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How do learners use in-game learning support in digital game-based math learning?

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Abstract: Learners often encounter difficulties in constructing knowledge in digital game-based learning. In-game learning supports offer in-situ guidance for knowledge-constructive gameplay. Yet, how learners use learning supports are still inconclusive. With a mixed methods study, we investigated learners' varied usage of different learning support features in digital game-based math learning. Preliminary findings with 22,615 speech utterances of thirty-four students revealed seven clusters of learning support use.

Introduction and theoretical background

Digital game-based learning environments are open-ended problem solving spaces that can be used as a sandbox for disciplinary practice, experiment, and exploration. In such learning environments, learners are given a high degree of agency for knowledge discovery and construction (Ke, 2016), whereas oftentimes learners encounter problems that lead to unsatisfying learning outcomes (De Jong & Van Joolingen, 1998). In-game learning support and scaffolding that offer in-situ guidance are critical to sustain learners' efforts to regulate planned and systematic discovery, reflections, and sense-making (Chang et al., 2008; De Jong & Van Joolingen, 1998). The types of learning support and its effects have been explored in the literature (Chang et al., 2008; Puntambekar & Hubscher, 2005). However, how learners use learning supports are still inconclusive (cf. Roll et al., 2014), especially in digital game-based math learning.

Without an understanding of how do learners use learning support when experimenting and discovering in digital game-based learning environments, the design of learning support may not meet the learning needs. Thus, this exploratory study aims to address the following research question*: how do learners use learning support features in digital game-based math learning?*

In-game learning support research has been dominantly focused on cognition and meta-cognition by depicting the "*whats*" (i.e., the content knowledge). Using learning supports for knowledge development of *why* and *how* to learn math during gameplay is also crucial to make learning personally meaningful (cf. Jankvist, 2009), yet has been largely underexplored. In this study, we investigate two types of learning supports featuring different knowledge in game-based math learning. *Task planner* is designed to assist learners' systematic and planned efforts for math problem solving, or *hows*. *Math story*, featuring historical stories and real-life applications of math concepts, is a support feature aimed to scaffold the understanding of *whys* of learning math (Jankvist, 2009).

Method

A convergent mixed methods study was conducted to address the research question by validating findings with both quantitative and qualitative techniques (Creswell & Plano Clark, 2018). We collected data from 34 college students who used two types of learning support (i.e., *task planner* and *math story*) in a math learning game called *E-Rebuild*. Each participant completed a two-hour gameplay, think aloud (in-situ gameplay speech), and semi-structured interviewing (gameplay speech and learner experiences) session. The data were in the form of video- and audio-recording; they were then transcribed verbatim by a professional speech-to-text service and reviewed by human coders. These transcriptions were served as text-based speech data for natural language processing and subsequent analysis. The preprocessing raw data consisted of 22,615 speech utterances (208,649 words).

We used unsupervised machine learning techniques with k-means cluster analysis for data-driven exploration of how did the learners use learning support in this study. Toolkits in *Python* (i.e., *pandas* and *sklearn*) were used. For example, speech data were vectorized into computer-recognizable features for extraction and used for nested (clustered) analysis based on the keywords. Qualitative data were analyzed through open coding. The data collection and analysis are ongoing; we present preliminary and tentative findings in this proposal.

Findings

The text-based cluster analysis validated by qualitative analysis revealed seven preliminary and potential clusters that the learners have used and interacted with the learning support features. For *task planner*, learners were found to use it for procedural problem solving, meta-cognitive awareness, and reflection. For *math story*, learners used it for reflection, reasoning, motivational support, and conceptual learning.

Table 1
The preliminary results of the cluster analysis supported by qualitative analysis for learning support features

Text-based clusters	Text-based cluster instances by key words (*italicized*)
Task Planner-Procedural Problem Solving (20%)	Like sort of *guide* you through those *steps* of how to do it.
Task Planner-Meta-Cognitive Awareness (13%)	I just needed, like *a reminder*, like I haven't ran into similar problems like this before. I just need to see like how to solve it.
Task Planner-Reflection (11%)	I *think* it gives you like the exact math of what you're doing so you can see how the volume of one *relates* to the volume of other, and then how you combine that information.
Math Story-Reflection (19%)	The families one, that's probably where I saw the most *connection,* and the ratios, like the two to one family ratio one and then, how I forgot what it was one of the civilizations that are talking about it was Egypt, how they use the fraction…computations…just like to see the overlap.
Math Story-Reasoning (16%)	It (Math Story) *explains* the different symbols and what numbers they stand for in hieroglyphs…it shows another way of like doing simple math. Like these symbols and everything…students have to go back (to the game) and see what each symbol stands for and multiply that by whatever it's asking.
Math Story-Motivational Support (15%)	It's just *fun* to…like it was just *interesting* to watch it; the math story is definitely *interesting*...it adds to *the beauty of math*.
Math Story-Conceptual Learning (6%)	(Math Story: "completing the square" method) Like the shape revealing algebra…I *don't really know* that *before*.

Discussion and conclusion

In this study, we empirically investigated learners' usage of learning supports featuring different types of knowledge development in digital game-based math learning. Preliminarily, in alignment with prior research findings, learning support of *task planner* was found to support learners' exploration of cognitive and meta-cognitive problem-solving strategies (De Jong & Van Joolingen, 1998). *Math story* appeared to support learners to explain and make connections between the game tasks and math concepts. It also supported learners' motivation to learn and supplement pedagogical values to the existing digital game-based math learning.

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