International Society of the Learning Sciences

# Does where you start matter? The interaction between prior knowledge and effectiveness of game-based interventions

Allison Liu, Worcester Polytechnic Institute, aliu2@wpi.edu
Jenny Yun-Chen Chan, Worcester Polytechnic Institute, jchan2@wpi.edu
Ji-Eun Lee, Worcester Polytechnic Institute, jlee13@wpi.edu
Lauren E. Decker-Woodrow, Westat Inc., laurenwoodrow@westat.com
Shihfen Tu, University of Maine, shihfen.tu@maine.edu
Adam Sales, Worcester Polytechnic Institute, asales@wpi.edu
Craig A. Mason, University of Maine, craig.mason@maine.edu

**Abstract:** The current study investigated how prior knowledge moderated the effects of three educational technologies (*From Here to There*, *DragonBox 12+,* and problem sets in *ASSISTments*) on seventh-grade students' later algebraic knowledge. Pretest scores only moderated effects of *From Here to There*, with larger effects among students with higher pretest performance. Our findings have implications for understanding how prior knowledge interacts with design features within game-based applications to impact algebraic understanding.

## Introduction

Algebra is a critical foundation for advanced mathematics, but many middle school students struggle to understand basic algebraic concepts (Kieran, 2006). Much of the difficulty stems from understanding how to create, transform, and interpret statements expressed in standard algebraic notation. Educational technologies use varying design philosophies to address this difficulty and teach algebraic concepts. Some tools, such as *From Here to There* (FH2T; https://graspablemath.com/projects/fh2t) and *DragonBox 12+* (DB; https://dragonbox.com/products/algebra-12), engage students in game-based learning, allowing students to interact with algebraic notations and solve puzzle-like problems in a playful environment. Other tools, such as online problem sets in *ASSISTments* (Heffernan & Heffernan, 2014), provide timely support and feedback on traditional homework problems. However, how the impacts of these different approaches vary with prior knowledge have yet to be thoroughly examined. Understanding whether students with higher or lower prior knowledge gain more from these technologies is important for providing effective and efficient instruction that supports all students. On one hand, students with high prior knowledge may be more equipped to benefit from these interventions compared to students with low prior knowledge (e.g., Swanson et al., 2008; Wood et al., 2020). On the other hand, students with low prior knowledge may have more room for improvement (e.g., Murphy et al., 2020; Ramani & Siegler, 2011). The current study builds on our prior work comparing the impacts of three distinct educational technologies—two game-based applications, FH2T and DB, and two modes of online problem sets in *ASSISTments*—on algebraic understanding among 1,847 seventh-grade students (Decker-Woodrow et al., in prep.). We present preliminary analyses of whether students' prior knowledge moderated the effects of these technologies on students' algebraic understanding.

## Method

Seventh-grade students ($N$ = 1,847) were recruited from 10 middle schools within a large suburban district in the Southeastern United States. Students completed nine 30-minute intervention sessions in one of four educational technology conditions (randomly assigned at the student level within each class): FH2T, DB, problem sets with immediate post-response feedback, or problem sets with post-assignment feedback (control condition). Teachers chose the days that their students would work on the assignment in class, and students had two weeks to complete each assignment. The study occurred between September 2020 and April 2021, during the peak of the COVID-19 pandemic in the United States. Prior to the fall semester, students and their families chose whether to attend school 100% in-person or 100% virtually, with the option to change their selection during the year. Regardless of instructional modality, all study assignments were administered online, and students worked individually at their own pace using individual devices. Before and after the intervention, students received a 40-45 minute 10-item pre- and post-test algebraic knowledge assessment (Star et al., 2015; $\alpha$ = .89).

## Results

We conducted two, 3-level hierarchical linear models, with students nested within classrooms ($n$ = 127), nested within teachers ($n$ = 34). The outcome variable was students' post-test scores; classroom format (in-person vs. virtual) was a Level 2 predictor, and all other variables were Level 1 predictors. Covariates included race/ethnicity,

 

gender, and participation in advanced mathematics classes, an Early Intervention Program, or an Individual Education Plan. Pre-test scores were grand mean-centered, and all other covariates were dummy-coded. The first model revealed a significant intervention main effect ($\chi 2(3) = 23.3$, $p < 0.001$), in which FH2T and DB significantly outperformed the control condition on the post-test. Next, a significant interaction was observed between intervention condition and pre-test scores ($\chi 2(3) = 11.0$, $p = 0.01$) but only for FH2T ($\gamma = 0.14$), reflecting larger FH2T effects among students with higher vs. lower pre-test performance.

## Discussion

After a 4.5-hour intervention, students in both FH2T and DB significantly outperformed students in the control condition on algebraic knowledge, suggesting that game-based contexts may increase students' interest and engagement with mathematics, and in turn, support their performance. However, only FH2T had larger effects among seventh-grade students with higher pre-test performance. One key difference between the two technologies is that FH2T grounds in-game actions in algebraic notations from the start, whereas DB gradually transitions students from pictures of monsters to abstract notation as the game proceeds. Thus, for this age range, FH2T's immediate introduction of algebraic notation may be more effective for those with higher starting algebraic understanding. Future work will explore potential mechanisms (e.g., if prior knowledge promotes greater engagement when algebraic notation is introduced from the start, or if prior knowledge supports connections between gesture-actions and concepts). The findings provide evidence that game-based learning platforms are effective for improving algebraic understanding, but that students' starting points need to be considered.

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## Acknowledgments

The research was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A180401 to Worcester Polytechnic Institute. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.