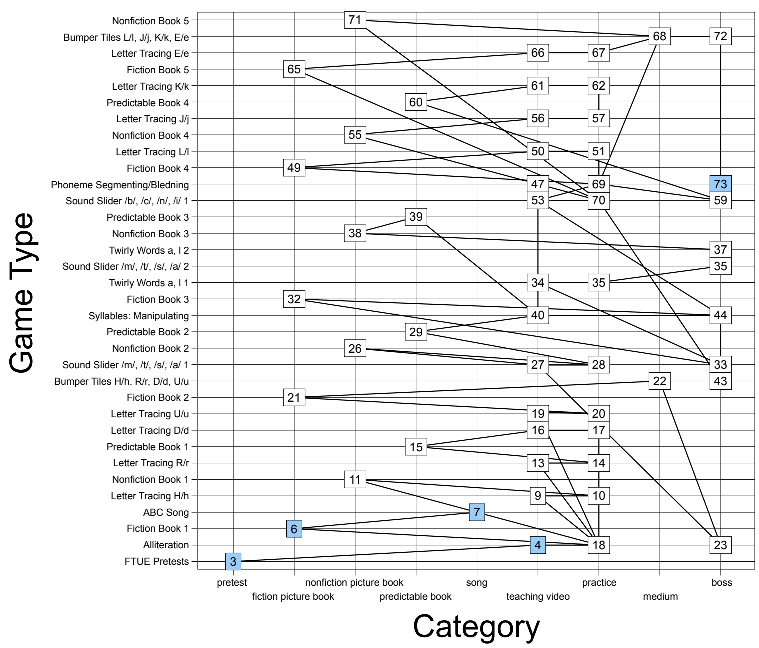


FIGURE 5. Examples of student learning trajectories in *My Math Academy* (from Betts, 2019)

Phonological Awareness Tasks



This graphic shows the actual Learning Pathway of a 4.5-year-old child through the learning content of *My Reading Academy*. The numbers indicate where the child completed the activity in the learning sequence. For example, number [7] indicates the seventh activity the child completed. **Game Type** on the y-axis describes the specific activity the child completed, and **Category** on the x-axis describes the types (e.g., book, song) and levels of practice (e.g., pretest, practice, boss) of each activity.

At the bottom-left of the chart, number [3] indicates that the third activity completed by the child was a pretest, followed by [4] an Alliteration teaching video, then [6] Fiction Book 1, and so forth, until activity number [73], where the child demonstrated mastery in the Sound Hound game (shown here as Phoneme Segmenting/Blending). Her progress after Sound Hound is not shown. ***Note:*** *Skipped numbers indicate that the child stayed on the same activity multiple times before moving on.*

FIGURE 6. A 4.5-year-old's journey in *My Reading Academy* (from Fabienke et al., 2021)

b. Game-Based Learning and Engagement

Play is essential to children's development and learning, and games can be great vehicles for learning.[9] Both *My Math Academy* and *My Reading Academy* sustain children's engagement and motivation via ongoing feedback, interactivity, and adaptive challenges that are personalized.[10] It also ensures that each child's in-game action is specifically designed to support Learning Objectives and provide evidence of growth over time (more below in **d.**). Additionally, storylines in game-based Learning Activities present authentic learning contexts for learners and help them make sense of math problems, facilitating their ability to transfer skills (or apply what they have learned).[11] Children help Shapeys™, Blurts, or friendly Letter and Word Tiles (characters and manipulatives in the games) in various story contexts, using their developing math knowledge (e.g., helping Shapeys with a headcount so they can go on a boat ride) or literacy skills (e.g. using Blurts to break a word down into phonemes). In *My Reading Academy*, children also interact with a live character instructor, Miracle, and her robot friend, Nano. As Miracle teaches content to Nano, she also encourages the child to teach the same content to their robot friend, Bitsy. In this way, children have an increased and vested interest in learning, improving their engagement and motivation.[12] Additionally, formative assessment (i.e., assessment for learning, rather than summative assessment, or assessment of learning) provides ongoing feedback to children.[13]

9 Golinkoff, R., Hirsh-Pasek, K., & Eyer, D. (2004). *Einstein Never Used Flashcards: How Our Children Really Learn and Why They Need to Play More and Memorize Less*. New York: Rodale Books. Fisher, K., Hirsh-Pasek, K., Golinkoff, R.M., Berk, L., & Singer, D. (2010). *Playing around in school: Implications for learning and educational policy*. In A. Pellegrini (Ed), *Handbook of the development of play* (pp. 341–362). New York, NY: Oxford Press.

10 Gee, J. P. (2003). *What Video Games Have to Teach Us About Learning and Literacy*. New York, NY: Palgrave Macmillan; Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning and Digital Media, 2*(1), 5–16; Rupp, A. A., Gushta, M., Mislevy, R. J., & Shaffer, D. W. (2010). Evidence-centered Design of Epistemic Games: Measurement Principles for Complex Learning Environments. *Journal of Technology, Learning, and Assessment, 8*(4).

11 Squire, K. (2011). Video games and learning. *Teaching and participatory culture in the digital age*. Gee, J. P. (2007). *Good video games+ good learning: Collected essays on video games, learning, and literacy*. Peter Lang. Gee, J. P. (2012, September). *Games Can Drive Assessment to a New Place*. Retrieved from http://gamesandimpact.org/wp-content/uploads/2012/09/Games-Can-Drive-Assessment-to-a-New-Place.pdf; Rieber, L. (1996). Animation as feedback in a computer-based simulation: Representation matters. *Educational Technology Research and Development, 44*(1), 5–22; Sullivan, P., Zevenbergen, R., & Mousley, J. (2003). The Contexts of mathematics tasks and the context of the classroom: Are we including all students? *Mathematics Education Research Journal, 15*(2), 107–121.

12 Chase, C. C., Chin, D. B., Oppezzo, M. A., & Schwartz, D. L. (2009). Teachable agents and the protégé effect: Increasing the effort towards learning. *Journal of science education and technology, 18*(4), 334–352.

13 Shute, V. J., & Kim, Y. J. (2014). Formative and Stealth Assessment. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 311–321). Ke, F., Shute, V., Clark, K. M., & Erlebacher, G. (2019). Interdisciplinary design of game-based learning platforms.

FIGURE 7. Children practice counting out quantities by helping Shapeys do a headcount for a boat ride

c. Consideration for Long-Term Retention and Transfer

Desirable difficulties such as actively retrieving previously learned information (retrieval practice) and alternating one kind of task with another (interleaving) support long-term retention.[14] Both *My Math Academy*'s and *My Reading Academy*'s algorithmic recommendation of activities employs these principles. It also helps children transfer through the games and at-home resources. With games, children explore each concept in depth, practicing with many examples with the same concept at work. At-home offline Learning Activities offer opportunities for children to apply concepts to different contexts (e.g., counting household objects, telling the first sound of "mac and cheese" at dinner). Furthermore, since children transfer better if they see opportunities to apply what they know, enrichment projects and math support activities encourage children to think about math and practice seeing the relevance of math in their daily lives.[15]

---

14 Bjork, R. A. (1994). Memory and metamemory considerations in the *Metacognition: Knowing about knowing, 185*; Bjork. R. A. & Yan, V. X. (2014). The Increasing importance of learning how to learn. In M. McDaniel, R. Frey, S. Fitzpatrick, & H. L. Roediger (Eds), Integrating cognitive science with innovative teaching in STEM disciplines [E-reader version]. doi:10.7936/K7QN64NR; Taylor, K., & Rohrer, D. (2010). The effects of interleaved practice. *Applied Cognitive Psychology, 24*(6), 837–848; Roediger III, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological science, 17*(3), 249–255.

15 Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational researcher, 25*(4), 5–11.

d. Game-Based Assessment and Structured Data for Evidence

As learners move through the systems, game interactions translate into learning performance data. Our approach borrowed much from the research on Evidence-Centered Design, an assessment framework that estimates learners' competency levels while generating the evidence to support claims about the targeted competency.[16] Each system continually measures growth, adjusts to each child's needs in real time for a personalized, engaging learning experience, and generates game events that can be interpreted directly in terms of competency types and Learning Objectives, which allow us to readily translate our analyses results into feedback and iterative game design.[17]

e. Design-Based Research

To effectively design for children, we employ child-centered design research practices to obtain a full understanding of our learners: how they learn, why they want to learn, and their learning contexts.[18] We conduct research with children to evaluate our user interface, user experience, player motivations, and interactions. We apply this human-centered approach with parents/caretakers and teachers in creating parent- and teacher-facing Dashboards and materials, as parents and teachers play a crucial role in supporting children's learning.[19] Via Dashboards, we offer child progress information to support real-time, interpersonal intervention and model effective uses of technology to help parents and teachers foster a positive learning environment at home and at school.[20]

---

16 Shute, V. J. (2011). Stealth assessment in computer-based games to support learning. In S. Tobias & J. D. Fletcher (Eds.), *Computer Games and Instruction* (pp. 503–524)

17 Shute, V. J., & Kim, Y. J. (2014) Formative and Stealth Assessment. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 311–321).

18 Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8; Laurel, B. (2003). *Design research: Methods and perspectives*. Cambridge, Mass.: MIT Press

19 Bloom, B. (1984). The 2-sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13*(6), 4–16; Henderson, A. T., & Mapp, K. L. (2002). A New Wave of Evidence: The Impact of School, Family, and Community Connections on Student Achievement. Annual Synthesis, 2002

20 Stevens, R., & Penuel, W. R. (2010). *Studying and fostering learning through joint media engagement*. Paper presented at the Principal Investigators Meeting of the National Science Foundation's Science of Learning Centers, Arlington, VA.

PHASE 3: IMPLEMENTATION RESEARCH AND ANALYSES

Multiple implementation and efficacy studies of *My Math Academy* have been conducted. A randomized controlled trial (RCT) conducted with pre-K and kindergarteners in 2017 showed that *My Math Academy* significantly accelerated their learning gains in comparison to the control group (N=453).[21] These results were replicated in another RCT in 2019 with kindergarteners, 1st graders and 2nd graders (N=958).[22] In both studies, those who mastered more skills in *My Math Academy* also demonstrated greater learning gains, and the greatest impacts were found on the most difficult skills. Additionally, teachers across both studies recognized *My Math Academy* as a valuable learning resource, especially given their students' greater engagement, motivation, and confidence in learning math. Similarly, results from a pilot study of *My Reading Academy* offer correlational evidence that *My Reading Academy* usage is associated with growth in literacy achievement. Additionally, teachers reported that students using *My Reading Academy* became more confident, interested, and focused on learning to read. They also found it to be a resource the allowed them to provide individualized, differentiated instruction. Several efficacy studies are currently underway; the results of these studies will provide additional evidence on the degree of *My Reading Academy*'s impact on reading skills.

---

21 Thai, K. P., Bang, H. J., & Li, L. (2021). Accelerating early math learning with research-based personalized learning games: A cluster randomized controlled trial. *Journal of Research on Educational Effectiveness, 15*(1), 28–51. Retrieved from https://www.tandfonline.com/doi/full/10.1080/19345747.2021.1969710

22 Bang, H. J., Li, L., & Flynn, K. (2022). Efficacy of an adaptive game-based math learning app to support personalized learning and improve early elementary school students' learning. *Early Childhood Education Journal.* Retrieved from https://link.springer.com/epdf/10.1007/s10643-022-01332-3?sharing_token=LOQ1al3YUaSFHbLgUv6zIfe4RwlQNchNByi7wbcMAY4cdMEtPYSk6jWKH8_UOJXyvzoXLRFDVhRklbUszKKmE2DCu4 m-QoaQCqS4tf-DnjcHViCvDPkbWYWylthxt3SNkeTPeazjFh14SLRxqGPUq_gCQWBs0G22iA_wxDlrtuo%3D

In Closing

A cross-disciplinary team of curriculum experts, learning scientists, game developers, and researchers at Age of Learning collaborate to create products to help children build a strong foundation for academic success. *My Math Academy* and *My Reading Academy* are designed to equip all children with early math and reading skills, which are the strongest predictor of later academic success and educational attainment.[23] To achieve this goal, we apply learning sciences research to inform our pedagogy and initial design, conduct user-centered research to make informed design decisions, and use evidence-centered design and learning analytics to drive learning outcomes. We have created and implemented a learner-centered development process that gives us a comprehensive view of the child and their environment, enabling us to build effective, engaging, personalized learning experiences for diverse learners. Please consult the references below for more information on the specific research that informed the creation of both *My Math Academy* and *My Reading Academy*.

23 Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., Pagani, L. S., Feinstein, L., Engel, M., Brooks-Gunn, J., Sexton, H., Duckworth, K., & Japel, C. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428–46. https://doi.org/10.1037/0012-1649.43.6.1428; Entwisle, D. R., Alexander, K. L., & Olson, L. S. (2005). First grade and educational attainment by age 22: A new story. *American Journal of Sociology, 110*(5), 1458–1502. https://doi.org/10.1086/428444