DOI: 10.34641/ctestem.2022.468

Pedagogical Use of Scratch Coding for Co-Developing English Language "Locations and Directions" Building Blocks and Computational Thinking

Siu Cheung KONG *, Wai Ying KWOK
The Education University of Hong Kong, Hong Kong
sckong@eduhk.hk , waiyingk@eduhk.hk

ABSTRACT

This study designed and evaluated a pedagogical innovation which used Scratch coding to foster Grade 4 students to co-develop subject knowledge and computational thinking (CT) in English Language classrooms. A 280-minute teaching in four lessons was arranged for 205 students from ten selected Grade 4 classes in three primary schools at Hong Kong. The Scratch-based pedagogy "To Play and Learn, To Think and Navigate, To Code" – supplementary with four Scratch games and four Scratch activity worksheets – was trialed for engaging students in Scratch coding to explore, think about, apply and consolidate English Language building blocks for talking about locations and directions. The pre-post-test results provide statistically significant evidence that students can advance all three topic-specific knowledge points and all four target CT concepts after learning under the designed pedagogy. The questionnaire survey results reveal the impact of the designed pedagogy on students' growing awareness of the two target CT practices, and their growing confidence in coding. The focus group interview results reveal students' confirmation on their success in and satisfaction with the designed pedagogy for developing English Language knowledge and CT competency through coding. This study validates that the pedagogical innovation of learning through coding is potential to foster the co-development of subject knowledge and CT competency in Grade 4 English Language classrooms. Future directions of integrating coding activities into senior primary curriculum are discussed.

KEYWORDS

computational thinking, English Language, locations and directions, primary schools, Scratch coding

1. INTRODUCTION AND BACKGROUND OF STUDY

Computational thinking (CT) is growingly recognized to be a necessary competency for the success in the digitalized society (Grover & Pea, 2013; Shute, Sun, & Asbell-Clarke, 2017). CT is a thinking process, as defined in the seminal work by Wing (2006, p.33), of "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science". According to Brennan and Resnick (2012) and Rodríguez-Martínez, González-Calero, and Sáez-López (2020), the competency of CT cover three areas – CT concepts about the concepts central to programming such as sequence, conditionals, repetition; CT practices about the process of creating programming products such as iterative and incremental, abstracting and modularizing, testing and debugging; and CT perspectives about students' perspectives for problem-solving in the digitalized society. School education sectors around the world realize that it is important and necessary to integrate CT education in school curriculum to develop CT among students. With the popularity of the educational use of block-based programming environments such as Scratch, researchers such as Parsazadeh, Cheng, Wu, and Huang (2021) and Sarasa-Cabezuelo (2019) advocate the introduction of CT activities in school curriculum for students as young as at primary grades to co-develop subject knowledge and CT. This study addressed this curriculum advocacy to innovate a pedagogical design which engaged senior primary students in Scratch programming to co-develop "Locations and Directions" building blocks and CT competency in English Language classrooms.

The learning topic "Locations and Directions" is a major component in primary English Language curriculum (Taliancich-Klinger, Bedore, & Peña, 2018; Williams, 2020). There are three knowledge points in the learning scope of this topic – 1) the vocabulary of places in the street, such as "bakery", "bank", "footbridge", etc.; 2) the prepositions / prepositional phrases for describing location of a place, such as "opposite", "behind", "next to", etc.; and 3) the prepositions / prepositional phrases for giving directions to a place, "turn right", "go straight", "walk across", etc. (Chen & Lee, 2018; Taliancich-Klinger et al., 2018). These are important building blocks for generating the information and procedural texts for communication to indicate directions and give instructions. To cultivate young children with these English Language building blocks, researchers such as Taliancich-Klinger et al. (2018) and Williams (2020) suggest that subject classrooms should provide students with ample opportunities to meaningfully learn and apply these grammatical constructs in authentic communication contexts. With the growth of e-Learning in recent decades, more and more English Language classrooms integrate the use of digital educational games in the subject learning and teaching process for motivating students to explore, construct, and consolidate building blocks for English Language communication in an interesting and interactive manner (Chen & Lee, 2018; Wu, 2018).

In primary education, there is a popularity of using block-based programming environment Scratch in subject classrooms (Sarasa-Cabezuelo, 2019; Rodríguez-Martínez et al., 2020). Scratch has an intuitive interface-design of which children can make simple actions to drag, drop, and combine code blocks for an easy creation of programs and an immediate observation of programming outcomes (Parsazadeh et al., 2021; Sarasa-Cabezuelo, 2019).

Regarding the use of Scratch programming environment for integrating CT education into subject curriculum, the frameworks proposed by Brennan and Resnick (2012) and Grover et al. (2017) are widely referred. Such curriculum integration has a rationale that the coding products serve as computational manipulatives which conceptually align with the traditional notion of educational manipulatives (Parsazadeh et al., 2021; Rodríguez-Martínez et al., 2020).

In the English Language subject curriculum for Primary 4 in Hong Kong school education, the knowledge taught in the topic "Locations and Directions" is procedural by nature (i.e. information and procedural texts for communication to indicate directions and give instructions). Such nature is very similar to the one of coding (as the essence of coding is to generate procedural commends for operating solutions on the computing devices). The topic "Locations and Directions" gives a natural point of introducing coding education elements into the curriculum delivery in the subject English Language. This topic is therefore selected as a point of pedagogical trial for learning English Language through coding in this study – for the design of subject-specific pedagogical innovations for Primary 4 students to learn information and procedural texts for communication using authentic scenario through computational tools.

Researchers suggest three main criteria for designing pedagogies which effectively integrate CT education in subject curriculum. The first criterion, according to Sarasa-Cabezuelo (2019) and Rodríguez-Martínez et al. (2020), is the provision of enough chances for students to work on the selected coding products to construct subject knowledge and stimulate their interest in coding. The second criterion, according to Parsazadeh et al. (2021) and Rodríguez-Martínez et al. (2020), is the provision of enough chances for students to apply subject knowledge in thinking about programming solutions for solving problems in subject-specific contexts. The third criterion, according to Parsazadeh et al. (2021) and Sarasa-Cabezuelo (2019), is the provision of enough chances for students to consolidate subject knowledge in generating coding products for solving subject-specific problems.

2. THE STUDY: RESEARCH DESIGN AND METHODOLOGY

This study pioneered a pedagogical design which integrated block-based programming activities in subject classrooms for supporting students to co-develop both subject knowledge and CT competency. The pedagogical innovation engaged students in Scratch coding for developing three types of building blocks for communication to indicate directions and give instructions (i.e. the vocabulary of places in the street as well as the prepositions and prepositional phrases for describing location of and giving directions to a place); and at the same time the competency of four CT concepts ("sequences", "conditionals", "repetition", and "operators") and two CT practices ("iterative and incremental" and "testing and debugging") – as in the CT frameworks by Brennan and Resnick (2012) and Rodríguez-Martínez et al. (2020).

A three-step pedagogy "To Play and Learn, To Think and Navigate, To Code" – supplementary with a Scratch programming environment with four Scratch games and four Scratch activity worksheets – was designed for engaging students in "playing" the Scratch games featured with Scratch-based interactive maps for "learning" the building blocks for talking about locations and directions when using maps; "thinking" of and "navigating" the movement actions of the sprites on the Scratch-based interactive maps to move from one place to another place; and "coding" in a Scratch template to create a Scratch animation with their own relocation of places on the interactive map, their own selection of sprites to be appeared on the interactive map, and their own design of routing for the sprites to walk from one place to another place (see Figure 1).

(a) Scratch games for the "To Play and Learn" step

"Locations" game

"Directions" game

(b) Scratch games for the "To Think and Navigate" step

"Treasure hunt" game

"Can you show me the way?" game

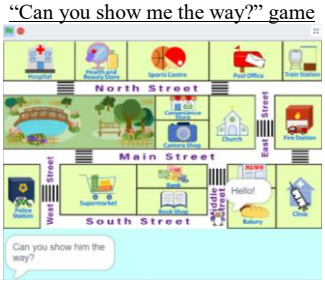

Figure 1. Scratch Games for the Designed Pedagogy.

A total of 205 students – from ten Grade 4 classes in three primary schools at Hong Kong – participated in this study (see Table 1). The English Language teachers of the ten participating classes made the class-specific trial of the designed pedagogy.

Table 1. Profile of Students Participated in This Study.

	School A	School B	School C
No. of students	100	59	46
No. of classes	5	2	3
Boys : Girls	52:48	24:35	27:19
Mean age (years)	8.91	8.96	8.96

The participating teachers completed a four-hour training workshop for their preparation before the trial teaching – covering the rationale of learning through coding in local

English Language curriculum; the implementation of the "To Play and Learn, To Think and Navigate, To Code" pedagogy in English Language classroom; and the integration of the four Scratch games and the four Scratch activity worksheets into topic-specific lessons. Two research questions were focused in this study: (1) What did the students achieve in developing English Language building blocks and CT under the pedagogical innovation? (2) How did the students perceive the pedagogical innovation for developing CT in English Language classrooms? This study adopted three methods for evaluating the designed pedagogy.

The first method was pre-post-tests at the beginning and the end of the designed pedagogy. It aimed to investigate students' achievement in English Language learning and CT development. The test papers contained eight questions: one question on testing the vocabulary of places in the street; two on the prepositions and prepositional phrases for describing location of a place; one on prepositions and prepositional phrases for giving directions to a place; and four on CT concepts including "operator", "repetition", "conditionals" and "sequence". Students' pre-test and post-test scores were statistically compared with the assistance of SPSS software. The Cronbach's alpha reliability coefficients for the pre-test and post-test are 0.81 and 0.82 respectively.

The second method was pre-post-surveys at the beginning and the end of the designed pedagogy. It aimed to investigate students' perception of developing CT in English Language classrooms. The questionnaire contained five 5-point Likert scale questions: three questions on the building of awareness, interest and confidence in coding, and two on the development of CT practices of "iterative and incremental" and "testing and debugging". The mean rating for each question and the corresponding standard deviation were then calculated. The Cronbach's alpha reliability coefficients for the pre-survey and post-survey are 0.86 and 0.84 respectively.

The third method was focus group interviews at the end of the designed pedagogy. It aimed to investigate students' perception of the designed pedagogy. There were 11 students randomly selected from the three participating schools for three focus groups, with each consisting of three to four students. The student respondents were asked to describe the helpfulness of the designed pedagogy in their development of English Language knowledge and CT competency, express how they enjoyed and were satisfied with the pedagogy for English Language learning through coding, and discuss the challenges in and suggestions on English Language lessons integrated with coding activities. All the interview content was transcribed and systematically summarized.

3. Results and Discussion

3.1. Students' Achievement in Developing Topic-specific Building Blocks and CT under the Designed Pedagogy

The pre-post-tests results show that the designed pedagogy effectively supported students to develop building blocks for communication to indicate directions and give instructions (see Table 2). There is a statistically significant increase in students' post-test scores for the question items on all three types topic-specific building blocks. This shows that students after the designed pedagogy had a noticeable gain in the knowledge about the vocabulary of places in the street as well as the prepositions and prepositional phrases for describing location of and giving directions to a place.

Table 2. Students' Achievement in Developing Topic-specific Building Blocks under the Designed Pedagogy.

Question items			***Pre-test***	***Post-test***	
Topic-specific building blocks	***No. of items***	***Max. scores***	***Mean (SD)***	***Mean (SD)***	***t-test***
A. Vocabulary - Places in the street	1	6	4.10 (1.80)	5.07 (1.31)	7.35***
B. Prepositions / Prepositional phrases - Describe location of a place	2	6	3.07 (1.80)	4.81 (1.54)	12.14***
C. Prepositions / Prepositional phrases - Give directions to a place	1	8	2.19 (2.03)	5.80 (2.08)	20.80***
Total	**4**	**20**	**9.36 (4.39)**	**15.69 (3.94)**	**19.54*** **

****p < 0.001*

The pre-post-tests also found that the designed pedagogy effectively supported students to develop CT concepts. There is a statistically significant increase in students' post-test scores for the question items on all four target CT concepts (see Table 3). This shows that students after the designed pedagogy noticeably enhanced their concepts used in coding.

Table 3. Students' Achievement in Developing Computational Thinking under the Designed Pedagogy.

Question items			***Pre-test***	***Post-test***	
CT concepts	***No. of items***	***Max. scores***	***Mean (SD)***	***Mean (SD)***	***t-test***
A. Operator	1	1	0.28 (0.45)	0.62 (0.49)	8.46***
B. Repetition	1	1	0.35 (0.48)	0.46 (0.50)	2.44*
C. Conditional	1	1	0.23 (0.42)	0.46 (0.50)	5.26***
D. Sequence	1	1	0.24 (0.43)	0.41 (0.49)	3.57***
Total	**4**	**4**	**1.11 (1.02)**	**1.96 (1.19)**	**8.29*** **

**p < 0.05 ***p < 0.001*

3.2. Students' Perception of the Designed Pedagogy for Learning English Language through Coding

The students positively perceived the designed pedagogy for developing CT in English Language classrooms (see Table 4). The students had a statistically significant increase in the level of agreement with the importance of the step-by-step development of a program and the operability-testing of the program after the trial teaching. This show that the students after the designed pedagogy noticeably enhanced their CT practice of "iterative and incremental" and "testing and debugging". The students after the trial teaching also had a statistically significant

growth of their confidence in programming and their understanding of the importance of programming.

Table 4. Students' Perception of the Designed Pedagogy for Developing Computational Thinking in English Language Classrooms.

Items	*Pre-survey Mean [#] (SD)*	*Post-survey Mean [#] (SD)*	*t-test*
I think it is important to develop a program step by step.	3.61 (1.36)	4.04 (1.13)	3.65***
I think it is important to test the program to make sure it works.	3.55 (1.35)	3.95 (1.23)	3.39***
I am interested in learning programming.	3.40 (1.37)	3.58 (1.28)	1.58
I think that programming is important in our daily lives.	3.30 (1.26)	3.51 (1.17)	1.97*
I am confident that I can write a simple program.	3.24 (1.37)	3.68 (1.21)	3.77***

[#]Note: 1=strongly disagree, 2=disagree, 3=neutral; 4=agree; 5=strongly agree.

**p < 0.05 ***p < 0.001*

The results of the focus group interviews, echoing with those of pre-post-tests and surveys, further confirmed students' positive perception of the designed pedagogy for developing CT in English Language classrooms (see Table 5).

Table 5. Feedback from Students' Focus Group Interviews on the Perception of the Designed Pedagogy.

What and how the designed pedagogy helped for the learning trial?
-The designed pedagogy enabled students to effectively learn about the vocabularies, prepositions and prepositional phrases for describing locations and giving directions when using maps. -The designed pedagogy enabled students to effectively develop Scratch coding knowledge and CT competency, in particular the components of "Conditional", "Repetition", and "Testing and Debugging".
How enjoyable and satisfactory was the designed pedagogy?
-The students liked the designed pedagogy for developing both subject knowledge and CT competency in a happy and interesting manner, as coding activities were funny and appealing. -One-third of students made additional efforts to play and re-create the Scratch game in the designed pedagogy after class time for exploring more the building blocks used to describe locations and give directions.
What are the challenges in and suggestions on this pedagogy?
-One-fourth of students at the beginning found the coding activities challenging, as Scratch programming environment was new to them and thus hard to recall the names and types of Scratch coding blocks for use. -One-third of students suggested an enrichment of the Scratch game scenario for learning both the topics of "Locations and Directions" and "Food and Drinks" at the same time specific for Grade 4 curriculum.

The students asserted the help of the designed pedagogy in the development of English Language building blocks and CT. Nearly three quarters of the student respondents confirmed that the designed pedagogy enabled them to effectively learn about the vocabularies of names of different places; and the ways to describe locations and directions in map-usage. A student respondent illustrated that after confirming the correct route he deliberately manipulated the sprite to go in the wrong and/or opposite directions, for a more interesting exploration of the locations appeared on the map. More than a third of the student respondents confirmed that the designed pedagogy enabled them to effectively learn about coding with Scratch to create games. Two student respondents pointed out that they have particular deep impression of CT concepts "Conditional" and "Repetition". The other two student respondents further explicated that the coding experience in the designed pedagogy fostered their awareness to test and debug coding products through the trial-and-error process.

The students expressed their high level of enjoyment in and satisfaction with the designed pedagogy for English Language learning through coding. All student respondents indicated that they had a happy and interesting experience in learning the target subject topic; and were greatly attentive during the coding activities which were funny and appealing. Around three quarters of the student respondents expressed that they liked the learning activities in the designed pedagogy. They considered the design of coding activities was easy to follow; and they gained a great sense of achievement when they successfully completed the coding activities. Nearly half of the student respondents indicated that they played the Scratch game after class time for learning exploration. Four of the students stated that they successfully altered the codes in the Scratch game after class time for creating new sprites and changing locations of the buildings on the map. One of them further noted that he had introduced his re-created Scratch game to his family members and friends for game-playing.

The students indicated challenges in and made suggestions on English Language lessons integrated with coding activities. As for the challenges in the designed pedagogy, around a third of the student respondents indicated that it was the first time for them to use Scratch; and at the beginning they found the coding activities were not easy as they were unfamiliar with Scratch programming environment. It took time for them to familiarize with the names and functions of the coding blocks. These student respondents therefore expected for pre-training of Scratch coding before the trial lessons. As for the recommendations on the designed pedagogy, more than half of the student respondents suggested that the designed pedagogy can be extended to the teaching of other topics in the English Language subject curriculum at the same learning grade (i.e. Grade 4). Five student respondents detailed their suggestion on a possible enrichment of the learning scenario of the designed pedagogy by combining the existing topic of "Locations and Directions" with the other topic "Food and Drinks" in the Grade 4 English Language subject curriculum. These students expected that building on the existing Scratch map, a zoom-in view of the places "Restaurant" and "Supermarket" can be added for game-extension: the sprites enter these places and make dialogs for making orders of food and drinks services in the restaurant and inquiring locations and prices of food and drinks products in the supermarket. Students in the enriched learning scenario can apply and consolidate knowledge about, for example, vocabularies of various types of food and drinks and sentence-making for making catering orders in restaurants and making general inquires in supermarkets.

4. CONCLUSION AND FUTURE WORK

This study pioneered a Scratch-based pedagogical design for Grade 4 students at Hong Kong for their co-development of English Language knowledge and CT competency in subject classrooms. The designed pedagogy focused on the development of building blocks in the English Language subject topic "Locations and Directions"; as well as four CT concepts and two CT practices. A four-lesson trial teaching was arranged for 205 students from ten selected Grade 4 classes in three Hong Kong primary schools to implement the pedagogy "To Play and Learn, To Think and Navigate, To Code", supplementary with four Scratch apps and four Scratch activity worksheets. From the pre-post-tests, the designed pedagogy is confirmed to be effective to support students to significantly enhance their knowledge about the vocabulary, prepositions and prepositional phrases for describing location of and giving directions to a place; as well as CT concepts of "operator", "repetition", "conditional" and "sequence". From the questionnaire surveys, the designed pedagogy is confirmed to be effective to support students to significantly enhance their CT practices of "iterative and incremental" and "testing and debugging". From the focus group interviews, the design and effectiveness of the Scratch-based pedagogy are confirmed to be well-received by the students for English Language learning and CT development through coding.

This study collected concrete suggestions on the potential expansion of topic coverage in the design of learning scenarios for Scratch-based interactive map games. Future work will consider these promising ideas for enhancing the design of games and worksheets of this Scratch-based pedagogical innovation to enrich students' experience in learning information and procedural texts for communication in senior primary English Language curriculum. Future work will also try to arrange a control group in the research design, in order to address the limitation in this study that no control group was involved in the evaluation of the effectiveness of the designed pedagogy. For providing a more accurate picture on the feasibility of smooth integration of coding elements into English Language classrooms, concerns will also be placed on the issues about the readiness of subject teachers, the sufficiency of class hours, and the solutions for cross-disciplinary barriers when preparing for the actual teaching arrangements of future trials of the pedagogical approach of learning English Language through coding.

5. REFERENCES

Bell, H., & Ainsworth, S. (2021). Difficulties assessing knowledge of grammatical terminology: Implications for teacher education and teaching. *Language Awareness*, *30*(2), 97-113.

Brennan, K., & Resnick, M. (2012). New frameworks for studying and assessing the development of computational thinking. *2012 Annual Meeting of the American Educational Research Association (AERA'12)*, Canada.

Chen, Z.-H., & Lee, S.-Y. (2018). Application-driven educational game to assist young children in learning English vocabulary. *Educational Technology & Society*, *21*(1), 70-81.

Grover, S., & Pea, R. (2013). Computational thinking in K-12: A review of the state of the field. *Educational Researcher*, *42*(1), 38-43.

Parsazadeh, N., Cheng, P.-Y., Wu, T.-T., & Huang, Y.-M. (2021). Integrating computational thinking concept into digital storytelling to improve learners' motivation and performance. *Journal of Educational Computing Research*, *59*(3), 470-495.

Rodríguez-Martínez, J. A., González-Calero, J. A., & Sáez-López, J. M. (2020). Computational thinking and mathematics using Scratch: An experiment with sixth-grade students. *Interactive Learning Environments*, *28*(3), 316-327.

Sarasa-Cabezuelo, A. (2019). Use of Scratch for the teaching of second languages. *International Journal of Emerging Technologies in Learning*, *14*(21), 80-95.

Shute, V. J., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review*, *22*, 142-158.

Taliancich-Klinger, C. L., Bedore, L. M., & Peña, E. D. (2018). Preposition accuracy on a sentence repetition task in school age Spanish–English bilinguals. *Journal of Child Language*, *45*(1), 97-119.

Williams, M. (2020). Fifth graders' use of gesture and models when translanguaging during a content and language integrated science class in Hong Kong. *International Journal of Bilingual Education and Bilingualism*, 1-20.

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33-35.

Wu, T.-T. (2018). Improving the effectiveness of English vocabulary review by integrating ARCS with mobile game-based learning. *Journal of Computer Assisted Learning*, *34*(3), 315-323.