

The impact of Game-Based Learning (GBL) strategy on cultivating learners' computational thinking

Jue Wang *

School of Information Technology in Education, South China Normal University, Guangzhou, China

* Corresponding Author Email: 20202831012@m.scnu.edu.cn

Abstract. This paper focuses on the graphical programming field and what effects would be brought to computational thinking by the utilization of game-based learning strategies. Through reviewing related and newly published literature it occurs that there has been a wide range of solid proofs for its efficiency. Additionally, researcher also widen paths not only from literature review but also from the perspective of affordances to discuss the advantages of GBL strategy. Computational thinking may be used in STEAM (science, technology, engineering, arts and mathematics) area since nowadays people with inter-disciplinary talent are greatly needed. And as technology develops in a fast pace, computational thinking is developing into an essential part of the age of artificial intelligence for us to use, recognize, and evaluate AI-based technologies.

Keywords: GBL; computational thinking; Affordance.

1. Introduction

In both our personal and professional life, computers have become a necessity and the foundation of all computing technology is programming. Students gain significant Computational Thinking (CT) abilities and are able to connect with these technologies in relevant and productive ways thanks to the introduction of basic programming. As a result of CT's growing acceptance as a necessary ability for everyone, school curricula all around the world are increasingly incorporating it. Serious games have been considered as a way that can draw learners into the learning process of programming. For the purpose of evaluating the learning effectiveness of GBL tactics on computational thinking, this research utilizes a literature review methodology. Through reading and summarizing relevant literature in the field, the aim is to explore how GBL can assist students in cultivating and developing their Computational Thinking skills by comprehensively analyzing existing research findings.

2. Core concepts

2.1. Computational Thinking

In the era of interactive computers, Papert [1] asserted that the educational and societal principles associated with these technologies have the potential to shape human cognition and the process of addressing challenges. Specifically, computational thinking has been treated as a method of resolving problems involves framing issues in a manner that enables individuals to seek computer assistance for their solutions effectively. (CSTA & ISTE, 2011)

There has been plenty of different definitions of Computational Thinking from various perspective while the best realized and The definition most commonly referenced comes from Wing, who depicts CT as "the cognitive procedures engaged in shaping problems and their resolutions in a manner that allows these solutions to be efficiently executed by an information-processing entity." [2] Compared to a systematic grammar or strict logic, it focuses more on the conceptualization and clarifying the logical link which between two components. Computational thinking, as well as the capability of problem solving, is under the spotlight. Furthermore, it is now widely believed that the fundamental units of CT encompass six parts, which involve the process of dissecting issues, constructing models, formulating systematic approaches, employing rational conditions, iterative cognition, and detecting and rectifying errors during the procedure. [3]

2.2. Game-based learning (GBL)

According to Corti, GBL strategy refers to the practical utilization of gaming principles within the process of teaching and learning. Serious games have gained acknowledgment as a valuable resource for enhancing situated learning ability and learning experience due to their unique storylines and clear target tasks. Serious games that adequately cultivate computational thinking often require learners to approach problems by building programs, a process that is thought to characterize computational thinking, and GBL has therefore been promoted as an innovative way to develop computational thinking.[4] The favourable effects of GBL concentrated on knowledge acquisition successes have been shown in massive former research papers. For instance, a study which focused on concentration, pace, together with immersion under GBL strategy had been conducted by Plass et al., revealing that active engagement with the game significantly enhances the learning process.[5] Similarly, Romero et al. identified critical elements in serious games, those keep up the pace with growing need for crucial 21st-century competencies like computational thinking. They came to the conclusion for fostering these skills crucial for thriving in contemporary society.[6]

2.3. Graphical programming

Under the information age, one of the fundamental skills of computer science is programming, which is also labeled as a vital component for the development of computer science [3]. Furthermore, graphical programming, which is represented by Scratch, is an efficient way to foster programming thinking in an attachable way which lower the learning cost also ensure that students remain undistracted from the core emphasis of CT, which revolves around conceptualization and the foundational cognitive procedures that are essential for problem-solving.

Scratch provides a visual interface with colorful blocks that represent programming concepts like loops, conditionals, variables, and events. Beginners can drag and snap these blocks together to create simple programs, helping them understand the fundamental building blocks of coding. In Scratch learning, it encourages creativity and problem-solving skills as students have the freedom to design and implement their ideas. The graphical programming environment not only simplifies the process of instructing novices in coding but also serves as a means to foster students' computational thinking (CT) skills[7].

As a matter of fact, there has been a great number of articles and research which explore how game-based learning strategy can improve students' computational thinking. And when we look deeper into how games can be utilized and exactly be used in coding learning, Lawrence[8] introduces an approach based on games as a method to motivate learners in acquiring programming knowledge, specifically emphasizing the use of games to teach data structures. According to Weinan Zhao, a video game called *Penguin Go* is designed by his group and it aims to target main elements of CT as well as reveal effectiveness of developing its skills towards middle school students. Meanwhile, the game *Penguin Go* can further explore the viewpoints of students regarding computer science. Outcomes revealed that following a session of playing *Penguin Go* for under two hours, there was an enhancement in students' scores on computational thinking assessments[9]. Additionally, robot Cozmo had been utilized in coding activities which was under comparison with Scratch, aiming to evaluate the impact on computational thinking by Shannon Smith. He conducted a pre-/post-test quasi-experimental study. The experiment took up a scheduled course, and two classes from a middle school located in the Midwest of the US took part in this experiment. One class, which consists of 21 students, received a coding curriculum by using Scratch, while the other class with 22 students learn with robot. After the entire procedure was complete, the findings demonstrated that neither post-test variations in CT nor beliefs about one's level of competency existed between the Scratch and Cozmo therapies. Although learners in the Scratch class were more engaged than those in the Cozmo class, both designs significantly increased students' perceptions of their computational thinking and proficiency from the baseline to the posttest.[10]

3. The affordances of games

3.1. Affordance

The concept of affordances has been formulated to provide an interpretation for how novel information technologies interact with users and IT artifacts. The fundamental idea behind the theory of affordance is that technological capabilities may not be exclusive to one type of object; rather, it relies on the interaction between the technology and users in a specific context [11].

Additionally, during their interactions with technology, IT users actively engage in understanding those perceived affordances. Since students can easily get attached to electronic devices not only for entertainment but also for learning process, they are also included as IT users. The theory of affordance can be transformed into the application of theories related to GBL.

3.2. The affordances of games

There are approximately about eight affordances of games utilized in education which are main features of games. *Playful*: Games provide a playful and entertaining experience which allow players to immerse themselves in enjoyable and engaging activities created by games and high levels of interests are one of the notable features of games. *Motivating/Incentives*: Games incorporate motivational elements, such as rewards, achievements, and progress tracking, which encourage players to continue playing and achieving their goals. *Engaging/Exploration*: Games offer immersive environments and opportunities for exploration, encouraging players to discover new content, areas, and challenges in which way can be an educational process. *Situated, Meaningful/Context*: Games often present scenarios and contexts that are relevant and meaningful to the players, making the gameplay experience more relatable and engaging. *Higher-level thinking/problem solving*: Many games require players to engage in strategic thinking and problem-solving to overcome obstacles and advance in the game. *Inducing Emotions*: Games can evoke a wide range of emotions, from joy and excitement during triumphs to frustration and determination during challenging moments. *Social/collaborative/competitive*: Games frequently include multiplayer modes that allow players to collaborate with others towards common goals or compete against each other, fostering social interactions and connections. *Adaptive/Personalized*: Some games utilize adaptive technologies and personalized experiences to tailor the gameplay based on the player's performance, preferences, and abilities, enhancing the overall experience.

Overall, these affordances contribute to the appeal of games, making them a popular form of entertainment that offers both enjoyment and cognitive stimulation to players of all ages.

4. The utilization of Computational Thinking in the near future

An examination was conducted to demonstrate that the outcomes of the random effects model indicated a noteworthy and favorable overall impact of GBL on students' computational thinking, accompanied by significant diversity among the importance of these effects. In addition to helping learners learn more about programming knowledge through visualization, graphical blocks and approaches based on games, they may develop the CT skills required for today's employment in STEAM fields. The field of CS is also expanding, AI, which refers to artificial intelligence is steadily being incorporated into numerous technological applications. Individuals engage with AI, often without realizing its presence in daily life. For example, AI provides personalized information as people conduct online searches in search engine and receive video recommendations on social media platforms. Furthermore, advanced AI technologies like autonomous vehicles and robots are anticipated to become prevalent. The functioning of AI shares certain similarities with the problem-solving methods utilized by humans. In essence, individuals are encouraged to consider diverse aspects of a problem and think of different ways to resolve the relevant problems [12]. The ability to reuse a problem-solving thinking train into another different scenario automatically is reflection of individuals' thinking and problem-solving which also reveals the nature of computational thinking.

Celik believes that individuals possessing advanced CT skills may exhibit a greater familiarity with AI concepts and a heightened ability to identify AI. The study revealed that computational thinking played a crucial role in determining AI literacy, enabling individuals to effectively use, recognize, and evaluate AI-based technologies, which indicates the significance of equipping CT skills in the coming future of artificial intelligence era [13].

5. Conclusion

Through extensive literature reading, the developmental history of computational thinking was explored, along with the organic integration of game-based learning, graphical programming, and their impact on computational thinking. GBL is an effective way for learners to acquire programming knowledge, enabling the cultivation of CT. Games can play an attractive part within the teaching process. Designing games should focus on affordances, integrating their characteristics with educational objectives to enhance teaching effectiveness. Compared to traditional coding learning, graphical programming has already greatly lowered cognitive cost which can be easier to learn and has been proved that it can cultivate CT positively. Moreover, since now is the time for artificial intelligence, there are unpredicted possibilities lying in the future path. There may be some fake news or photos created by AI when computational thinking is growing to be a vital part in AI era for people to use, analyze and identify information that is of varying quality.

References

- [1] Papert S A. *Mindstorms: Children, computers, and powerful ideas* [M]. Basic books, 2020.
- [2] Cuny J, Snyder L, Wing J M. Demystifying computational thinking for non-computer scientists [J]. Unpublished manuscript in progress.
- [3] Grover S, Pea R. Computational thinking in K–12: A review of the state of the field [J]. *Educational researcher*, 2013, 42(1): 38-43.
- [4] Gong Xin, Qiao Ailing. The impact of game based experiential learning on computational thinking [J]. *Modern Education Technology*, 2021,31 (11): 119-126
- [5] Plass J L, Homer B D, Kinzer C K. Foundations of game-based learning [J]. *Educational psychologist*, 2015, 50(4): 258-283.
- [6] Romero M, Usart M, Ott M. Can serious games contribute to developing and sustaining 21st century skills? [J]. *Games and culture*, 2015, 10(2): 148-177.
- [7] Theodoropoulos A, Lepouras G. Digital game-based learning and computational thinking in P-12 education: a systematic literature review on playing games for learning programming [J]. *Handbook of research on tools for teaching computational thinking in p-12 education*, 2020: 159-183.
- [8] Lawrence R. Teaching data structures using competitive games [J]. *IEEE Transactions on Education*, 2004, 47(4): 459-466.
- [9] Zhao W, Shute V J. Can playing a video game foster computational thinking skill? [J]. *Computers & Education*, 2019, 141: 103633.
- [10] Smith S M. *A Comparison of Computer-based and Robotic Programming Instruction: Impact of Scratch Versus Cozmoon Middle School Students' Computational Thinking, Spatial Skills, Competency Beliefs, and Engagement* [D]. Kent State University, 2019.
- [11] Treem J W, Leonardi P M. Social media use in organizations: Exploring the affordances of visibility, editability, persistence, and association [J]. *Annals of the International Communication Association*, 2013, 36(1): 143-189.
- [12] Hooshyar D. Effects of technology-enhanced learning approaches on learners with different prior learning attitudes and knowledge in computational thinking [J]. *Computer Applications in Engineering Education*, 2022, 30(1): 64-76.
- [13] Celik I. Exploring the Determinants of Artificial Intelligence (AI) Literacy: Digital Divide, Computational Thinking, Cognitive Absorption [J]. *Telematics and Informatics*, 2023: 102026.