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Fostering Middle School Students' Computational Thinking Competency in Game-based Learning

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Abstract:
Computational thinking is acknowledged as a fundamental and essential competency that everyone needs to learn for the future. Game-based learning could be a potential platform for improving students' computational thinking competency with respect to its unique features. However, prior research studies in the field of using games to improve computational thinking draw predominant attention to programming concepts and skills which are fundamental skills of computer science than developing computational thinking competency which students can use across the interdisciplinary. Therefore, the current study investigated how curriculum-oriented game-based learning impacted middle school students' learning processes, particularly on the development of students' computational thinking competency, self-efficacy toward computational thinking, and learning engagement in terms of their grade, gender, and prior gaming experience.

Keyword: Computational thinking, game-based learning, self-efficacy, learning engagement

Introduction

Computational thinking (CT) is considered a thinking process of solving problems computationally (Cuny et al., 2010) and has gained increasing attention of scholars and educators in the past decade (Hsu et al., 2018; Liu & Jeong, 2022; Madariaga et al., 2023; Turchi et al., 2019; Zhao & Shute, 2019). There continues to be accepted that CT is a fundamental and an essential competency, along with reading, writing, and arithmetic, for everyone to learn for the future (Atmatzidou & Demetriadis, 2016; Tikva & Tambouris, 2022; Wing, 2006; Zhao & Shute, 2019). As such, more systematic actions should be taken to scale CT in K-12 settings (Grover et al., 2017; Madariaga et al., 2023).

Game-based learning (GBL) is regarded as a salient platform for students to enhance CT competency. Empirical evidence has shown the potential of using GBL to develop students' both cognitive and non-cognitive aspects of learning CT (Hooshyar et al., 2020; Hsu et al., 2018; Liu & Jeong, 2022; Zhao & Shute, 2019), by engaging students in a meaningful context of problem-solving experience (Israel-Fishelson & Hershkovitz, 2020). However, the existing research studies mostly draw a predominant focus on computer programming concepts and skills which are fundamental skills of computer science (e.g., introductory computing concepts, Lai, 2021). Indeed, few studies integrate curriculum-oriented interventions into classroom practices, which makes it difficult for teachers to implement these approaches in classroom teaching and learning.

Therefore, the current study describes the implementation of curriculum-oriented game-based learning in middle school students, focusing on various possible impacts that the educational approach might have on the development of students' CT competency, self-efficacy toward CT, and learning engagement. In addition, we examine how individual differences (i.e., grade, gender, and prior gaming experience) affect students' performance. Specifically, the current study addresses four research questions below:

- Did students improve their computational thinking competency after playing the game?
- Did students improve their self-efficacy of computational thinking after playing the game?
- How did students perceive their engagement when solving game-based problems corresponding to CT?
- Were students' learning performances, self-efficacy, and engagement moderated by grade, gender, or prior gaming experience?

Methodology

Research design

We adopted a one-group pretest-posttest research design to investigate the effects of game-based learning on the development of CT competency, self-efficacy of CT, and learning engagement.

Participants

We recruited 31 middle school students in a summer camp at a non-profit community center in Texas in the summer of 2022. Among the participants, 16 (52%) students were male and 15 (48%) were female. Most students (29, 94%) identified as Hispanic. 12 were in 6th grade, 9 were in 7th grade, and 10 were in 8th grade.

Intervention

STEM+C is a 3D, multi-level architecture game that aims to enhance CT competency for middle school students, with a focus on Data and Analysis, Algorithms and Programming, and Impacts of Computing. We used data analysis learning standards of the Computer Science Teachers Association (CSTA) to design and develop each game quest. The tasks examined in the selected three game levels include: using encoding schemes (2-DA-07), collecting data using computational tools (2-DA-08), and building and refining computational models (2-DA-09).

The primary goal of the game is to produce enough materials to construct beacons for protecting the planet from the damage caused by the upcoming meteor shower. Students take on the roles of engineers who help build sustainable, intricate, and automated factories in Tiny Town. In the selected three game levels, students must fulfill orders by crafting and refining the resources.

Procedure

Students participated in a 6-day experimental study. On Day one, each participant completed a demographic survey, a pretest of CT content knowledge (i.e., NAEP Question Tool), and the Computational Thinking Self-Efficacy Survey (Weese & Feldhausen, 2017). Afterward, students played 40 minutes of the game for consecutive four days. On the first day of game play, students must complete a tutorial, aiming to teach them how to play the game with the mouse and the keyboard, as well as the basic game mechanics which will be used in the selected three game levels. After playing the game on each of the four days, each participant completed a User Engagement Scale (Wiebe et al., 2014). On the last day of the experiment, students completed a posttest of CT content knowledge and the Computational Thinking Self-Efficacy Survey again.

Results and Discussion

Content knowledge. The overall difference in students' CT content knowledge was not statistically significant. General increases were observed for students across the other subgroups, but the increases were only statistically significant for male students ($p < .05$).

Self-efficacy. Students' self-efficacy for general problem solving increased after the gameplay experience ($p < .01$). We observed that female students increased in general problem-solving self-efficacy ($p < .05$); whereas male students did not increase significantly. We also observed an increase in general problem-solving self-efficacy in students with limited Minecraft experience ($p < .05$) and students entering Grade 8 ($p < .01$).

Engagement. Students reported statistically significant changes in perceived usability, but we did not observe differences in scores on the other scales (i.e., focused attention, aesthetics, and satisfaction) across lessons. Specifically, post hoc tests indicated that the differences were marginally statistically significant between the tutorial and lesson 2 ($p = .049$), with perceived usability decreasing and then remaining consistent across lessons 2 and 3. In addition, we observed a statistically significant interaction for gender with male students reporting consistently decreasing perceived usability across lessons; whereas female students reported decreasing perceived usability across the tutorial, lesson 1, and lesson 2, but perceived usability increased for lesson 3.

In conclusion, we observed evidence of using GBL to foster middle school students' CT competency, though there were no statistically significant differences before and after game play. Further, compared to the grade level and previous gameplay experience, we observed that gender may play a vital role in developing students' CT, self-efficacy of CT, as well as perceived engagement across lessons. We will provide more detailed results and discussions in the presentation.