Developing A Game-based Learning Assessment Framework Towards Ubiquitous Computational Thinking among Undergraduate Students

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To cite this article (APA): Jonathan, H.Y.K., Yatim, M.H.M. Tan, W.H., & Wong, Y.S. (2021). Developing a game-based learning assessment framework towards ubiquitous computational thinking among undergraduate students. *Journal of ICT in Education*, *8*(4), 130-144. https://doi.org/10.37134/jictie.vol8.sp.2.13.2021

To link to this article: https://doi.org/10.37134/jictie.vol8.sp.2.13.2021

Abstract

This article discusses on a working study from a research on the usage of a game-based learning assessment framework as a standard guideline to assess undergraduate students' understanding and performance towards ubiquitous computational thinking properly. The objective of this research is to construct an appropriate game-based learning assessment framework to learn ubiquitous computational thinking and to determine the importance of the game-based learning approach. The methods in conducting this research study are a mixed method research with Delphi methodology approach. The game-based learning assessment framework was constructed based on results gathered by literature reviewing papers and afterward questionnaires as an online survey given to experts from game development and computer science fields by phases to answer and validate. The results gathered according to phases were performed using thematic analysis and descriptive statistics respectively. The expected results of this study are that the game-based learning assessment framework is able to assess undergraduate students' understanding and learning performance towards ubiquitous computational thinking and also able to align and incorporate into computing curriculum.

Keywords: game-based learning, computational thinking, assessment framework, learning assessment, video games

Received: 1 October 2021; Accepted: 1 November 2021; Published: 25 December 2021

INTRODUCTION

Computer and mobile games are gradually becoming a global mass medium for people of all ages and genders, rather than only a medium for young guys. (Guenaga, Eguíluz, Garaizar, & Gibaja, 2021; Wu & Richards, 2011). In the education industry, they are also recognised as a learning-teaching system as most schools have computers with internet connectivity and they are able to be use and implement as an appropriate instrument into students learning in the present day. Despite the fact that game-based learning is a prominent teaching and learning medium in the field of education, how does game-based learning perform as an efficient assessment tool for learning ubiquitous computational thinking? Ubiquitous computational thinking is widely recognised as a vital core skill in the IT industry, as well as one of the most difficult problem-solving disciplines to be used for lecturers in teaching and students in learning. Besides that, the long-established teaching method is very difficult to gain undergraduate students' interest in learning ubiquitous computational thinking due to current tutorial or lecture classes could only provide a learning environment with only one way of learning instead of a fun and interesting learning environment (Gardner,2017). Therefore, game-based learning comes into play in this research study. Game-based learning requires a proper framework that can be used as an assessment to assess undergraduate students' understanding towards ubiquitous computational thinking properly, which is currently absent (Gris & Bengtson, 2021). In order to assess undergraduate student in terms of their understanding and learning performance towards ubiquitous computational thinking, an efficient game-based learning assessment framework is required as an assessment tool to assess them. This research will focus on the developing of a game-based learning assessment framework as an effective guideline to assess undergraduate students' understanding and learning performance towards ubiquitous computational thinking. With an effective game- based learning assessment framework, it can ensure to produce undergraduate students with solid ubiquitous computational thinking equipped. Moreover, the knowledge gathered could help to judge the importance of using a game-based learning technique, in which could lead in constructing an appropriate game-based learning assessment framework to learn ubiquitous computational thinking.

CONCEPTUAL FRAMEWORK

The conceptual framework is constructed based on techniques to assess computational thinking, approach and concepts of computational thinking from Csizmadia et al. (2015). Figure 1 shows the combination of game-based learning and computational thinking of the constructed conceptual framework. The main purpose of the constructed conceptual framework is to provide a well-designed structure as a standard and effective guideline to develop computer games that aim for the presentation of learning material.

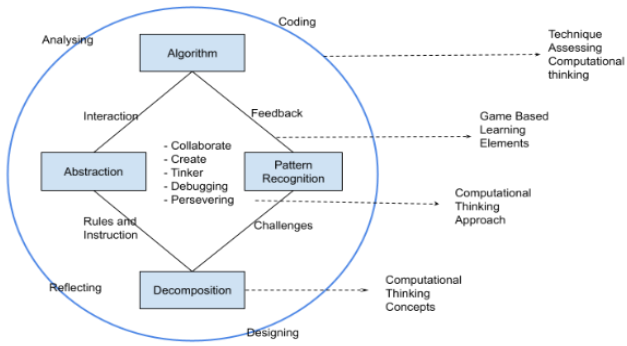

Figure 1: Proposed conceptual framework

In the proposed constructed conceptual framework, there are few combinations, such as concept of computational thinking, game-based learning elements, technique to assess computational thinking and computational thinking approach. Each of them is categorised into table forms.

Table 1 explains the key components of the computational thinking concepts for this conceptual framework. It is also referring to the process that are required to understand the problems and generate a result out.

Table 1: Concept of Computational Thinking

Concept of Computational Thinking	Explanation
Algorithm	Algorithms are the ability to develop a sequence process, understand the problem, and solve the problem so that the work is replicable.
Decomposition	Pattern recognition is the ability to identify the similarities, patterns and connections among small, decomposed problems and then exploit the features to assist us in solving more complicated problems efficiently
Decomposition	Decomposition is the ability to split down difficult situations into smaller chunks, more manageable parts which can be understand, developed, solved and evaluate easily. This can help in solving complicated problem easily, have better

Received: 1 October 2021; Accepted: 1 November 2021; Published: 25 December 2021

	ability to understand the situations and have the ability to design large systems easily.
Abstraction	Abstraction allows us to traverse complexity at scale and find relevance and clarity. It is a process to help us figure out how to work with the different parts efficiently and accurately, making an artefact more understandable through reducing the unnecessary detail.

Table 2 explains the game-based learning key elements that go a long way in reinforcing a better learning objective through playing, effectively improve learning skills and also imparting knowledge and learning through playing.

Table 2: Game Based Learning Elements

Game-based Learning Elements	Explanation
Feedback	Feedback in games is almost constant and immediate. It helps the learner to know his current status and enables the learner to move further to reach his goals. Including feedback continuously will have a positive impact on learning and motivation
Interaction	Games are a great resource to be exploit and experimenting with ideas. Interaction enables learners to engage in the gameplay, enables them to see their decision-making results in real time, make their decision in improving their performance by trying different things or method.
Rules and Instruction	When it comes to learning games in your courses, clear and effective instructions are essential. In order to succeed, learners must understand what they must do and how the game is played.
Challenges	Challenges can engage more learners to play the games. Besides that, it can increase a student's motivation.

Table 3 shows the solution with explanation of the technique to assess the computational thinking. The technique to assess computational thinking are as follow:

Table 3: Techniques to assess computational thinking

Technique to assess computational thinking	Explanation
Coding	Coding involves translating the computer science converting the idea into code and testing it to ensure that it works as expected under all circumstances. Debugging is a skills analysis and evaluation in coding, it requires users to test and trace the problems, analyse and think logically to predict and verify outcomes
Analysing	Analysing entails the use of logical thinking to have a better comprehend and better evaluation skills. In computational thinking, it involves breaking down the complex into components (decomposition), reducing complexity and focusing on relevant and important details (abstraction), identifying the processes and developing solutions to the problems (algorithms).
Reflecting	Reflecting involves making compatible judgments (evaluation) in complicated and tough conditions. Based on the criteria, users need to specify the product and guide the judgements.
Designing	Designing involves planning and developing an artefact with structure, aspects and functionality. In computational thinking, users are required to create representations of the design, which is readable and presentable.

Received: 1 October 2021; Accepted: 1 November 2021; Published: 25 December 2021

Table 4 explains the details for undergraduate students in approaching computational thinking. It discovers where computational thinking happens during the computing curriculum.

Table 4: Computational Thinking Approach

Computational Thinking Approach	Explanation
Collaborate	Collaborates are defined as working together with other learners as a way to approach computational thinking.
Create	Collaborates are defined as working together with other learners as a way to approach computational thinking.
Tinker	Tinker is defined as learners in experimenting and playing, with the attempt to repair or improve, enables learners to approach computational thinking.
Debugging	Debugging is defined as learners' ability to find the errors and fix it. With this ability, learners are able to assess and approach computational thinking easily.
Persevering	Persevering is defined as the learner that keeps on going without giving up. This enables learners to easily approach computational thinking.

LITERATURE REVIEW

The purpose of literature review is to help in understanding the current literature on the research topics, indicates the learning challenges faced by undergraduate students and give specifics on game-based learning methodologies for ubiquitous computational thinking. Therefore, literature reviews are done on the research area and within the framework of the proposed study.

Game Based Learning

Game based learning is an appealing and engaging platform that are acknowledged as a growing trend in the education field and industries. It allows learners to improved their learning performance, achieved learning outcomes and it certainly has a favourable impact on the teaching and learning process (Abdulmajed, Park, & Tekian, 2015; Wang, Liu, & Li, 2011). In game-based learning, game rules are set and players will engage with a normal and typical gameplay, while testing the game's mechanics in order to meet their objective set out by the game rules. Players will need to follow the

rules and fulfil the objectives or levels in order to win the games. As a student who is a player of the game, they will enjoy the game's fun component while also learning instinctively through the changes of game environment, animations and the gameplay. Game-based learning is a teaching-learning strategy that can be implemented into the educational system and environment to achieve learning goals (Wong et al., 2017). According to Hsu, Chang, and Hung (2018) research study, students' interest in game-based learning was found to be increased, and it was found that they are satisfied with the learning activity Based on literature reviewed articles, journals, papers, there is literature highlighting how game-based learning strategically approaches and assesses the learning theories, engaging players to learn while playing.

Table 5: Game- based learning research analysis

Research Work	Key Finding
Sitzmann (2011)	GBL approach increased confidence by 20%, with 9% higher retention, 14% better procedural knowledge, and 11% better declarative knowledge.
Wang, Liu, & Li (2011)	GBL is a visually appealing and engaging platform that helps students enhance their learning performance.
Kazimoglu, Kiernan, Bacon, & Mackinnon (2012)	Participants reported that enjoyable game approach are beneficial and can enhance students learning on the fundamentals of computer programming, improve their problem-solving abilities.
Pho, & Dinscore (2015)	By incorporating game-based learning into online classroom and in-person, these attributes can be use by educators to create a more compelling learning experiences for the students
Abdulmajed, Hind; Park, Yoon Soo, Tekian, Ara (2015)	Gaming has a beneficial effect towards teaching and learning. Gaming creates a beneficial learning environment by requiring students to take part in questioning and answering the scenarios that reinforce students to retain information.

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Computational Thinking

Ubiquitous computational thinking is widely recognised as a vital core skill in the IT sector and plays a crucial and outstanding role as the foundation for STEM (Science, Technology, Engineering and Mathematics) related courses or subjects. Computational thinking is one of the newest learning tools, and it has quickly become ingrained in educational curricula at all levels around the world (Israel-Fishelson & Hershkovitz, 2020). In the meantime, it is regarded as one of the most challenging problem-solving studies for students to learn and lecturers to teach. Computational thinking is an effective and impactful framework for studying courses or subjects related to computing, far beyond computing itself. The computational thinking abilites enables peoples to access sections of the computing topics' content, relate their problem-solving and thinking skills across the entire curriculum and of course throughout life (Sidek, Yatim, & Said, 2020; Csizmadia, Curzon, Dorling, Humphreys, Ng, Selby, & Woollard, 2015). Increase students' exposure to computational thinking is a difficult and complex process because it heavily relies on student's involvement and drive towards learning. Students' participation in the developed computational thinking skills and gamified learning activities can positively impact students' learning. (Kotini & Tzelepi, 2015). Computational thinking holds an important key mental techniques and practises used in computing, although it is applicable to a wide range of fields outside of computer science. Students can practice logical reasoning and tackle challenging and complex tasks and be able to deal with a lot of ideas and concepts among the other skills by using computational thinking (de Jesus & Silveira, 2019). Therefore, it is a very significant and beneficial method of thinking in practically all fields and school topics with as an insight into what can and cannot be computed (Kalelioglu, Gulbahar, & Kukul, 2016).

By acquiring computational thinking skills, users will be able to take actively in the creation and development of systems that are changing to meet their demands (Turchi, Fogli, & Malizia, 2019). The nature of computational thinking was introduced in Figure 2.1 and Figure 2.2. It is a guide from the researchers, Csizmadia, Curzon, Dorling, Humphreys, Ng, Selby, and Woollard, (2015), it provides a vocabulary which educators, lecturers, teachers may discuss, comprehend, and teach the main concepts, approaches, and techniques related with computational thinking.

Undergraduate Students Approach on Computational Thinking

Ubiquitous computational thinking is multi-layered talent that can be tedious, scary and hard to relate ubiquitous computational thinking to a student's daily learning experience. There are various difficulties faced by the students when they are learning computational thinking. The lack of essential knowledge, low interest in learning theoretical side of computational thinking, insignificant and meaningless engagement with the lecturers greatly impact students in learning computational thinking (Gokhale, 2018; Peteranetz, 2018). While programming consists of computational thinking concepts, it has become an issue to the students. When it comes to building a programme to solve a task, incorporating functionality into procedures, understanding language syntax, identifying bugs in programming, and mastering basic programming ideas, undergraduates tend to struggle. (Wong et al.,

2017). Nowadays, some of the students who have passed the programming courses have difficulties in using programming codes to solve problems (Hsu & Mimura, 2018). This is considered a concerning issue because what they have learnt does not impactfully impact them. Given the difficulties that undergraduate students have encountered, it is clear that the existing technique of teaching programming using computational thinking ideas is inadequate.

Most of the students might not have programming experience and background when they enrol in their foundation, diploma, degree programme in undergraduate school. Students will have a hard time in adapting their computing studies. Assignments, tasks, exercises with computational thinking learning subjects will certainly be tiresome and burdensome to the undergraduate students (Watson & Li, 2014; Bennedsen, Caspersen, & Kölling, 2008). Students will end up refusing to learn programming because they believe it is difficult to comprehend, understanding it and applying it into a program. Undergraduates cannot keep up with the pace of lectures, they will get detached from the teaching and learning process, such issues may result in a higher rate of dropout for learning computing courses. (Watson & Li, 2014). This has proven that current teaching of programming courses in computer science, related programmes, tutorial and lecture classes with ubiquitous computational thinking approach are not appealing and uninteresting to provide undergraduate students a better learning environment (Gardner, 2017).

Assessment Framework

Assessment is very crucial issue for game-based learning since without it, learners can't be verified whether they have truly accomplished intended learning goals (Loh, 2012). A framework aids in maintaining the link between the rules and the underlying philosophy of user-system interaction. (Barak & Williams, 2007). Game based learning assessment framework is needed because the existing challenges faced such as the current formal assessment method inadequate to assess students' understanding and performance, unable to apply programming concepts appropriately will be overcome. With the effective game-based learning assessment framework to assess students, it can ensure to produce students who are well equipped with solid ubiquitous computational thinking. A proper, engaging and impactful assessment framework certainly benefits students in achieving the assessment objectives.

But up to date, an approach for assessing the prevalence of computational thinking that is both relevant and correct has yet to be published. Many assessment frameworks had been proposed, but each assessment framework has their own assessment approach. Despite their popularity, game-based learning applications lack a reference model for game-based learning material designed criteria. (Wang, Liu, & Li, 2011). There are number of processes and considerations had to be made in the evaluation of educational games before they could be deemed effective (Abdulmajed, Park, & Tekian, 2015). Without a proper and engaging assessment approach, students are unable to achieve the assessment objectives properly. In the research study, the interaction between teaching and learning computational thinking and game-based learning methodologies is significant. Most of the papers are

lacking theoretical or conceptual backgrounds and also, they lack research designs (Kalelioglu, Gulbahar, & Kukul, 2016). There are studies that can be referenced but minorities of the studies are focused on developing computational thinking aspects in computer and mobile games. (Giessen, 2015).

Van Staalduinen and de Freitas (2011) stated that game-based learning strategy is beneficial for designing, selecting, facilitating, and assessing educational games for educational objectives. By designing the assessment framework with learning approach, a practice-feedback-practice method need to be active. Once a skill or knowledge is acquired, the same skill can be practiced to the point where both extrinsically and intrinsically can be complete. Designing learning activities that embracing the concept of fun and enjoyable game design, game-based learning will be more enjoyable for students and will increase learning results if the ideas of computational thinking and constructivism theory are applied early on. (Kotini & Tzelepi, 2015).

Game Based Learning with Computational Thinking

The popularity of game-based learning as an interactive learning platform has grown in recent years. Learners can participate in computational thinking in a fun and casual way by playing video games. (Weintrop, Holbert, Horn, & Wilensky, 2016). Once learners can offer solutions that can be experienced in an animated environment with images and colours, video games can be useful partners in computational thinking learning. (de Jesus & Silveira, 2019). As stated by Hsu, Chang, and Hung, (2018), Game-based learning was adopted in the computational thinking activities for all educational institutions which are pre-school, elementary school, middle school, high school, and university college. to stimulate their interest in learning. They also stated that based on their research study, it shows that students' creativity and imagination may be sparked through game-based learning, which can also aid in the development of computational thinking skills. Therefore, using game-based learning as a learning platform, the computational thinking community can benefit from engaging learning experiences that are aligned with the abilities and practises.

Games use many characteristics of problem solving as their learning strategies to adopt computational thinking learning activities such as unpredictability and many paths to reach goals, the construction of problem context, collaboration between multiplayers and the elements of competition and chance (Hsu, Chang, & Hung, 2018). By integrating computational thinking into video games, learners will begin to see practices and ways of thinking as a different way of interacting with the world, rather than as abilities that are exclusively useful in one domain. (Weintrop, Holbert, Horn, & Wilensky, 2016).

According to Turchi, Fogli, and Malizia (2019), the two main approaches which are learning through creating games and learning through gameplay have been introduced in order to help to acquire computational thinking skill. There are many researchers who use learning through creating games approaches as part of their experiment, such as Alice, Scratch, AppInventor and more. With each researcher using a different kind of approach, the results of the research analysis concludes that game-based learning with ubiquitous computational thinking approaches shows a promising and positive

outcome on learning experience, but further improvement is still needed in the future. Therefore, the proposed assessment framework for this research study focuses on the learning through creating games approach.

RESEARCH METHODOLOGY

The constructed methodology that are presented in Figure 2 are implemented in detail, which can be used in this study for the purpose to create and finalize a game-based learning assessment framework that can assess students' understanding and execution towards ubiquitous computational thinking. Experts with a minimum of five years' experience that is involved in game-based learning or computer science related development are going to be recruited to participate in this research study.

Data Collection

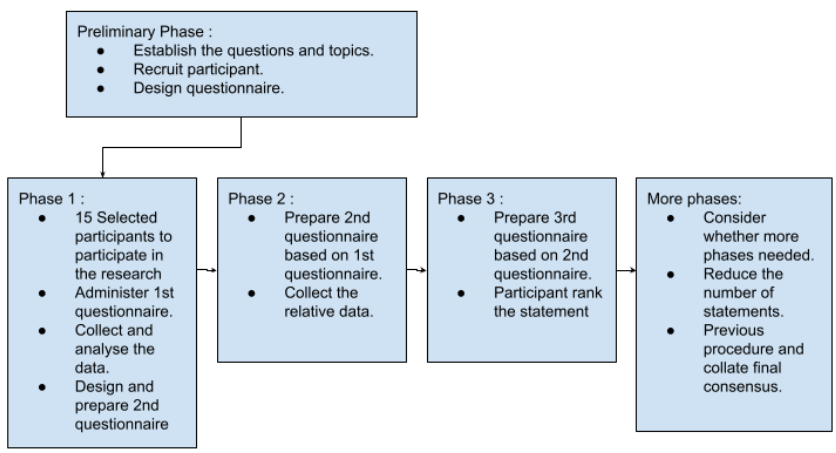

Figure 2: Data Collection Phases by using Delphi Technique

The constructed instruments and methods with Delphi technique approach were categorised into few phases for data collection.

a) Preliminary Phase

Preliminary phases consider as a pilot testing, which represent a fundamental phase of the research process. It can help researchers to get an initial overview by identifying the problem and solutions encountered before establishing the actual tools and also improve the game instrument (Seng, W. Y., Yatim, M. H. M., & Hoe, T. W., 2018). Therefore, the assessment framework is constructed based on literature reviewing paper related to assessment framework for game-based learning and computational

Received: 1 October 2021; Accepted: 1 November 2021; Published: 25 December 2021

thinking. It was suggested that in general, groups should consist of 5 to 20 experts with varying topic experience. Therefore, the conducted study in this phase only included 15 subjects with relevant expertise. The assessment framework is prepared along with the questionnaire for them to validate.

b) Phase 1

Questionnaires to be distributed to the experts for participants to answer. Participants are encouraged to give their opinions to maximize the chance to cover important opinions and issues. Once participants are done in providing their opinions and issues, questionnaires will be collected, and analysis will begin.

c) Phase 2

Phase 2 questionnaires are prepared based on Phase 1 questionnaire's responses. Phase 2 require participants answer the questionnaire by rating the items so that it can be analysed and produced a statistical summary for each item. The questionnaires administered with Likert scale with the two "strongly agree" and "strongly disagree " linguistic scales at both ends of a spectrum and constructed with the following label: strongly disagree, disagree, somewhat disagree, somewhat agree, agree, and strongly agree.

d) Phase 3

In phase 3, the results of the analysis of Phase 2 responses with statistical information are going to be presented to the participants to indicate items that have been gained through collecting opinions from other experts are sent to the participants. Phase 3 questionnaires to be prepared based on Phase 2 questionnaire's responses. Same as Phase 2, administered the questionnaires with a Likert scale for participants to rate the items. Gathered response from all the participants are going to be analysed to see whether consensus can be obtained in this 3rd phase.

e) More Phases if necessary

Additional phases to be considered if needed. More phases or processes will be ongoing with the number of statements reduced until no further consensus can be reached. Previous phase data will be collated for final consensus.

Research Process

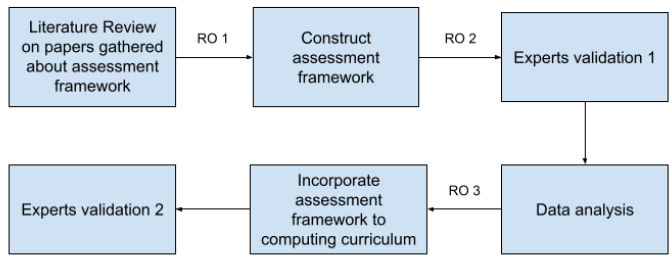

Figure 3: Research Flowchart

The research process shown in Figure 3 involves the objective for the research, the method used for research and the procedure of the research. The three research objectives (RO) are categorised into 3 parts:

a) To develop game-based learning assessment framework to assess ubiquitous computational thinking on undergraduate students. (RO1)

b) To examine students understanding and performance with the newly developed assessment framework towards ubiquitous computational thinking. (RO2)

c) To align the newly developed assessment framework for game-based learning into the computing curriculum (RO3)

Data Analysis

The reliability of the proposed study shall be assessed with Delphi technique. Findings from a Delphi technique helps in organizing work, which can be used as an adjunct to meetings, thus more individuals are allowed and the reliability and validity of the results will be improved (Hasson, Keeney, & McKenna, 2000). Delphi technique is very handy to researchers when it comes to collect thoughts from experts on a certain issue and reach an agreement in order to reveal the underlying assumptions and perspectives among the experts (Habibi, Sarafrazi, & Izadyar, 2014). Besides that, the biggest impact on the effectiveness of Delphi methodology relies on human judgment throughout the entirety of the process (Grime & Wright, 2014).

Data collected from Phase 1 to be analysed by grouping similar items together. The data analysis is a qualitative data for Phase 1 because it is an open-ended set of questionnaires, the data are more to the

experts' comments and responses. All the comments and responses gathered from phase 1 to be analysed using thematic analysis. For other phases, the experts' responses are more on quantitative data. Therefore, after experts' responses are gathered, the number percentage and the mean score of their opinions for each criterion analyse using descriptive statistics. SPSS is used to measure the number percentage and the mean score of the panel of experts' responses. Nvivo is used to measure the comments and responses to a series of open-ended questions More phases will be considered if the received data is analysed and consensus cannot be reached.

CONCLUSION

The objectives of the proposed framework is to develop a game-based learning assessment framework as an effective guideline to assess undergraduate students' understanding and learning performance towards ubiquitous computational thinking. With an effective game-based learning assessment framework, it can ensure to produce undergraduate students with solid ubiquitous computational thinking equipped. Computing curriculum will be able to align with the newly developed game-based learning assessment framework and examine students understanding and performance towards ubiquitous computational thinking. Furthermore, the knowledge acquired may aid in establishing the importance of a game-based learning approach to develop an appropriate evaluation framework for learning ubiquitous computational thinking.

REFERENCES

Abdulmajed, H., Park, Y. S., & Tekian, A. (2015). Assessment of educational games for health professions: A systematic review of trends and outcomes. *Medical Teacher, 37*(1), 27-32. https://doi.org/10.3109/0142159X.2015.1006609

Barak, M., & Williams, P. (2007). Learning elemental structures and dynamic processes in technological systems: A cognitive framework. *International Journal of Technology and Design Education*, *17*(3), 323-340. https://doi.org/10.1007/s10798-006-9006-0

Bellotti, F., Kapralos, B., Lee, K., Moreno-Ger, P., & Berta, R. (2013). Assessment in and of serious games: An overview. *Advances in Human-Computer Interaction*, 1–11. https://doi.org/10.1155/2013/136864

Bennedsen, J., Caspersen, M. E., & Kölling, M. (Eds.). (2008). *Reflections on the teaching of programming: Methods and implementations* (Vol. 4821). Springer.

Csizmadia, A., Curzon, P., Dorling, M., Humphreys, S., Ng, T., Selby, C., & Woollard, J. (2015). *Computational thinking: A guide for teachers*. Hachette, UK: Hodder Education.

de Jesus, Â. M., & Silveira, I. F. (2019, November). A collaborative game-based learning framework to improve computational thinking skills. In *2019 International Conference on Virtual Reality and Visualization (ICVRV)* (pp. 161-166). IEEE. https://doi.org/10.1109/ICVRV47840.2019.00038

Gardner, M. (2017). *Understanding integrated STEM science instruction through the experiences of teachers and students*. Phd Dissertation. Syracuse University.

Gokhale, A., & Machina, K. (2018). Guided online group discussion enhances student critical thinking skills. *International Journal on E-Learning, 17*(2), 157-173.

Grime, M. M., & Wright, G. (2014). *Delphi Method*. Wiley Online Library, https://doi.org/10.1002/9781118445112.stat07879

Gris, G., & Bengtson, C. (2021). Assessment measures in game-based learning research: A systematic review. *International Journal of Serious Games*, *8*(1), 3-26. https://doi.org/10.17083/ijsg.v8i1.383

Guenaga, M., Eguíluz, A., Garaizar, P., & Gibaja, J. (2021). How do students develop computational thinking? Assessing early programmers in a maze-based online game. *Computer Science Education*, *31*(2), 259-289. https://doi.org/10.1080/08993408.2021.1903248

Habibi, A., Sarafrazi, A., & Izadyar, S. (2014). Delphi technique theoretical framework in qualitative research. *The International Journal of Engineering and Science*, *3*(4), 8-13.

Hasson, F., Keeney, S., & McKenna, H. (2000). Research guidelines for the Delphi survey technique. *Journal of advanced nursing*, *32*(4), 1008-1015.

Hsu, T. C., Chang, S. C., & Hung, Y. T. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers & Education*, *126*, 296-310. https://doi.org/10.1016/j.compedu.2018.07.004

Israel-Fishelson, R., & Hershkovitz, A. (2020). Persistence in a game-based learning environment: The case of elementary school students learning computational thinking. *Journal of Educational Computing Research*, *58*(5), 891-918. https://doi.org/10.1177/0735633119887187

Kalelioglu, F., Gulbahar, Y., & Kukul, V. (2016). A framework for computational thinking based on a systematic research review. *Baltic Journal of Modern Computing*, *4*(3), 583-596

Kazimoglu, C., Kiernan, M., Bacon, L., & Mackinnon, L. (2012). A serious game for developing computational thinking and learning introductory computer programming. *Procedia-Social and Behavioral Sciences*, *47*, 1991-1999. https://doi.org/10.1016/j.sbspro.2012.06.938

Kotini, I., & Tzelepi, S. (2015). A gamification-based framework for developing learning activities of computational thinking. In *Gamification in Education and Business* (pp. 219-252). Springer, Cham.

Loh, C. S. (2012). Information trails: In-process assessment of game-based learning. In *Assessment in game-based learning* (pp. 123-144). Springer, New York, NY.

Peteranetz, M. S., Flanigan, A. E., Shell, D. F., & Soh, L. K. (2018). Helping engineering students learn in introductory computer science (CS1) using computational creativity exercises (CCEs). *IEEE Transactions on Education*, *61*(3), 195-203. https://doi.org/10.1109/TE.2018.2804350

Seng, W. Y., Yatim, M. H. M., & Hoe, T. W. (2018). Learning object-oriented programming paradigm via game-based learning game—Pilot study. *Int. J. Multimed. Its Appl*, *10*, 181-197. https://doi.org/10.5121/ijma.2018.10615

Sidek, S. F., Yatim, M. H. M., & Said, C. S. (2020). Characterizing computational thinking for tertiary education learning. *Journal of Contemporary Issues and Thought*, *10*(1), 58-69. https://doi.org/10.37134/jcit.vol10.sp.6.2020

Sitzmann, T. (2011). A meta-analytic examination of the instructional effectiveness of computer-based simulation games. *Personnel Psychology*, *64*(2), 489-528. https://doi.org/10.1111/j.1744-6570.2011.01190.x

Turchi, T., Fogli, D., & Malizia, A. (2019). Fostering computational thinking through collaborative game-based learning. *Multimedia Tools and Applications*, *78*(10), 13649-13673. https://doi.org/10.1111/j.1744-6570.2011.01190.x

Van Staalduinen, J. P., & De Freitas, S. (2011). A game-based learning framework: Linking game design and learning. In *Learning to play: Exploring the future of education with video games*, *53*, 29-53.

Wang, C. S., Liu, C. C., & Li, Y. C. (2011, October). A game-based learning content design framework for the elementary school children education. In *The 16th North-East Asia Symposium on Nano, Information Technology and Reliability* (pp. 53-57). IEEE. https://doi.org/10.1109/NASNIT.2011.6111121

Watson, C., & Li, F. W. (2014, June). Failure rates in introductory programming revisited. In *Proceedings of the 2014 conference on Innovation & technology in computer science education* (pp. 39-44).

Weintrop, D., Holbert, N., Horn, M. S., & Wilensky, U. (2016). Computational thinking in constructionist video games. *International Journal of Game-Based Learning (IJGBL)*, *6*(1), 1-17. https://doi.org/10.4018/IJGBL.2016010101

Wu, M. L., & Richards, K. (2011, September). Facilitating computational thinking through game design. In *International Conference on Technologies for E-Learning and Digital Entertainment* (pp. 220-227). Springer, Berlin, Heidelberg.

Yatim, M. H. M. (2021). A classification of computational thinking model based on computational thinking abilities in game-based learning activities. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(3), 1029-1035. https://doi.org/10.13189/ujer.2020.080135