



Toward an Approach of Developing  
Computational Thinking by Educational  
Gaming: a Systematic Review of Literature

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# **Educational games & Computational Thinking**

## **Toward an approach of developing computational thinking by educational gaming: A systematic review of literature**

### **Authors**

**Abstract.** Educational games & Computational thinking (CT) are part of the necessary concern of the research to implement 21<sup>st</sup> century skills. The connection of these research areas appeared strongly in the literature. This paper presents a systematic review of literature of educational games and computational thinking. The paper seeks to identify the main areas of research concerning educational games and computational thinking, and find out the critical transitions in the history of the development of the research. Number of 157 papers were accessed on the Web of Science (WOS) Core Collection, number of 148 valid paper collected as total literature. The study uses the software CiteSpace to review the literature, and answer the research questions. The n papers were clustered and visualized the data and get major milestones in the development of educational games and computational thinking showed in the analysis.

**Keywords:** Computational Thinking. Educational Games. Strategies. Approach, Implementation. Game-based learning. Gaming. Citespace.

### **1 Introduction**

Diverse methods and approaches used to improve 21<sup>st</sup> century skills. One of these methods is computational thinking [11]. The term computational thinking (CT) was used among computer scientists more than other disciplines; though, the appeal now days is to use CT as fundamental skill for other disciplines not only inclusive to a specific domain and for everyone not only for computer programmers as example [7, 8, 11]. Therefore, what is the computational thinking? CT defined as a way “involves solving problems, designing systems, and understanding human behavior, by drawing on concepts fundamental to computer science” [15]. It also believes that CT

is a way to solve the problems, or design systems or even understand the human behavior through concepts essential to computer science. From this definition, CT helps in solving the problem based on a specific process using particular steps computationally rather than syntactically. The particular steps encompass of decomposition of the problem, abstraction, algorithmic thinking and pattern recognition [6]. However, based on the literature there is a connection between CT and educational games. Through this connection to what extent they may work together through research area. Therefore, this study addresses the literature review to investigate the approaches or methods that explain the connection of educational games and CT. The study also seeks to investigate which one could be used to serve the other.

One of the approaches is developing logical thinking and problem solving as a requirement for CT could be achieved through teaching games designed for mobile apps to teach subject such as mathematics [13]. The study applied designed mobile app games to teach elementary algebra for middle school in Hong Kong. The study defined mathematical gamification process to embed concepts of mathematics and the logical manipulations of the concepts in a puzzle game-like. The setting of the game aided by computing technologies, and then evaluated the mobile app games learning efficacy to gain numeracy proficiency in the annual tournament of computer science for students of middle school in Hong Kong.

Another approach used video-game to develop CT. The study evaluated the cognitive and attitudinal influences of playing a video game for middle school students. They addressed the overall effective of the game and investigated the impact of a specific game feature constraints on the number of blocks in a solution. The results showed that after playing Penguin Go for less than two hours, students' CT skills improved significantly, but the additional constraints did not generate a significant impact on learning. In addition, the game overall did not influence students' attitudes toward computer science, but the constraints condition of the game negatively influenced students' attitudes toward computer science [17].

The video games also used to teach CT. Based on the assumption of the negative correlation between the game playing with success in introductory programming classes, the study identified existence of the correlation between previous gaming experience (game playing) and individual CT skills [2]. The data was on the student history gaming and their separate assignment on Scratch. Based on the core CT skills of the students, each project analyzed subsequently to determine the mastery level of CT. A test of trend called Cochran–Armitage was executed on individually CT skill category with considering to the coded gaming experience. The results revealed correlation between gaming experience and specific CT categories in areas of abstraction, problem-solving and interactivity of user. This means it is important matter to account influence of gaming experience on the students to draw strategy for CT in the classroom practice [2].

Furthermore, building a system with an initial game was used based on the children's interest and skills to engage children in CT activities as social gameplay. This approach helps children to theoretically do some work such as solve puzzles on

paper and then use the computer to complete their suggested solutions. Learners guided by complex algorithmic thinking activities during the learning process and with ought use of programming languages the authors built a CTArcade system with an initial game (TicTac-Toe). With evaluation for 18 children aged 10-15, the study revealed that following this approach was helped the children to draw out and articulate algorithmic thinking patterns in a better mode when they played naturally on paper. However, unless children used the CTArcade interface the pattern not obviously apparent to them [8].

A meta-design approach to foster computational thinking through collaborative game-based learning suggested to support end-users to design skills to be used in designing a system in new and engaging modalities [14]. This design expected to help understanding an algorithmic solution to a problem solving. Then, this may enable end-users to understand and trust algorithms, and at the same time enable the participants to design and develop systems according to their needs. Baes on this study there were two different ways suggested to improving CT skills: firstly, playfulness and collaboration, and introduce a game-based system TAPASPlay to foster CT skills. The study explored 18 users; based on hypothesis that learning CT through gameplay is effective. The study then involved participants in game sessions providing playful experience and collaborative learning to test the hypothesis [14].

From the above mentioned, the current study concludes that CT is connected to the educational games as a medium used to develop computational thinking [1, 3, 5, 8, 9]. For further identification and investigation, the study applying Citespace to show the main research areas between educational games and CT and to what extent the connection of them is existed. Notable, Citespace also shows the active areas and turning point as well as types of educational games used to develop CT. As a result, Citespace in this study works as a major tool helps the study to conduct the systematic literature review.

## **2 Research Questions**

Since the purpose of the paper focuses on the investigation of literature to discover the status of the educational games and to what extent it led to develop the CT skills. Therefore, the research questions lead this paper are as follows;

1. What are the major research areas of educational games and Computational Thinking?
2. What are the active areas of educational games and Computational Thinking?
3. Where are the 'turning points' of educational games and Computational Thinking?

### 3 Methods

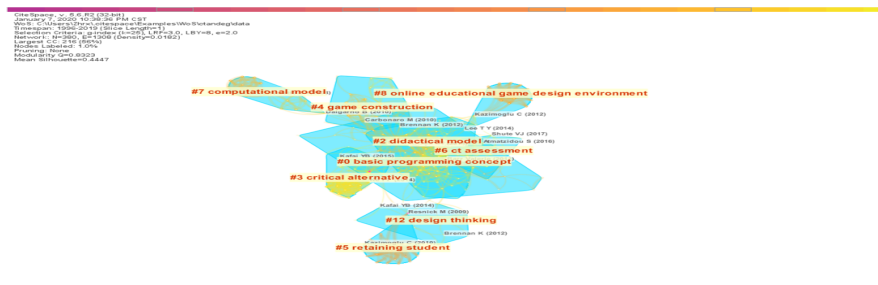
Systematic literature review is a critical work for researchers to develop, identify limitations, quality and potential or answer research questions, and justify future research areas [13]. This study uses systematic review to investigate the main research areas of educational games and computational thinking using Citespace to detect the related work from the Web of Science (WOS) based on the keywords, and inclusion/exclusion criteria. The keywords are ;“computational thinking, strategies for computational thinking, approach to teach computational thinking, implementation of computational thinking, game-based learning, gaming, games & computational thinking, models to CT” to explore electronic data bases to identify the papers related to game and CT. The study also used inclusion & exclusion criteria include papers that; (1) Related to the educational games and computational thinking. (2) Written in English. (3) Available in Web of Science (WOS)Core Collection based on the research topic. (4) Papers published from 1996 to 2019. While the exclusion criteria include papers that; (1) Not related to the educational games and computational thinking. (2) Paper related only to the educational games. (3) Paper related only to computational thinking. (5) Papers were not written in English. (6) Papers published before 1996 excluded by Citespace.

### 4 Results & Discussion

The study presents the results as follows; using Citespace based on the key words of the study figured out number of 157 papers were accessed on the Web of Science (WOS) Core Collection. The 157 papers imported to Citespace, and after the data cleaned by Citespace, number of 148 paper imported to be analyzed by the Citespace. The analysis showed 12 visualized groups separated in the periodic time from 1996-2019. To answer the research questions, in the next space the study presents and discusses the main results obtained by applying the software (Citespace).

#### **RQ1: Major Research Areas of Educational Games and Computational Thinking**

To figure out the main research areas of the study, the analysis first showed the visualization of the educational games & CT. The map includes many areas based on cited journal maps. The number of disciplines visualized include; computational model, game construction, online educational game design environment, didactical model, CT assessment, basic programming concept, critical alternative, design thinking, retaining student. The figure below shows these areas.

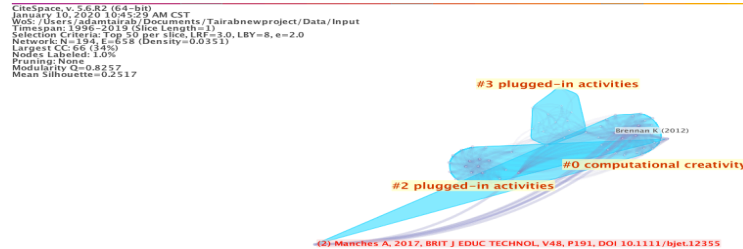


**Fig. 1.** Visualize distribution of educational games & CT research areas (Source: Study analysis software).

The visualization shows numbers of processed records processed by the CiteSpace as mentioned in the methods of the study. Therefore, it is expected to show the number of visualized nodes which are mentioned above. Based on the co-citation network, the visualization process showed a record of 131 publications in the range of 1997-2019 with several references (4316). The visualization of the data collected from the web of science (WOS) showed number of 12th research areas as the main visual groups. These are the main research areas shared between educational games and CT. However, [9] a study argues that “game making” and “game-playing” are effective approaches to develop CT. Playing game associated with CT development could support the fundamental programming concepts. Furthermore, some studies argue that game related CT skills should be included as a pedagogical tool to help in teaching CT skills for the students in the classroom and involve them in tasks for problem solving. By such strategy the students will be able to demonstrate and design game following the CT steps and make effective learning scenarios even if they are outside the classroom or outside of the game environment [16]. Which means that this is an important strategy to improve CT.

### **RQ2: The active areas connecting educational games and Computational Thinking**

Answering this question has been done based on the clustering analysis. Clusters seek to identify the median year of the most citing articles which shows the active connection of the research areas. Nonetheless, clustering also could be explained by size, where a big clustering size means high homogeneity and vice versa. Our study showed 51 clustering groups. These groups with a zero (#0) clustering rate which means the cluster concentrates on making games. (#0) representing the largest area with the largest member of references. Average of the publications years indicates recent papers cited or old papers. The large node connected to itself with a big number of nodes and in the same time connected the other groups of nodes (group3) in figure2 below.



**Fig. 2.** Clustering of active areas of educational games & CT research areas (Source: Study analysis software).

Nevertheless, the connection between the clusters of the active area of educational games and CT as showed in the figure 2 above - stem and coding - as clusters connected to the clusters shows that most cited references is for Boyle EA published in 2016. This active area of the educational games and computational thinking witnessed a huge publications rate between 2010-2016. This time shows more cited references in the major research area.

### RQ3: The ‘turning points’ of educational games and Computational Thinking?

Although, the active area of the educational games and computational thinking witnessed huge publications rate between 2010-2016. However, the timeline views showed that the critical transition in the history of the field development is between 2007-2019 as showed by clusters and key papers cited in the field and explained in the timeline of clusters. However, in this study the labels of highly cited references concentrated in the period of time from 2011-2014.

### Top 1 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	1996 - 2019
Resnick M, 2009, COMMUN ACM, V52, P60, DOI	2009	3.5567	2016	2017	

**Fig. 3.** shows number of references with top citation burst explain the major milestones in the development of Edu games & CT (Source: Study analysis software).

However, the study seeks to find out how educational games develop CT. Based on the literature games have an impact to improve the skills of the CT. For instance, making games develop CT through engagement and motivational, providing real interactions make learners solve problems effectively, think from designer perspective, put their ideas in models, or design programs to reflect these ideas, and this help them to develop more skills such as managing information or solve

problems. Solving problems include making models, design new methods, or interpret the related data, generate new algorithms or evaluate algorithms, making or analyzing codes, or make simulation or developing apps to solve the problem [7, 11]. These skills are the way to develop the CT skills. Therefore, CT requires games as necessary connection to be demystified and applied by learners and sated as a main skill of 21st century required in school.

## 5 Conclusion

This paper presents a systematic review of literature of educational games and computational thinking. The paper aims to identify the main areas of research concerning educational games and computational thinking, and find out the critical transitions in the history of the development of the research. To answer the first research question, the analysis showed 12 research areas. Visualize of the data showed number of 51 clusters grouped in three main groups. These groups with a zero (#0) as a main cluster focus on making games. The connection between the clusters of the active area of educational games and CT is computational creativity. The timeline views shoed that the critical transition in the history of the field development is between 2007-2019.

Nevertheless, educational games improve CT because through games students can learn and practice the steps of CT. Games also motivate and promote the students' knowledge of computer more than other approaches do not employ games [11, 12]. The games develop CT through engagement and motivational, providing real interactions make learners solve problems effectively, think from designer perspective, put their ideas in models, or design programs to reflect these ideas. This enable them to develop more skills such as managing information or solve problems. Solving problems include making a model, design a new method, or interpret the related data, generate new algorithms or evaluate algorithms , making or analyzing codes, or make simulation or developing apps to solve the problem [7,11].

## References

- [1] Angeli, C., & Valanides, N.: Developing young children's computational thinking with educational robotics: An interaction effect between gender and scaffolding strategy. *J.Computers in Human Behavior*(2019)
- [2] Ch'ng, S. I., Low, Y. C., Lee, Y. L., Chia, W. C., & Yeong, L. S. : Video Games: A Potential Vehicle for Teaching Computational Thinking. In *Computational Thinking Education*(pp. 247-260). Springer, Singapore (2019)
- [3] Chen, Chaomei.: The CiteSpace Manual. <http://cluster.ischool.drexel.edu/~cchen/citespace/CiteSpaceManual.pdf> (2014)
- [4] García-Peñalvo, F. J., & Mendes, A. J.: Exploring the computational thinking effects in pre-university education(2018)



- [5] Garneli, V., & Chorianopoulos, K.: Programming video games and simulations in science education: exploring computational thinking through code analysis. *Interactive Learning Environments*, 26(3), 386-401 (2018).
- [6] Grover, S., & Pea, R.: Computational thinking in K-12: A review of the state of the field. *Educational researcher*, 42(1), 38-43 (2013)
- [7] Kazimoglu, C., Kiernan, M., Bacon, L., & MacKinnon, L.: Learning programming at the computational thinking level via digital game-play. *Procedia Computer Science*, 9, 522-531(2012)
- [8] Lee, T. Y., Mauriello, M. L., Ahn, J., & Bederson, B. B.: CTArcade: Computational thinking with games in school age children. *International Journal of Child-Computer Interaction*, 2(1), 26-33(2014)
- [9] Pellas, N., & Vosinakis, S.: April). How can a simulation game support the development of computational problem-solving strategies?. In 2017 IEEE Global Engineering Education Conference (EDUCON) (pp. 1129-1136). IEEE(2017)
- [10] Piper, A. R. J.: How to write a systematic literature review: a guide for medical students. *National AMR, Fostering Medical Research*, 1-8(2013)
- [11] Shute, V. J., Sun, C., & Asbell-Clarke, J.: Demystifying computational thinking. *Educational Research Review*, 22, 142-158(2017)
- [12] Sengupta, P., & Clark, D. B.: Modeling Games in the K-12 Science Classroom (2019)
- [13] Tan, C. W., Yu, P. D., Ling, L., FUNG, C. K., LAI, C. K., & CHENG, Y.: Teaching computational thinking by gamification of k-12 mathematics: Mobile app math games in mathematics and computer science tournament. In *International Conference on Computational Thinking Education 2017* (pp. 55-59). The Education University of Hong Kong(2017)
- [14] Turchi, T., Fogli, D., & Malizia, A.: Fostering computational thinking through collaborative game-based learning. *Multimedia Tools and Applications*, 78(10), 13649-13673(2019)
- [15] Wing, Jeannette M.: "Computational thinking." *Communications of the ACM* 49, no. 3.33-35(2006)
- [16] Wu, M. L., & Richards, K.: Facilitating computational thinking through game design. In *International Conference on Technologies for E-Learning and Digital Entertainment* (pp. 220-227). Springer, Berlin, Heidelberg (2011)
- [17] Zhao, W., & Shute, V. J.: Can playing a video game foster computational thinking skills? *Computers & Education* 103633. doi: 10.1016/j.compedu.2019.103633(2019).