How Can We Help? Examining Learning Behavior Patterns in A Mathematic Game

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INTRODUCTION
Computer games have been increasingly used for educational purposes in recent years. Researchers of game-based learning have argued that well-designed computer games have their unique educational potentials (Garris, Ahlers & Driskell, 2002; Gee, 2003; Ke, 2008). These researchers also proposed that the use of scaffolding to help and enhance learning could be critical. In some game-based studies, researchers have started to explore the design and impact of scaffolding in educational computer games. However, there are still limited empirical findings about the effects of different types of scaffolds. Empirical-based guidelines for designing scaffolds to support learning in educational games is also lacking in the current literature.

Educational computer games are also believed to be a tool of promoting engagement. While previous studies have identified some features of good learning games that promote engagement, such engagement does not necessarily lead to mindful, goal-directed behaviors, or learning engagement behaviors (Ke, Xie & Xie, 2015). It remains an area of research as to what elements specifically promote the learning engagement during gameplay.

In this study, our purpose was to explore and understand the use of different types of scaffolds and how they relate to learning engagement in a digital educational game through analyzing learners' gameplay behaviors. The research questions we aimed to address are: (1) what are the patterns of scaffolding usage that learners demonstrated when playing a math computer game? (2) what is the relationship between different types of scaffolds and students' learning engagement when they play a math computer game?

To answer these research questions, we recruited 14 middle school students to play a mathematic computer game named *Earthquake Rebuild*. *Earthquake Rebuild* (E-Rebuild) is a single-player 3D architecture game that aims to facilitate mathematics learning. The math content embedded in the game tasks is aligned with Common Core State Standards. E-Rebuild currently consists of three episodes with three core game tasks: collecting/purchasing building materials, constructing architecture, and allocating people to new homes. The participants played the game for 45 minutes, twice a week for six weeks. We screen captured the participants' gameplay and recorded their facial expressions, behaviors, and speech during gaming.

Two major types of scaffolds were provided when participants played the game: The first type was coded as External Help (EH), which included scaffolding from a facilitator (EH-facilitator) and that from a peer

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(EH-peer). Such scaffolds mainly included individual question answering and were recorded by headshot recording. The other type of scaffolding was coded as Using Help (UH), which refers to the use of five types of scaffolds programmed into the game: 1) summary screen: a pop-up window providing summative feedback on student performance in a game task; 2) prompting: prompts guiding players to calculate the quantity and cost of building materials needed; 3) tool tips: tools facilitating constructional tasks; 4) scratch board: a calculator-like board where players can type in numbers or notes for mathematical calculation; and 5) help panel: providing instructions on gameplay and operations.

In the preliminary round of analysis, we coded and analyzed learners' behaviors in a total of 70 videos. Five coders conducted calibration with each other through cross-case comparisons and debriefing on the results from coding the first 20 videos. We reached an inter-rater reliability of .90 and a 100% interrater agreement after the debriefing. We also developed a systematic coding scheme during the calibration process.

Through a quantitative coding and a mixed-method exploration of game-based learner behaviors data, we identified multiple patterns on learners' scaffolding usage when playing the learning game. First, students sought for a similar number of human facilitator scaffolds and in-game scaffolds, but they spent much longer time with human facilitators. In addition, students received much more scaffolding, in both frequency and time spent, from adult facilitators than from their peers. Second, help panel was the most frequently used in-game scaffold and was used for the longest time, followed by tool tips, prompts, and summary screen. However, the time spent on these in-game scaffolds was short on average, ranging from 6.85 to 44.65 seconds per 50-minute game session. Last, we found a significant correlation between facilitator scaffolding and learner's learning engagement behaviors (r=.261, p=.029). Using in-game scaffolds has a positive correlation (r=.200) with learning engagement as well. These findings will contribute to the design of both external and internal scaffolding in educational games that promotes learning engagement.

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