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A Qualitative Look at Fostering Computational Thinking Within a Game-based Learning Environment

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Abstract: This study explored how participants practice computational thinking (CT) concepts and skills while playing the game. Regarding 11 learning standards from the Computer Science Teacher Association (CSTA), researchers designed gameplay tasks in Minecraft and a supplemental platform called Minecraft Factory Planner (MFP). Data was collected through the cognitive walkthrough with a think-aloud method and semi-structured retrospective interview. The results showed that different game tasks triggered gameplay actions that allowed the practice of different CT skills.

Introduction

Computational thinking (CT) is acknowledged as a vital skill for collaborating effectively with computing technology in solving complex problems (Cansu & Cansu, 2019). The definition for CT that earned the most concord was to recognize it as a thought process to solve problems that involved formatting complex problems and solutions that can be efficiently executed by humans or machines (Wing, 2010). However, for the incorporation of CT into K-12 education, educators must understand the intended student learning outcomes and be familiar with suitable classroom activities that facilitate the application of CT concepts and skills (Barr & Stephenson, 2011). In this case, finding the similarities and relationships across different scholars' explanations of CT would be a method to recognize the overlapping and crossing to understand CT better and develop suitable learning activities (Voogt et al., 2015). As such, we synthesized and defined CT as consisting of five elements, which were decomposition, abstraction, algorithmic thinking, evaluation, and communication through the literature review in this study. The process of investigating scholars' different descriptions of CT also benefited us in comparing gameplay actions to resembled CT learning practices.

Most studies had primarily focused on using programming as the main teaching tool, presenting a challenge for educators lacking the necessary programming expertise to teach CT (Ouyang et al., 2018). Therefore, it is imperative for researchers to explore suitable and diverse teaching tools for teachers (Barr & Stephenson, 2011). Game-based learning (GBL) offers an immersive environment that motivates students to play and learn (Sharp, 2012). Research suggests that the effectiveness of this approach may rely on the situations simulated in the games (Antonietti & Mellone, 2003). In other words, the success of a GBL environment for fostering CT concepts and skills depends on the situations and practices the game provides. To assess whether our lessons, integrated into Minecraft and based on CSTA learning standards, can effectively simulate situations for teaching CT, we referenced CT practices developed by Weintrop et al. (2016), which closely resembled our lessons. Using their criteria for CT practices situated in Science and Math classrooms, we evaluated the effectiveness of our lessons for CT learning.

This study was part of an interdisciplinary project and aimed to determine whether the gameplay tasks in question facilitated the learning and application of specific CT concepts and skills. These gameplay tasks were aligned with the CSTA learning standards (CSTA, 2017). To gather qualitative data, a cognitive walkthrough method with think-aloud techniques was employed, involving four participants aged 12-13. This report underscores the exploration of students' in-game actions in Minecraft and MFP to check whether the gameplay content provides opportunities for teaching CT. The research question is: what in-game actions were performed by participants that could be associated with CT concepts and skills?

Method

For this research, we enlisted four participants who were middle school students between the ages of 12 and 13, using a convenient sampling approach. All of these participants had varying levels of experience with Minecraft. The tasks we designed were based on the CSTA learning standards (CSTA, 2017) and were structured following the 5E instructional model by Bybee (2009). The gameplay tasks conducted in this data collection were centered on two core concepts: data collection and data access. We implemented these tasks on two platforms, Minecraft and MFP. MFP is an online supplementary tool designed to help students translate recipes from Minecraft into flowcharts, representing an input-output model for item production. This allowed participants to explore different

ways of presenting data. We hypothesized that participants could practice the targeted Computational Thinking (CT) concepts and skills while solving these tasks.

During the data collection phase, the participants had to complete tasks on two platforms: two in Minecraft and four input-output model buildings in MFP. They were encouraged to vocally describe and explain their actions as they played through these tasks. Following completing each task, we conducted retrospective interviews to gather their insights. Throughout the cognitive walkthrough, the research team was organized as follows: one researcher served as the host, two researchers focused on taking field notes, and one researcher provided technical support to address any issues. As a result, we obtained data from three distinct sources: video recordings of the participants' in-game actions, transcripts from the retrospective questions and think-aloud commentary, and field notes. However, our initial data analysis primarily emphasized the players' gameplay actions. Regarding the data analysis phase, one researcher watched videos and open-coded participants' in-game actions of playing games in the first cycle of coding. The codes also included their think-aloud explanation. A codebook was constructed with the description of in-game actions and compared them with the meanings indicated in the taxonomy of "data practice" by Weintrop et al. (2016). After comparisons, we preliminarily grouped in-game actions into three themes: collecting data, manipulating data, and visualizing data.

Findings

The results illustrated that the gameplay tasks could cover three data practices: collecting, manipulating, and visualizing data. Students in Minecraft had gameplay actions about collecting data, including checking the recipe book to learn how to produce an item, mining resources (e.g., breaking wood to get logs), etc. Students in MFP manipulated and adjusted the number of resources (inputs) to test how to produce the correct number of items (outputs) and visualized Minecraft's recipes as production models. Upon reviewing the explanations of the three data practices in the taxonomy of Weintrop et al. (2016) and the meaning of CT's five elements, the gameplay tasks allowed participants to practice three computational thinking elements: decomposition, algorithmic thinking, and communication. However, the overall design comprises three units, each containing seven lessons. For this study, participants engaged in the first two lessons of Unit One, and specific CT assessments were not utilized to evaluate participants' acquisition of CT concepts and skills. Consequently, the initial inference is that the designed gameplay tasks may offer promising chances for players to develop CT. In future research, it is imperative to expand the scope by incorporating additional lessons and units for participants to explore, along with integrating CT assessments to validate this conclusion.

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