Harnessing the Power of Data: Driving Game-Based Personalized Instruction Through Learning Telemetry

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Age of Learning®

ABSTRACT

Just-in-time formative feedback + Adaptive recommendation + Well-crafted learning games = Engaging personalized learning at scale

cf. Gee, 2005; Baker, Chung, & Delacruz, 2012

ABCmouse Mastering Math™: A Data-Driven Personalized Learning System

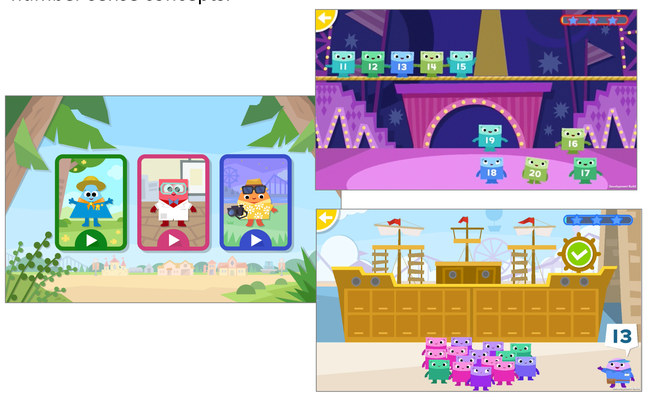
Evidence-centered design (ECD; Groff et al., 2015), Embedded assessments (Shute, 2011), Strong learning telemetry (Chung, 2015), & Learning analytics (Owen & Baker, in press)

. . . drive individual learning pathways

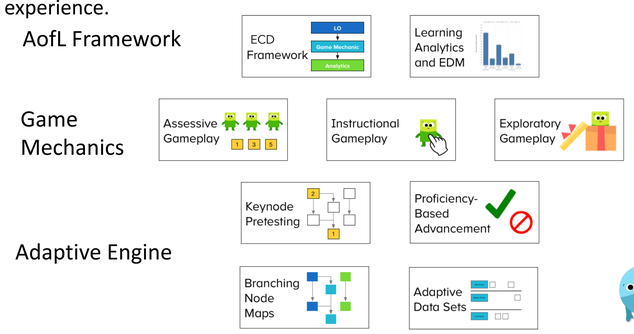
- **A culture of data** (ECD-based learning design + aligned, consistent telemetry) is embedded in the production processes from inception to fuel insightful analytics and iterative design.
- Preliminary results show learning gains for the target age group and instances of telemetry-based learning analytics that give insight into diverse learning trajectories—informing **iterative, data-driven design and personalization** within an engaging learning system.

WHAT IS MASTERING MATH?

A system of **adaptive learning games** designed to help preschool to kindergarten children build a strong understanding of fundamental number sense concepts.



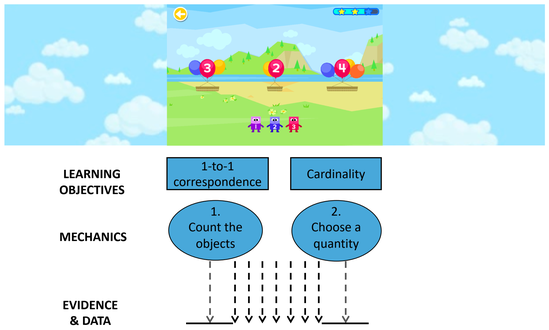
Personalized Mastery Learning System uses interaction data to recommend learning games and adapt both the sequence of activities and within each activity to optimize each child's learning experience.



A DATA-DRIVEN SYSTEM: FOUNDATIONS OF LEARNING AND TELEMETRY DESIGN

A. Evidence-Centered Design

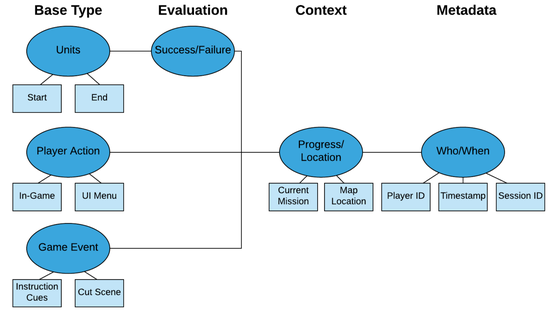
- Embedded assessment through ECD principles (Groff et al., 2015) built into design from inception
- Enables formative assessment, just-in-time scaffolding, and formative feedback as students play
- Comprehensive, design-aligned, event-stream data structure → assessment milestones



Design-aligned data: a simplified diagram

B. Telemetry Design for Learning Analytics

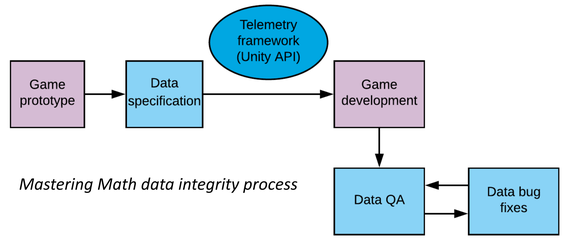
- Resulting event-stream data (telemetry) captures all player action and system feedback, labeled within the context of learning mechanics and game progress (e.g., corresponding to each assessment milestone in play).
- This framework enables learning analytics of all kinds.



Simplified Mastering Math telemetry flowchart. Assessment milestones are represented as "units."

DATA INTEGRITY: A MASTERING MATH FOUNDATION

- Data specification design for each game supports design-aligned and comprehensive telemetry that is consistent across all games (currently 160 activities).
- Telemetry framework (i.e., API for Unity developers) was designed to support efficient and consistent implementation in each game and across games from early stages of development.
- Data integrity analysis (QA) ensures that the data coming through is what was intended.

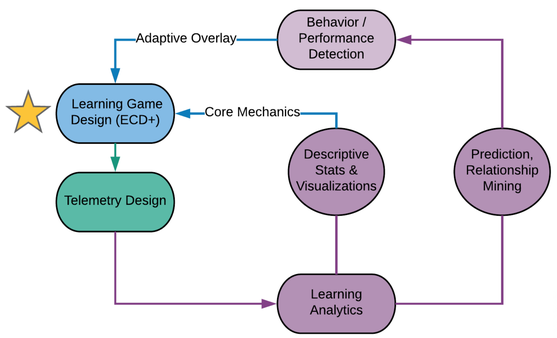


Mastering Math data integrity process

DATA-DRIVEN DESIGN: ITERATIVE SYSTEM IMPROVEMENT WITH LEARNING ANALYTICS

A. Iterative design cycle

Insights empowered through the embedded data culture and data integrity components above are the final layer of our data-driven system, feeding directly back into design for continuous improvement of our learning system.



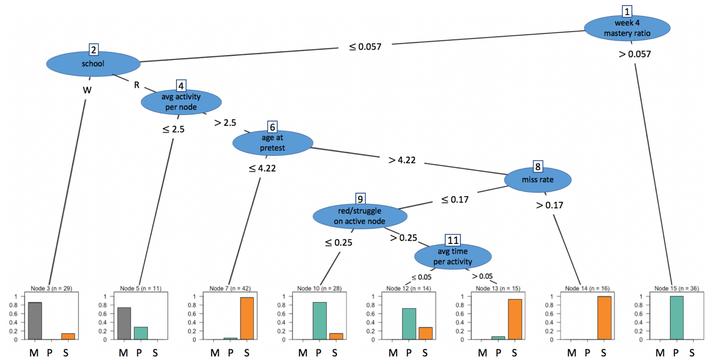
Iterative data-driven design cycles (starting point marked with star)

B. Descriptive visualizations for designers

Descriptive analysis and visualizations are powerful to inform core learning mechanics aligned with evidence. These analyses fuel iterative design for improved playful learning experiences personalized to each student.

Sample Games	Age Groups 2	3	4	5	6	7
Boats 6-10	22%	32%	37%	49%	68%	60%
	467	1,214	1,558	1,388	780	194
Horses 6-10	36%	33%	45%	64%	82%	84%
	485	1,192	1,571	1,393	787	202
Trees 1-5	46%	60%	77%	88%	89%	83%
	640	1,405	1,731	1,504	844	227

Pretest pass rate by age (n underneath). This informed age-based pretesting.



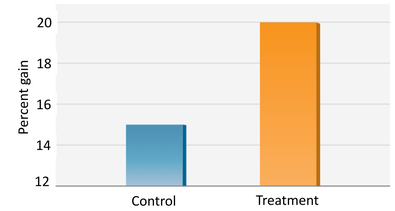
Prediction of students' week-12 behavior classification using week-4 telemetry (J48 method, 10-fold validation, cross-validated kappa = .36, multi-class AUC ROC = .545). S = Stuck, P = Productive persistence, M = Other.

C. Educational Data Mining (EDM) for intelligent system overlays

- Rich, structured data stream allows exploration of emergent player patterns through methods like EDM (Baker & Yacef, 2009), from prediction for behavior detection to cluster analysis and structure discovery for mining emergent player profiles.
- An example: a behavior detector for differentiating stuck students in the system from those with productive persistence (simply learning at their own pace). Detecting this behavior in real time can inform system adaptivity (e.g., offering support to stuck students) as well as interpersonal, classroom-based intervention.

ANALYTICS FOR EFFICACY

In a classroom setting, these analytics also support validation of the system as a whole through efficacy testing with appropriate age groups.



Percent gain on an external standardized assessment by Mastering Math users (treatment, n = 233) and non-users (control, n = 195, effect size = .23, p < .05) in a randomized controlled study (Thai, Li, Schachner, in press). Treatment group averaged 5 hours of usage over 10 weeks.

The more students used Mastering Math, the greater their learning gains (r = .10, p < .01). For children who demonstrated mastery on at least one skill, the more skills they mastered, the greater their learning gains, as measured by an external, standardized assessment (r = .38, p < .01).

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