When Games Hurt Transfer: Comparing Game-Based and Non-Game Learning for Mathematics

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Introduction

Digital learning games have frequently been shown to support student learning (Clark et al., 2016; Mayer, 2019). Mechanisms for this include improved engagement and positive affective experience among learners.

Transfer is a long-studied and debated concept in educational psychology (Woodworth & Thorndike, 1901). A robust taxonomy comparing “near” and “far” transfer was introduced by Barnett & Ceci (2002).

Digital learning games are often assumed to improve engagement and learning. More research can be done on games’ transfer to non-game academic contexts. In this study, students using a non-game mathematics tutor significantly outperformed students using a game-based version on far transfer measures.

Methods

Participants and Procedure

220 fifth- and sixth-grade students were recruited from two schools outside a small USA city. 7 students did not participate. 73 students were excluded from analysis because they did not complete the study. The remaining 140 students completed a pretest, intervention, and posttest. The materials took approximately one week to complete and were administered in school during math class.

The study used a 2x2 format to test two variables: game versus non-game format and presence of prompted self-explanation questions (Chi et al., 1989). Students were randomly assigned to both a game or non-game condition and a self-explanation or no self-explanation group. In this paper, we consider the effects of the intervention format. Of the 140 students who completed the study, 67 were in the game condition and 73 were in the non-game condition.

Materials

The game and non-game contained identical content and problem sequences; the only differences were the visuals and narrative.

Angle Jungle

Angle Jungle is a mathematics digital learning puzzle-solving game that focuses on an introductory understanding of angles (Khan et al., 2017). The game follows a treasure hunt narrative. To solve problems, students should first estimate or measure an angle that is represented by a crystal, beam, and orb (Figure 1.1). Then, they must drag-and-drop the correct set of angle measures, represented by gems, to compute the angle. Levels become increasingly complex and introduce concepts such as complementary, supplementary, and negative angles.



Figure 1.1. Intermediate difficulty problem in *Angle Jungle*.

Angle Tutor

Angle Tutor is similar to *Angle Jungle*, but it lacks the game narrative, e.g. the treasure map. The visual representation of the goals is different; they are in the form of targets (Figure 1.2). The process of dragging “gems” into slots to construct the target angles remains the same.

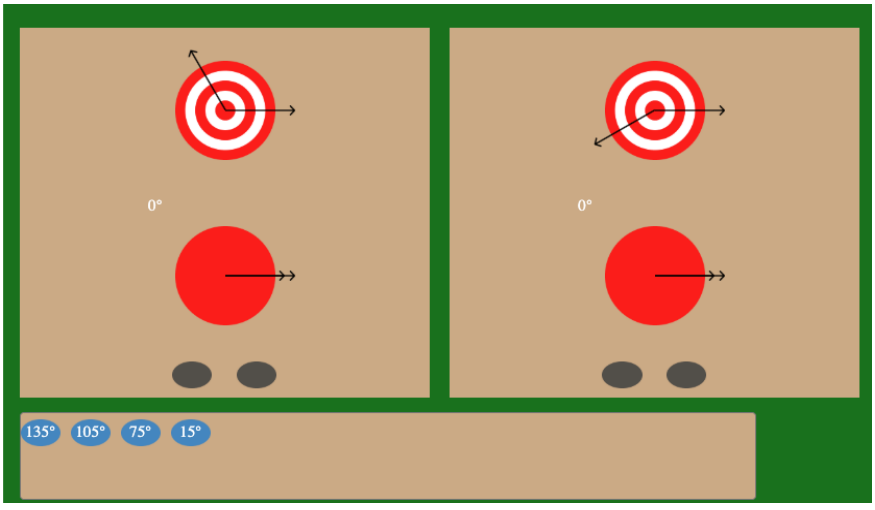


Figure 1.2. *Angle Tutor’s* equivalent problem to the one shown in Figure 1.1.

Assessment

Students completed two tests (pre-intervention and post-intervention) that covered estimating, measuring and calculating angles. Although pre- and post-tests can not perfectly predict holistic learning, the tests were intentionally written to compare separate transfer distances. Tests comprised 5 near transfer (to the intervention content), 10 medium transfer, and 5 far transfer items (Barnett & Ceci, 2002). Both tests were identical in item order, answer choices, and content. Tests were counterbalanced with test order randomly assigned.

Results

A paired t-test comparing pretest and posttest scores across the full sample (N = 140) showed a significant difference ($p = 0.021$, $d = 0.20$), where posttest scores were on average 2.21 points higher (95% CI [0.345, 4.084]).The mean pretest score was 30.76, and the mean posttest score was 32.98.

ANCOVA analyses controlled for pretest scores showed that pretest scores significantly predicted posttest performance on all transfer measures (all *p*s < .001). Condition did not significantly predict performance on near or medium transfer items. However, condition significantly predicted posttest far transfer item performance ($b = 5.61$, $p = 0.039$), with the non-game condition outperforming the game condition.

Discussion

Although learning conditions did not significantly influence near or medium transfer after controlling for prior knowledge, it significantly affected far transfer performance, with students in the non-game condition outperforming those in the game-based condition.

One plausible explanation is that the interactive and narrative features of the game environment imposed extraneous cognitive load that limited deep conceptual processing. Consistent with this interpretation, Parong and Mayer (2018) found that students learning in an immersive virtual reality environment performed worse than those learning through a traditional slideshow. In the present study, the gameplay demands and visual interactions in Angle Jungle may have reduced the cognitive resources necessary for abstraction and schema construction, which are critical for far transfer.

This interpretation is supported by deHaan et al. (2010), who found that students actively playing an educational video game recalled significantly less instructional content than students who only watched gameplay, suggesting that gameplay mechanics can divide attention and interfere with encoding of transferable knowledge. Similarly, game-based environments may encourage learners to prioritize immediate task completion and performance-oriented strategies over deeper conceptual understanding (DeLeeuw & Mayer, 2011). Collectively, these results suggest that instructional simplicity may better support the conceptual processing required for far transfer.

Limitations and Future Work

First, the sample of students may have been too young for the intervention materials. Teacher interviews at one school showed that this population of students had not yet learned supplementary, complementary or negative angles.

Learning gains were small from pretest to posttest, and scores overall were quite low. We can't be sure if the learning materials themselves were flawed or if the materials were simply not a good fit for our study population. Characteristics of learning games affect what can be gained from digital learning games, so future research may isolate particular game characteristics.

We found no difference in performance between conditions. This could be because the non-game tutor was perceived as a game due to the angle-dragging mechanic. A future study should implement an even less game-like tutor to more effectively compare the differences between a game and non-game materials.

Regression analyses from this study revealed that students with higher accuracy in self-explanation responses tended to have higher posttest scores. Further analyses may reveal interaction between self-explanation tendencies and performance on transfer categories.

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