

## Development of Mathematical Teaching Materials Integrated with Computational Thinking: Taking the Mathematical Rectangular Coordinate System Lesson as an Example

Yi-Jin Ju<sup>1</sup> Cheng-Hsuan Li<sup>2</sup>  
Pei-Chen Wu<sup>3</sup> Pei-Jyun Hsieh<sup>4</sup>

### Abstract

Computational thinking (CT) encompasses essential skills such as abstraction, modeling, modularization, reusability, iteration, and optimization, which have a solid connection to mathematical thinking. In response, a study developed three mathematics textbook units focused on the rectangular coordinate system and integrated computational thinking into the curriculum. The objective was to investigate whether incorporating computational thinking in math classes could enhance students' learning outcomes for both computational thinking and mathematics courses. To facilitate the study, specific coding blocks related to mathematics were created, including coding blocks for calculating the triangle area and moving from one position to another. Students were required to combine CT and mathematical ability (MA) to solve given math problems. The study's findings show that students achieved similar learning outcomes through traditional teaching methods and the Computational Thinking  $\times$  Mathematical Education courses. The effect sizes of CT ability and MA for the experimental group were medium, while the MA of the control group also had a medium effect size. Notably, the experimental group's effect size surpassed that of the control group. Regarding student feedback, a more significant number of students preferred the Computational Thinking  $\times$  Mathematical Education course, as they found it innovative and engaging.

**Keywords:** Computational Thinking, Mathematical Ability, Rectangular Coordinate System Lesson, Teaching Material

1. Yi-Jin Ju, PhD candidate, Graduate Institute of Educational Information and Measurement, National Taichung University of Education
2. Cheng-Hsuan Li, Professor, Graduate Institute of Educational Information and Measurement, National Taichung University of Education
3. Pei-Chen Wu, PhD candidate, Graduate Institute of Educational Information and Measurement, National Taichung University of Education
4. Pei-Jyun Hsieh, PhD, Graduate Institute of Educational Information and Measurement, National Taichung University of Education

Received: 2023.06.02; Revised: 2023.11.19; Accepted: 2023.11.26

Corresponding Author: Cheng-Hsuan Li; Email: ChengHsuanLi@gmail.com

Address: No. 140, Minsheng Rd., West Dist., Taichung City 403514, Taiwan

Graduate Institute of Educational Information and Measurement, National Taichung University of Education

《測驗學刊》  
第七十一輯第三期 2024 年 9 月 363~391 頁

## 開發運算思維結合數學教材： 以數學直角坐標平面課程為例

朱怡瑾<sup>1</sup> 李政軒<sup>2</sup> 鄔珮甄<sup>3</sup> 謝佩鈞<sup>4</sup>

### 摘要

運算思維 (CT) 涵蓋了抽象、建模、模組化、再用、迭代和優化等重要技能，與數學思維有著密切關聯。因此，本研究開發了三個數學教材單元，重點放在直角坐標平面上，並將運算思維融入課程中。研究目標是探究將運算思維納入數學課堂是否能提升學生在運算思維和數學課程方面的學習成果。為了便於研究，創建了與數學相關的特定編碼模塊，包括計算三角形面積和從一個位置移動到另一個位置的編碼模塊。學生需要結合運算思維和數學能力 (MA) 來解決所給予的數學問題。研究結果顯示，學生透過傳統教學方法和「運算思維×數學教育」課程實現了類似的學習成果。實驗組的 CT 能力和 MA 的效果量達到中度，而對照組的 MA 效果量也是中度。值得注意的是，實驗組的效應大小超過了對照組。關於學生反饋，更多學生偏好「運算思維×數學教育」課程，因為他們覺得這種課程創新且引人入勝。

**關鍵詞：**直角坐標平面課程、教學教材、運算思維、數學能力

- 
1. 朱怡瑾，國立臺中教育大學教育資訊與測驗統計研究所博士候選人
  2. 李政軒，國立臺中教育大學教育資訊與測驗統計研究所教授
  3. 鄔珮甄，國立臺中教育大學教育資訊與測驗統計研究所博士候選人
  4. 謝佩鈞，國立臺中教育大學教育資訊與測驗統計研究所博士
- 收件日期：2023.06.02；完成修改：2023.11.19；正式接受：2023.11.26  
通訊作者：李政軒；Email：ChengHsuanLi@gmail.com  
地址：403514 臺中市西區民生路 140 號  
國立臺中教育大學教育資訊與測驗統計研究所

## Introduction

The term STEM is a combination of the acronyms of Science, Technology, Engineering, and Math. STEM education is a combination of the above four dimensions of subject content and knowledge to develop and teach courses. Students use the knowledge of science and mathematics learning in engineering and technical design to solve problems (Chen & Ku, 2017; Chamberlin & Pereira, 2017; Margot & Kettler, 2019). According to research, a good STEM education consists of six frameworks: (a) curriculum content covering mathematics and science, (b) a teaching method that puts students at the center, (c) curriculum content is attractive and challenging, (d) Covers the challenges of engineering creation and technology, (e) reflection and learning from mistakes, (f) teamwork learning (Margot & Kettler, 2019; Moore et al., 2014). In the STEM review paper, it is found that there are not many curriculum materials that are combined with mathematics knowledge. According to the previous six framework goals, the difficulties encountered by most teachers are (a) unable to integrate Specific courses (such as biology and geometry, etc.) are combined with other STEM subjects, (b) it is impossible to integrate multiple boring cross-field curriculum (c) different teachers have different views on each field, and communication is It has obstacles and is easy to cause disputes, leading to the failure of STEM curriculum integration (Asghar et al., 2012; Margot & Kettler, 2019). Therefore, this study designs a curriculum that combines programming and mathematics, and this curriculum is interesting.

The concept of computational thinking (CT) was introduced in the journal *AMC Communications* by Professor Jeannette M. Wing (2006) of Carnegie Mellon University. Because CT ability is integral to successful adaptation in the future, it is a critical educational topic in many countries (Hsu et al., 2018). For example, the British Ministry of Education included computer learning courses in primary and secondary school curricula (stages 1-4). The content of these courses encompassed CT, information processing, and mathematical literacy (Brown et al., 2014; GOV.UK, 2013; Hsu et al., 2018). Furthermore, Australia has established CT as a national course, combining DT courses with CT courses to cultivate students' ability to understand and solve

problems, use computers to solve problems, and apply CT in real-life situations (Armoni, 2012; Falkner et al., 2014; Hsu et al., 2018).

Mathematical thinking (MT), including logical and analytic thinking, refers to engagement with numbers and abstract mathematical concepts related to daily life (Devlin, 2012; Onal et al., 2017; Yeşildere, 2007). MT concerns four fundamental processes: specializing by looking at examples and finding special cases, generalizing by looking for patterns and relationships, conjecturing by predicting relationships and results, and convincing through communication of reasons (Stacey, 2006). CT is highly correlated to MT; for example, the concepts of modelling and specializing (Calao et al., 2015; Stacey, 2006) are quite similar to those of abstracting and modelling (Zhong et al., 2016). Moreover, if MT is employed to design a mathematical model, then CT may be required to implement the model using computer languages. In mathematics, at least two connection courses between MT and CT can be found, namely the algorithm and the numerical courses. Therefore, in this study, we developed mathematics learning materials using CT such that students could learn mathematics unit material by using the CT-enabled Blockly coding platform.

The majority of CT courses, both plugged and unplugged, such as the courses on Code.org and Blockly Games and some board games, begin with moving forward and turning left or right (Code.org, 2018; Google, 2014; Lee et al., 2011). The foundational concept informing these courses is very similar to that informing the K-7 mathematical lesson on the rectangular coordinate system. However, the concepts of the x-axis and y-axis are not mentioned in these courses. Hence, we developed an improved learning platform for learning about the rectangular coordinate system through CT. Some coding blocks, including  $x + 1$ ,  $x - 1$ ,  $y + 1$ , and  $y - 1$ , were designed for helping the students understand the x-axis and y-axis. We also developed coding blocks for mathematical operations such as computing triangular areas. Teachers can use our course during or after the teaching of the rectangular coordinate system. This may simultaneously improve students' learning of some CT concepts and the rectangular coordinate system.

Therefore, this study aims to explore the following questions: (a) Whether students' performance in mathematics and CT improves after completing a Computational Thinking  $\times$  Mathematical Education course; (b) Whether there are significant

differences in students' mathematics and CT abilities under different teaching methods; (c) How do students perceive the satisfaction and acceptance of the Computational Thinking  $\times$  Mathematics Education course after its completion.

## Related Works

In the realm of CT, it is generally that CT focuses on problem-solving using computers, and it can be categorized into three domains, namely concepts, practices, and perspectives (Brennan & Resnick, 2012; Wing, 2008). Concepts refer to the basic tools and flow controls of computers, such as objects, instructions, sequences, loops, parallelism, events, conditionals, operators, and data (Brennan & Resnick, 2012; Zhong et al., 2016). Practices concern engagement with concepts and are centred around the process of thinking and learning, including planning and designing, abstracting and modeling, modularizing and reusing, iterating and optimizing, and testing and debugging (Brennan & Resnick, 2012; Zhong et al., 2016). Perspectives focus on users delineating evolving understanding of themselves and their relationships with others and the technological world around them, which manifests through creation and expression, communication and collaboration, and understanding and questioning (Brennan & Resnick, 2012; Zhong et al., 2016). According to these definitions, CT can be viewed as a specific type of human thinking that can be put into practice in our everyday lives (Wing, 2006, 2008). Recently, CT has been integrated into the teaching of several subjects, including mathematics, biology, computer science, and programming (Hsu et al., 2018).

Although some scholars have contended that CT is not the same as programming, programming is undeniably one of the best tools for developing CT skills (Brennan & Resnick, 2012; Hsu, 2019). This research lists some of the pertinent visual building block programming teaching platforms suitable for learning CT, such as Scratch, Code.org, and Google Blockly. In this research, Blockly, developed by Google, was the chosen platform for curriculum development.

Nowadays, in mathematics education, most of the difficulties encountered by students are that mathematics concepts are abstract and difficult to understand, computationally complex topics have difficulty, or when solving problems, there are dif-

difficulties in method selection and verification (Zhong & Lu, 2015). Therefore, many researchers try to integrate CT into mathematics teaching; for example, Chen (2020) employed CT teaching strategies to teach the perimeter and area units and volume units in elementary school mathematics. Students have been shown to effectively improve their mathematics ability by learning math through CT-focused teaching strategies. Tseng (2019) integrated a unit on statistical tables in third-grade mathematics into a CT course for effect analysis. The experimental results highlighted students' significant progress in mathematics through the CT course or traditional teaching. The students' average scores in the experimental group were higher than those of students in the control group, indicating that integrating CT into the statistical table mathematics unit significantly helped the students. Therefore, this research selects the rectangular coordinate system of mathematics and hopes that the integration of mathematics into CT has improved students' learning effectiveness through image-based methods.

Numerous studies have highlighted the extensive application of CT in the field of mathematics (Hsu et al., 2018). Benakli et al. (2017) developed the following four computational projects through R and RStudio: visualizing the graph of a nowhere differentiable function, visually exploring the Weierstrass family of functions and the Weierstrass parametric curve, applying Monte Carlo simulations to estimate the volumes of hyper-balls and ellipsoids, and applying Monte Carlo simulations to estimate difficult integrals from calculus. Snodgrass et al. (2016) combined CT and mathematics for students with disabilities. In their study, after teaching one unit, teachers provided supplementary computing activities using Scratch. Most teachers used both CT and mathematical concepts to implement a mathematical model or solve a problem. According to the research conducted by Bortz et al. (2020), integrating CT across various domains can provide deeper insights into students' strengths and weaknesses. In most instructional materials that combine CT with mathematics, the geometry category comprises 45.45% of the content (Lv et al., 2023). Therefore, this study focuses on the development of instructional materials for a CT curriculum, using the Cartesian coordinate system in mathematical planes as its foundation. This unit, situated within the geometry category of mathematics, aids students in deepening their understanding of mathematical concepts and enhancing their logical think-

ing through programming. We developed mathematical materials to be taught through CT on the basis of the mathematics curriculum in Taiwan. Our goal was to create materials that teachers could use to teach mathematics and students could benefit from in terms of improved learning performance in both CT and mathematics.

## Method

In this study, we developed teaching materials that could be taught during or after learning a unit in a mathematics course. Hence, this study selected the index 7-a-11 in the curriculum guide for grades 1-9 of mathematics learning in Taiwan for teaching material development. The curriculum meaning corresponding to the index is to be able to understand the rectangular coordinate system. Its content meaning refers to the extension of the number line to the two-dimensional rectangular coordinates. It introduces related definitions and contents (including the terms of the vertical axis, horizontal axis, and quadrant, knowing the points corresponding to the numbers, the rules of symbols on the four quadrants, etc.). This study used the unit on the plane rectangular coordinate system as an example to design the course of Computational Thinking  $\times$  Mathematical Education. The methodology comprised three components: a conceptual framework, participants, and the research instrument.

### Participants

This study engaged 53 ninth-grade junior high school students from Taiwan in an experimental research project. The participants were divided into two groups: an experimental group of 25 students and a control group of 28 students. These participants were selected from typical classroom environments from a regular class grouping, reflecting a broad spectrum of abilities. Before the commencement of the study, all students had been exposed to the content of Unit 7-a-11. Despite this, there was considerable variation in the student's retention of the material, as some demonstrated a firm grasp of the concepts while others displayed varying levels of memory lapse. Moreover, under the guidance of the school curriculum, these participants have acquired fundamental programming skills.

In this study, the contents of the pre-test and post-test questions were divided



into two parts. The first part that had 15 questions that tested mathematical and MT abilities. The second part testing CT ability comprised five questions. The quiz had a total of 20 questions, each of which was worth 5 points, yielding a total of 100 possible points. The mathematical ability (MA) test was modified from the rectangular coordinates and graphics of a system of linear equations in the unknowns (Lu et al., 2009). The MT test considered only items related to spatial reasoning and style reasoning because of the focus on planar rectangular coordinates and tested MT through test questions focusing on spatial reasoning and style reasoning (Huang, 2006; Tsai, 2010). The test questions on the CT test drew material from the international computing thinking ability test designed by Lee et al. (2014, 2015, 2016). The Cronbach's alphas of the pre-test and post-test were 0.819 and 0.864, respectively. Considering that both of them were  $> 0.800$ , the tests were declared to have favorable internal consistency (Cortina, 1993).

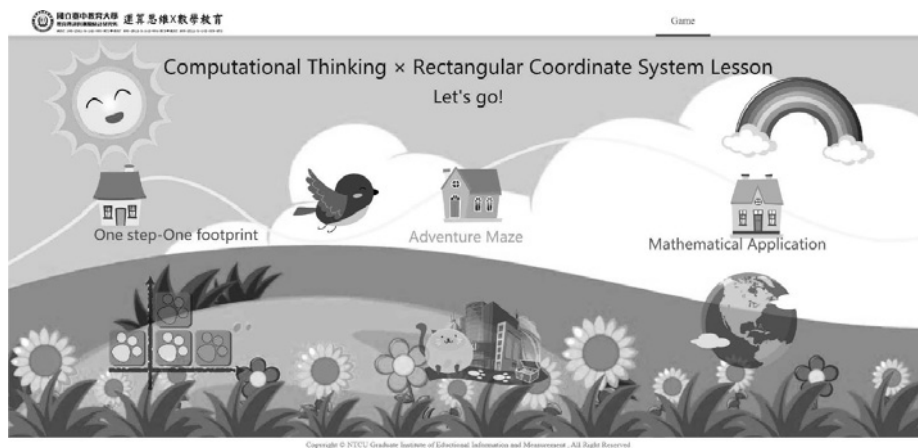
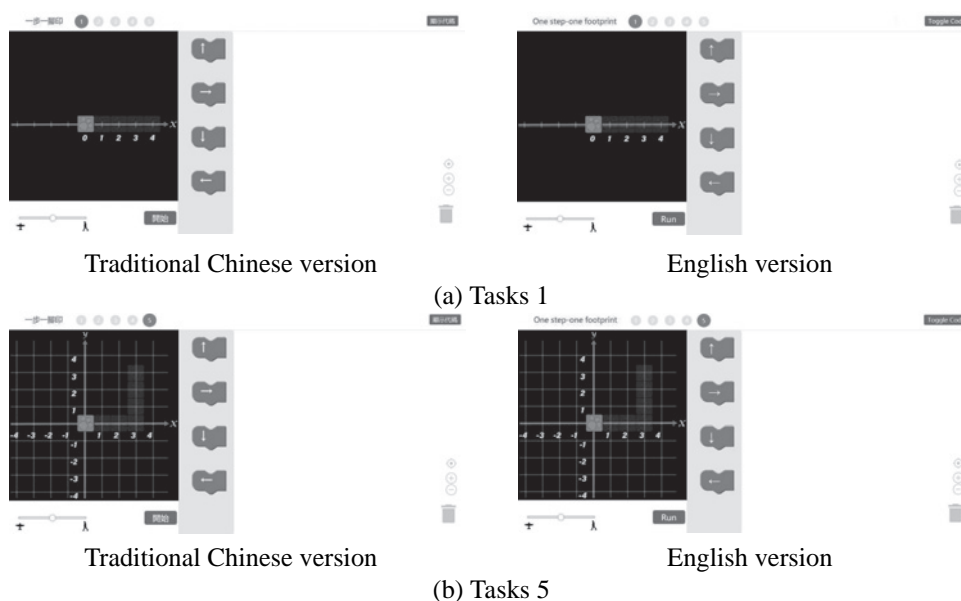
### Research instrument

In this study, we focused on the seventh-grade curriculum in Taiwan, combining the unit on planar rectangular coordinates with the CT course. Furthermore, we referred to Google Blockly (Google, 2016) and the i-code visual programming language website (Tsai et al., 2018) to develop the website for our Computational Thinking  $\times$  Mathematics Education course (Figure 1). The course content comprised the following three modules: one step-one footprint; adventure maze; and mathematical application. Each unit had five tasks, yielding a total of 15 tasks (Ju, 2018).

In addition to using educational course websites as research tools for this study, we provided learning worksheets during the course to reinforce students' knowledge. Upon concluding the course, we gathered students' feedback using questionnaires to understand their perceptions of the curriculum. Additionally, we employed both pre-test and post-test questions to evaluate the student's learning outcomes.

The course content of one step-one footprint unit (Figure 2) was designed with the objective of enhancing students' awareness of the rectangular coordinates of mathematics using the left, right, up, and down forward coding blocks. These four blocks are usually used for learning CT. In the first four tasks, students learn concepts pertaining to the x-axis and y-axis by using the left/right forward coding block and

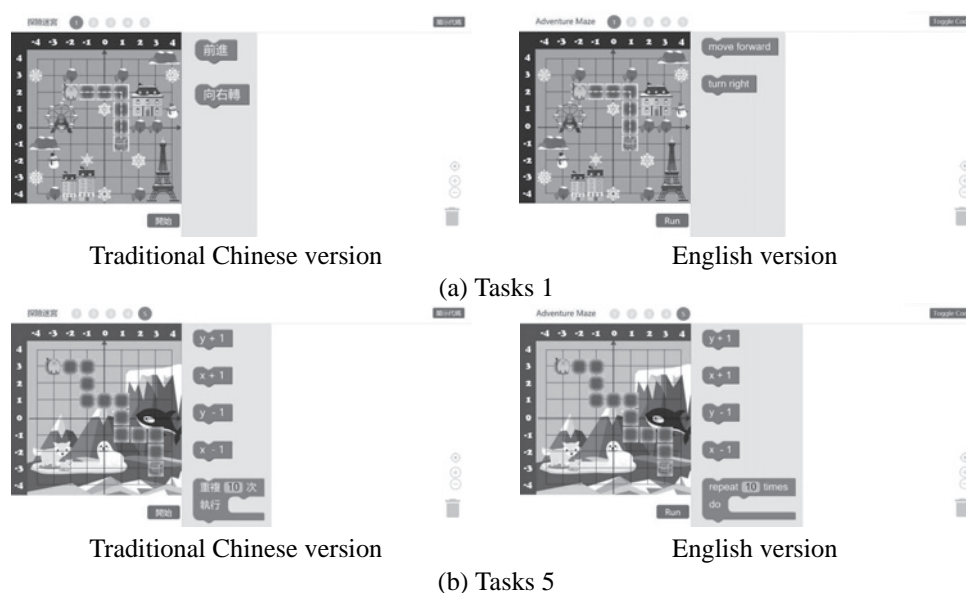


**Figure 1.** *Computational Thinking × Mathematical Education course website***Figure 2.** *One step-one footprint unit*

the up/down forward coding block, respectively. The fifth task combined the x-axis and y-axis to learning the concept of coordinate diagrams using planar rectangular coordinates. In addition to cultivating MA, a target was to familiarize students with different methods of employing CT and the operation of the course web pages.

The adventure maze (Figure 3) was designed to aid students' learning of  $x + 1$ ,  $x - 1$ ,  $y + 1$ , and  $y - 1$  through use of the corresponding coding blocks. In addition, the concept of planar rectangular coordinates was explained using CT such that the students could correctly locate the coordinate position on the planar coordinate system.

**Figure 3.** *Adventure maze unit*



CT abilities were taught, ranging from the most basic concept of sequence capability to the use of cyclic iteration to identify the optimization solution. In the first task, students first moved forward and then turned left toward the building blocks to familiarize themselves with the movements they could make at that level and to correctly determine the corresponding coordinate position. In Tasks 2-5, cyclic building blocks were introduced and the number of building blocks were limited. Students had to use the CT abilities of abstracting and modeling, iterating and optimizing, and testing and debugging to find the best solution.

The second and fourth tasks were similar in their use of directional building blocks by adding cyclic building blocks and limiting the number of building blocks

used to identify the best solution (Figure 4). In the third and fifth tasks, the mathematical building blocks were switched to  $x + 1$ ,  $x - 1$ ,  $y + 1$ , and  $y - 1$  instead of only directions to move forward given through CT. In these tasks, students learned the mathematical symbols used in a coordinate system. In addition, they employed the concept of mathematical coordinates with CT blocks such as the for loop block and their abilities to solve the problem (Figure 5). Moreover, the students were asked to observe differences in terms of the building algorithm between using the CT instructions of forward, turn left, and turn right blocks and using the mathematical concepts of  $x + 1$ ,  $x - 1$ ,  $y + 1$ , and  $y - 1$ .

**Figure 4.** Problem solving through the use of building blocks



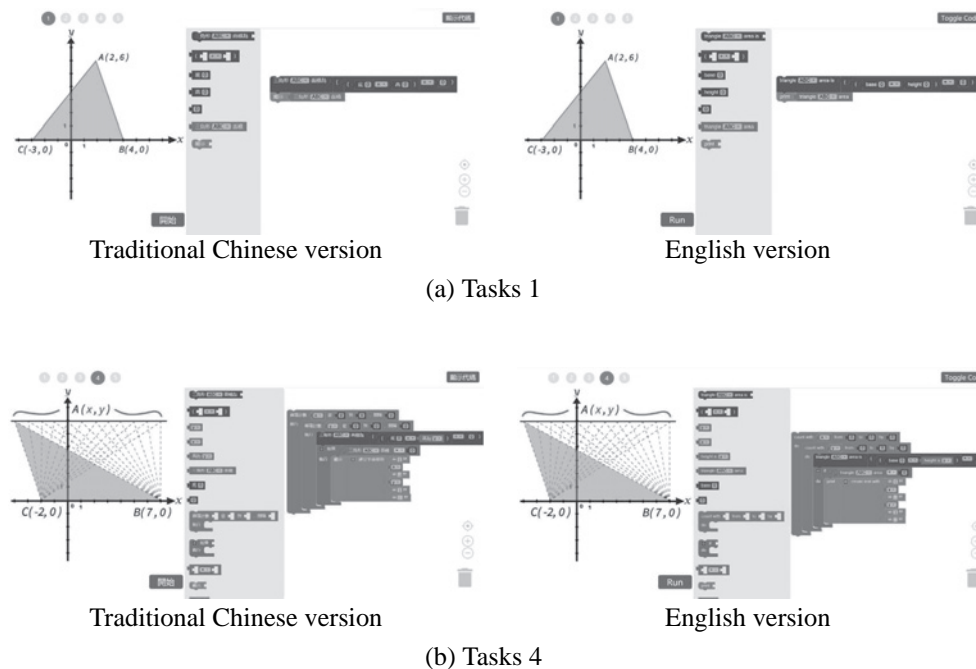
**Figure 5.** Problem solving using the coordinate concept of building blocks



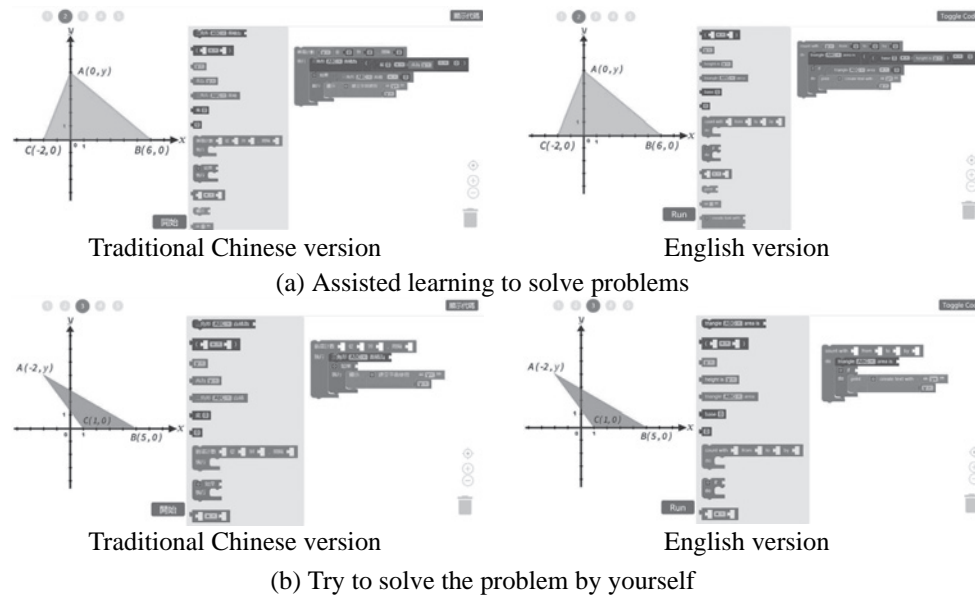
The main purpose of the curriculum design in the mathematical application unit (Figure 6) was to enable students to incorporate CT into mathematics. The first task involved using CT to calculate the area of a triangle. In the second and third tasks, three fixed coordinate points were provided using the known triangular area. The stu-

dents were instructed to find the height of the triangle, that is, identify the coordinate position of the point coordinates. In the fourth and fifth tasks, only two fixed coordinate positions at the bottom edge were provided, and the third coordinate position had to be determined using the known triangular area and the equal triangular area.

**Figure 6.** *Mathematical application unit*





In the first, second, and fourth tasks, the predefault building blocks were used and the students were guided through auxiliary teaching to solve the problem. The third and fifth tasks were similar to the second and fourth tasks; no preset building blocks were provided to students to facilitate independent problem solving. Students could switch between tasks to simulate the algorithm for organizing an appropriate algorithm to solve the given problem (Figure 7).

**Figure 7.** *Practice of similar questions*

Some coding blocks related to mathematics were created for use in the Computational Thinking  $\times$  Mathematics Education course; for example: a block for calculating the area of a triangle and a block that enabled movement from a position to another were provided. Using the blocks designed for calculating the area of a triangle as an example, these were developed based on the triangle area formula. They correspond to CT skills, including instructions, sequences, conditionals, operators, data, and modularization. Figure 8 presents the corresponding JavaScript codes of the coding blocks developed through Google Blockly.

**Figure 8.** JavaScript codes of the coding blocks developed through Google Blockly

Coding block	JavaScript code
	<pre>Blockly.JavaScript['set_abc'] = function(block) {   // Variable setter.   var argument0 = Blockly.JavaScript.valueToCode(block, 'VALUE',     Blockly.JavaScript.ORDER_ASSIGNMENT)    '0';   var varName = Blockly.JavaScript.variableDB_.getName(     block.getFieldValue('VAR'), Blockly.Variables.NAME_TYPE);   return varName + ' = ' + argument0 + ';' + '\n'; };</pre>
	<pre>Blockly.JavaScript['move_distance_A'] = function(block) {   var dropdown_list_1 = block.getFieldValue('list_1');   var dropdown_list_2 = block.getFieldValue('list_2');    switch (man_position) {     case 2:       // V1-V1       if (dropdown_list_1 === 'number_2' &amp;&amp; dropdown_list_2 === 'number_5') {         alert('阿! 沒辦法移動到同一個點啦!');       }     } else {       // V2-V1       if (dropdown_list_1 === 'number_2' &amp;&amp; dropdown_list_2 === 'number_4') {         man_position = 1;         console.log(man_position);         return 'turnright(' + 35 + '°, ' + 'block_id_' + block.id + '°\n';       } else {         return 'turnright(' + 35 + '°, ' + 'block_id_' + block.id + '°\n';       }     }   } };</pre>

To facilitate students' learning to enable them to more practically and diligently finish the Computational Thinking×Mathematical Education course, we also designed a learning manual that covered a simple topic to determine whether the students were actually learning from the course (Figure 9).

**Figure 9.** Learning brochure for Computational Thinking×Mathematical Education

**壹、一步一步腳印**

說明：根據題目的說明，完成系統的教學，並回答試題。

➤ 題意說明

(一) 選擇點位置，軸-1的位置。

( ) 1. 在第 ① 關中會使用到下列哪個種本？

(A) (B) (C) (D)

(二) 選擇點位置，軸-3的位置。

( ) 2. 在第 ② 關中會使用到下列哪個種本？

(A) (B) (C) (D)

(三) 選擇點位置，軸-4的位置。

( ) 3. 在第 ③ 關中會使用到下列哪個種本？

(A) (B) (C) (D)

(四) 選擇點位置，軸-3的位置。

( ) 4. 在第 ④ 關中會使用到下列哪個種本？

(A) (B) (C) (D)

(五) 選擇點位置，軸-3、軸-3的位置。

( ) 5. 在第 ⑤ 關中會使用到下列哪個種本？

(A) (B) (C) (D)

**貳、探險迷宮**

說明：根據題目的說明，完成系統的教學，並回答試題。

➤ 題意說明

(一) 選擇點位置(2,2)，請沿著道路走到點位置(1,1)。

(二) 選擇點位置(3,3)，請使用相關種本，沿著道路走到點位置(3,3)。

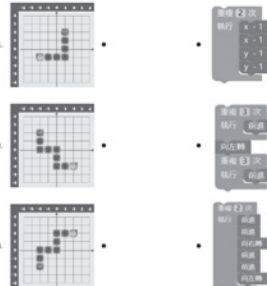
(三) 選擇點位置(3,3)，請使用相關種本，沿著道路走到點位置(3,3)。

(四) 選擇點位置(3,3)，請使用相關種本，沿著道路走到點位置(3,3)。

(五) 選擇點位置(3,3)，請使用相關種本，沿著道路走到點位置(3,3)。

➤ 小月小試

說明：請將咖啡移動到寶藏的位置，並將最適當的答案左右相連。



**參、數學應用**

說明：請配合系統教學理解題意，完成程式並將程式結果填入表格中。

關卡	題意說明	答案
①	請問所示，A 點座標為(0, y)，y 範圍為 0~7。	A(0, ____)
②	請問所示，A 點座標為(-2, y)，y 範圍為 0~7。	A(-2, ____)
③	請問所示，A 點座標為(x, y)，x 範圍為 -4~7，y 範圍為 0~7。	A(____, ____)
④	請問所示，A 點座標為(x, y)，x 範圍為 -4~7，y 範圍為 0~7。	A(____, ____)
⑤	請問所示，A 點座標為(x, y)，x 範圍為 -4~7，y 範圍為 0~7。	A(____, ____)

(a) One step-one footprint      (b) Adventure maze      (c) Mathematical application

The responses on the feedback questionnaire were collected at the end of the course (Appendix A). Our questionnaire drew from and was a modified version of the Mathematical Intelligent Tutoring System Feedback Questionnaire (H.-F. Chen, 2016) and the Computational Thinking  $\times$  Mathematical Education Feedback Questionnaire (International Association for the Evaluation of Educational Achievement [IEA], 2016). The questionnaire comprised 13 questions. The first 10 questions evaluating satisfaction levels required answers to be given on a 4-point scale with points 1-4 representing strongly agree, agree, disagree, and strongly disagree, respectively. Question 11 was a multiple-choice question, and questions 12 and 13 were short answer questions.

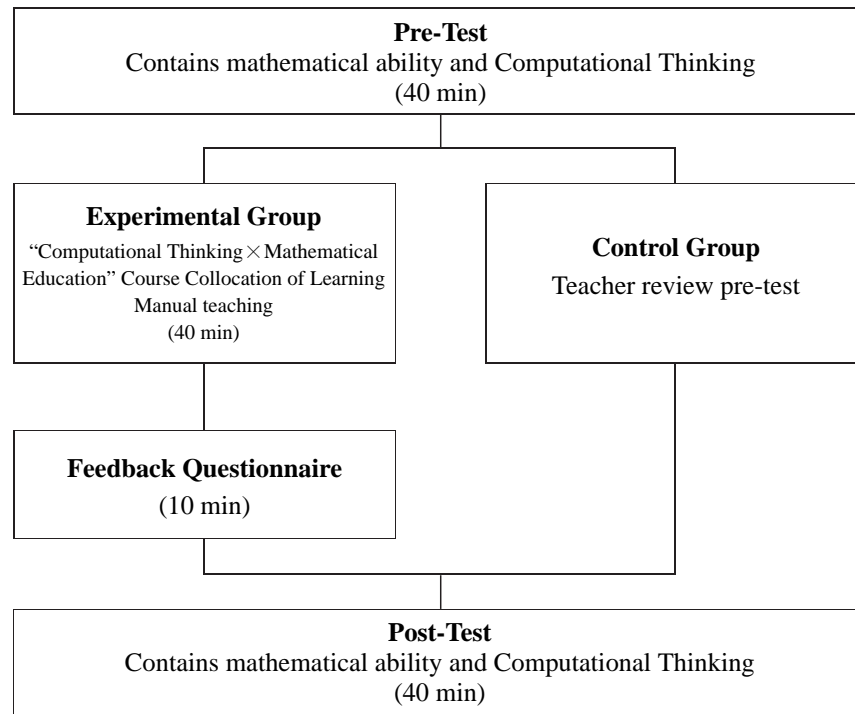
### Experimental design

In this study, both the experimental group and the control group students participated in the pre-test and post-test. The experimental group received instruction using the “Computational Thinking  $\times$  Mathematics Education” method for a total duration of 40 minutes and were asked to complete feedback questionnaires. Meanwhile, the control group reviewed the pre-test papers using traditional teaching methods, with the instruction time also being 40 minutes. After the teaching sessions, both groups participated in the post-test. Figure 10 illustrates the experimental process.

## Results

This study designed effective teaching materials for mathematics concepts that involved the use of information technology to improve students’ understanding as well as their mathematics performance, cross-disciplinary accomplishment, and problem-solving abilities. To this end, we conducted experiments on ninth-grade junior high school students. The results revealed the learning effectiveness of the course materials and students’ opinions on Computational Thinking  $\times$  Mathematical Education for experiments. This study uses Hedges’  $g$  to calculate the effect size (ES) of the student’s learning effectiveness because it can correct the error caused by the small number of samples. The index of Hedges’  $g$  is explained and defined by Cohen (2013), ES is small (0.2), ES is medium (0.5), and ES is large (0.8) (Hedges & Olkin,



**Figure 10.** *Research procedure of the first experiment*

1985; Hofmann et al., 2010). This study adopted the noun-form definition of MA, which generally refers to MA and MT.

Table 1 presents the results, revealing significant differences in CT and MA among students in the experimental group. These findings suggest that the practical group students effectively learned the material from the rectangular coordinate courses using the Computational Thinking × Mathematical Education approach, improving their CT and MA levels. In contrast, the results from the control group experiment demonstrated significant differences in students' mathematical abilities. This observation indicates that the student's mathematical abilities were effectively enhanced through traditional instruction and teacher review.

The effect sizes of CT ability and MA of the experimental group were medium. MA of the control group has a medium effect size; however, the effect size of the experimental group was better than that of the control group. Hence, using the Computational Thinking × Mathematical Education course can effectively improve students' MA.

**Table 1.** Paired-sample *t* test summary of the learning effect of the test group and control group students' CT and mathematical abilities

		Pre-test		Post-test		Post-test- Pre-test	<i>t</i>	Hedges's <i>g</i>
		<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Experimental group	Computational Thinking Ability	18.6	6.38	21.4	5.5	2.8	2.17*	0.455
	Mathematical Ability	64.4	11.58	69.8	7.43	5.4	3.21**	0.538
Control group	Mathematical Ability	63.57	11.70	68.57	7.31	5.00	3.59**	0.498

\* $p < .05$  \*\* $p < .01$  \*\*\* $p < .001$

This study explored whether the learning effectiveness of students in the experimental and control groups differed under different teaching methods. To prevent different teaching methods from being affected by the pre-test, the covariate difference was excluded. Furthermore, the post-test score was set to a dependent variable for a one-way analysis of covariance (ANCOVA).

Before ANCOVA analysis was performed, the homogeneity of regression coefficients within the group was tested, the results of which ( $F = .613$ ,  $p = .438 > .05$ ) did not reach a significant level; therefore, the basic assumption of homogeneity of the regression coefficients within the group was accepted (Table 2).

**Table 2.** Homogeneity test of the regression coefficients within the group

Source	Type III Sum of Squares	<i>df</i>	Mean Square	<i>F</i>	Sig.
Group* Pre-test	21.708	1	21.708	.613	.438
Error	1736.466	49	35.438		
Total	256225.000	53			

\* $p < .05$  \*\* $p < .01$  \*\*\* $p < .001$

Table 3 presents the two teaching methods and the results of the post-test single-factor covariate analysis. After exclusion of the influence of the pre-test on the post-test, we discovered that significance was not reached ( $F = .312$ ,  $p = .579 > .05$ ), indi-

cating that no significant difference was observed between the learning effect of the Computational Thinking  $\times$  Mathematical Education course and the traditional teaching focused on MA. Although no significant evidence indicated that the proposed teaching method outperformed the traditional group teaching, a comparison of the results in Table 1 revealed that the proposed teaching method could simultaneously improve students' CT and MA learning performance.

**Table 3.** *Summary of one-way ANCOVA results*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Pre-test	1008.683	1	1008.683	28.686	.000
Group	10.970	1	10.970	.312	.579
Error	1758.174	50	35.163		
Total	256225.000	53			

\* $p < .05$  \*\* $p < .01$  \*\*\* $p < .001$

We administered a questionnaire to the experimental group, and 24 students provided responses. The responses revealed that 75% (18 people) of the participants liked the Computational Thinking  $\times$  Mathematics Education course and 25% (6 people) liked the traditional teaching, indicating that the majority of the students preferred the Computational Thinking  $\times$  Mathematics Education course.

Table 4 presents the reasons cited by students for preferring the Computational Thinking  $\times$  Mathematics Education course. Students who preferred our course did so because they found it to be interesting and novel as well as simple, clear, and easy. Students who favored the regular mathematics teaching found our course content and programming to be difficult. The Computational Thinking  $\times$  Mathematics Education course required them to learn two disciplines at the same time, which they found to be complicated.

**Table 4.** *Comparison of preference factors for the two teaching modes (Case 1)*

Teaching modes	Reason	Number
Computational Thinking $\times$ Mathematical Education	The course content is interesting	10
	New and special learning style	3
	The course is simple and clear	1
Traditional Teaching	The course content is difficult	3
	It is difficult to learn two subjects at once	1
	Not good at programming	1
	It's hard to learn with a computer	1

## Discussion

According to the previous literature, most of the difficulties current teachers encounter in STEM courses are the inability to integrate many cross-field courses. This problem is also the same in CT teaching. Some teachers also don't know how to integrate CT with other subjects, or some teachers are unable to clarify students' questions because they are worried about not being able to grasp the content of CT courses (Margot & Kettler, 2019; Reichert et al., 2020). Some methods are proposed for the teaching restrictions of these teachers. A 20-hour robot course is provided, assisted by a student of the computer course, and the teacher is the main body of teaching planning and implementation (Reichert et al., 2020). Therefore, the researchers also suggest that mathematics teachers can participate in more workshops, such as block programming workshops, and use these tools more.

The current study found that students' CT ability can be improved through the Computational Thinking  $\times$  Mathematics Education course. Additionally, our experimental course was integrated into the mathematics curriculum, which in turn improved students' MA. Rodríguez-Martínez et al. (2020) conducted a study to assess the impact of using Scratch for instruction on students' CT and mathematical learning. The research identified significant differences in MA between the two student groups, with a medium effect size. However, no significant difference was observed in their CT ability. Based on these findings, it can be concluded that students can effectively improve their mathematical skills by learning through Scratch. T.-J. Chen (2016) used

AutoTutor to design sixth-grade elementary school mathematics courses and subsequently analyzed the learning effectiveness of remedial teaching. The experimental results highlighted significant differences, irrespective of whether the course was conducted through group teaching or the use of the smart tutoring system for remedial teaching. No significant differences were observed between the two teaching methods.

Pai et al. (2021) utilized an intelligent tutoring system (ITS) for remedial mathematics teaching. The experimental results revealed significant differences between the pre-test and post-test scores, irrespective of whether the ITS, regular class teaching, or self-study using reading material was used. However, no significant differences were observed between the three different teaching methods. Hu et al. (2012) examined student performance in a mathematics afterschool program that was conducted through traditional teaching approaches and ALEKS (Assessment and Learning in Knowledge Spaces). The results revealed that students who learned through ALEKS experienced the same learning effect as the students who were taught in group classes. Similar results were obtained by Craig et al. (2013). Wang (2009) constructed a programming-aided teaching system that used an agent to explain unit knowledge to students learning programming through questions and answers, guidance, and images. The study results highlighted significant differences in students' learning outcomes between agent-assisted teaching and group class teaching, indicating that the use of teaching through a learning system can help to improve students' programming ability. Similar results were obtained in our study. Although no significant differences were observed in our study between the two teaching methods, the experimental results highlight that the Computational Thinking  $\times$  Mathematical Education learning platform could have similar learning effects as group teaching; therefore, it can be considered beneficial. The courses developed by previous studies and the Computational Thinking  $\times$  Mathematical Education course that we developed all demonstrate that the use of ITS for the remedial teaching of mathematics can effectively improve students' learning performance in the same manner that group remedial teaching does. Moreover, such learning platforms enable students to learn course material independently when teachers cannot provide appropriate guidance. Nevertheless, students can improve their CT and mathematical abilities simultaneously by

using the proposed Computational Thinking  $\times$  Mathematical Education learning platform.

This study contains some limitations and difficulties in experimenting because of the need to match the progress of the school curriculum and the difficulty of borrowing computer hardware equipment in this research. The experiment time is relatively short, with only one class (about 45 minutes). CT courses are a relatively new teaching method, and students need to learn programming and mathematics simultaneously, which is more complicated overall. Therefore, in each mathematics unit course, students need to give more time to study, so it is also recommended to extend the teacher's teaching time for each unit. In addition, only one mathematical unit was integrated with CT and visual block programming in this study. Hence, it only involves some not all CT concepts and some mathematical concepts. In addition, in the future, the same concept can be used to develop more combination units to cover more CT and MT concepts and enhance CT and MT simultaneously. In addition, only one mathematical unit was integrated with CT and visual block programming in this study. Hence, it only involves some not all CT concepts and some mathematical concepts. In addition, in the future, the same concept can be used to develop more combination units to cover more CT and MT concepts and enhance CT and MT simultaneously. Furthermore, this study focus on using both CT and MT to solve a problem. Using CT to teach MT or using MT to teach CT are both two interesting questions and worth developing in the future.

## Conclusions

In our study, a Computational Thinking  $\times$  Mathematical Education learning platform was developed to teach mathematical concepts using CT. The mathematics lesson on the rectangular coordinate system was considered because of similarities with the beginning lesson of most CT courses. Some specific coding blocks, such as  $x + 1$ ,  $x - 1$ ,  $y + 1$ , and  $y - 1$ , were designed for teaching coordinate systems, and students could use these mathematical coding blocks combined with CT coding blocks to solve a given problem.

The experimental results demonstrate a significant improvement in both the

mathematical and CT abilities of the students in the experimental group. While the findings revealed no significant difference in learning outcomes between students taught using the Computational Thinking  $\times$  Mathematical Education approach, and those receiving traditional group instruction, the effect size for the experimental group was superior to that of the control group. This study also utilized questionnaires to gather students' feedback on the Computational Thinking  $\times$  Mathematics Education course. Overall, students appreciated the course due to the innovative and engaging teaching method.

Upon completing the Computational Thinking  $\times$  Mathematics Education course, the students' CT ability improved significantly. Although no significant differences were observed between the two teaching methods, most students preferred the Computational Thinking  $\times$  Mathematics Education course. They expressed a desire for the development of similar courses in the future. Therefore, we will develop similar methods for teaching mathematics units in the future. Teachers can use these courses during or after teaching mathematics units to improve their students' CT and mathematical abilities simultaneously. Additionally, we plan to deeply integrate the CT course with real-world scenarios in the future. By adopting a competency-based teaching approach, we aim to provide students with more guidance and hands-on opportunities. Such a teaching method not only deepens students' understanding but also assists them in naturally incorporating CT skills into their daily lives and problem-solving processes.

## Acknowledgements

This research was successfully completed and published with the support of the editor-in-chief and reviewers, to whom I express my sincere gratitude. The valuable suggestions provided during the review process, as well as the professional advice from Wallace Academic Editing, greatly contributed to the improvement of this study. Additionally, this research was funded by the National Science and Technology Council (NSTC) of Taiwan [Grant No. MOST-106-2511-S-142-003-MY3], and I would like to extend my heartfelt thanks for their support.



## Reference

- Armoni, M. (2012). Teaching CS in kindergarten: How early can the pipeline begin?. *ACM Inroads*, 3(4), 18-19. <https://doi.org/10.1145/2381083.2381091>
- Asghar, A., Ellington, R., Rice, E., Johnson, F., & Prime, G. M. (2012). Supporting STEM education in secondary science contexts. *Interdisciplinary Journal of Problem-Based Learning*, 6(2), 85-125. <https://doi.org/10.7771/1541-5015.1349>
- Benakli, N., Kostadinov, B., Satyanarayana, A., & Singh, S. (2017). Introducing computational thinking through hands-on projects using R with applications to calculus, probability and data analysis. *International Journal of Mathematical Education in Science and Technology*, 48(3), 393-427. <https://doi.org/10.1080/0020739X.2016.1254296>
- Bortz, W. W., Gautam, A., Tatar, D., & Lipscomb, K. (2020). Missing in measurement: Why identifying learning in integrated domains is so hard. *Journal of Science Education and Technology*, 29(1), 121-136. <https://doi.org/10.1007/s10956-019-09805-8>
- Brennan, K., & Resnick, M. (2012, April 13-17). *New frameworks for studying and assessing the development of computational thinking* [Paper presentation]. 2012 annual meeting of the American Educational Research Association, Canada. <https://reurl.cc/YeOMql>
- Brown, N. C., Sentance, S., Crick, T., & Humphreys, S. (2014). Restart: The resurgence of computer science in UK schools. *ACM Transactions on Computing Education (TOCE)*, 14(2), 1-22. <https://doi.org/10.1145/2602484>
- Calao, L. A., Moreno-León, J., Correa, H. E., & Robles, G. (2015). Developing mathematical thinking with scratch. In G. Conole, T. Klobučar, C. Rensing, J. Konert, & E. Lavoué (Eds.), *Design for teaching and learning in a networked world* (pp. 17-27). Springer. [https://doi.org/10.1007/978-3-319-24258-3\\_2](https://doi.org/10.1007/978-3-319-24258-3_2)
- Chamberlin, S. A., & Pereira, N. (2017). Differentiating engineering activities for use in a mathematics setting. In D. Dailey, & A. Cotabish (Eds.), *Engineering instruction for high-ability learners in K-8 classrooms* (pp. 45-55). <https://doi.org/10.4324/9781003234951-7>
- Chen, C.-C., & Ku, C.-K. (2017). The action research of applying STEM education to the teaching of scientific inquiry & implementation- “friction” as an example (in Chinese). *Chinese Physics Education*, 18(2), 17-38. <https://doi.org/10.6212/CPE.2017.1802.02>
- Chen, H.-F. (2016). *Utilization of the Mathematical Intelligent Tutoring System for elemen-*

- tary grade six remedial instruction in speed unit (in Chinese) [Unpublished master's thesis]. National Taichung University of Education.
- Chen, T.-J. (2016). *Effectiveness of elementary fifth-grade mathematics intelligent tutoring system in Line symmetry* (in Chinese) [Unpublished master's thesis]. National Taichung University of Education.
- Chen, Y.-T. (2020). *The effects of computational thinking instructional strategies on fourth graders' mathematics learning achievement and problem solving attitude* (in Chinese) [Unpublished master's thesis]. National University of Tainan.
- Code.org (2018). <https://code.org/>
- Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic Press. <https://doi.org/10.4324/9780203771587>
- Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology*, 78(1), 98-104. <https://doi.org/10.1037/0021-9010.78.1.98>
- Craig, S. D., Hu, X., Graesser, A. C., Bargagliotti, A. E., Sterbinsky, A., Cheney, K. R., & Okwumabua, T. (2013). The impact of a technology-based mathematics after-school program using ALEKS on student's knowledge and behaviors. *Computers and Education*, 68, 495-504. <https://doi.org/10.1016/j.compedu.2013.06.010>
- Devlin, K. J. (2012). *Introduction to mathematical thinking* (Version ed., Vol. 331). Keith Devlin.
- Falkner, K., Vivian, R., & Falkner, N. (2014, January). The Australian digital technologies curriculum: Challenge and opportunity. In *Proceedings of the Sixteenth Australasian Computing Education Conference-Volume 148*, 3-12.
- Google. (2014). *Blockly Games*. <https://blockly-games.appspot.com/>
- Google. (2016). *Blockly > Demos > Code Editor*. <https://blockly-demo.appspot.com/static/demos/code/index.html>
- GOV.UK (2013). *National curriculum in England: computing programmes of study*. <https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study/national-curriculum-in-england-computing-programmes-of-study>
- Hedges, L. V., & Olkin, I. (1985). *Statistical methods for meta-analysis*. Academic Press. <https://doi.org/10.1016/B978-0-08-057065-5.50006-3>
- Hofmann, S. G., Sawyer, A. T., Witt, A. A., & Oh, D. (2010). The effect of mindfulness-based therapy on anxiety and depression: A meta-analytic review. *Journal of Consulting and Clinical Psychology*, 78(2), 169-183. <https://doi.org/10.1037/a0018555>

- Hsu, T.-C. (2019, April 15). *Information technology and computational thinking* (in Chinese). Happy Teacher Newsletter. [https://www.945enet.com.tw/Main/Ha/teach\\_d.asp?pno=192&dt=A4](https://www.945enet.com.tw/Main/Ha/teach_d.asp?pno=192&dt=A4)
- 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>
- Hu, X., Craig, S. D., Bargagliotti, A. E., Graesser, A. C., Okwumabua, T., Anderson, C., & Sterbinsky, A. (2012). The effects of a traditional and technology-based after-school setting on 6th grade students' mathematics skills. *Journal of Computers in Mathematics and Science Teaching*, 31(1), 17-38.
- Huang, T.-C. (2006). *The research of elementary school students' pattern reasoning and mathematics creativity: Using the sixth grade students as an example* (in Chinese) [Unpublished master's thesis]. National Taichung University of Education.
- International Association for the Evaluation of Educational Achievement. [IEA] (2016). *About IEA*. <https://www.iea.nl/>
- Ju, Y.-J. (2018). *Development and evaluation of teaching materials for mathematical rectangular coordinate system lesson combined with computational thinking* (in Chinese) [Unpublished master's thesis]. National Taichung University of Education.
- Lee, C.-M., Koh, J.-L., Lin, Y.-T., Chiang, T.-C., Lin, Y.-L., Jhu, D.-C., & Wang, Y.-Y. (2014). *Bebras International Computing Thinking Ability Test 2014 question Bank and detail* (in Chinese). Bebras. <https://bebras.csie.ntnu.edu.tw/>
- Lee, C.-M., Koh, J.-L., Lin, Y.-T., Chiang, T.-C., Lin, Y.-L., Jhu, D.-C., & Wang, Y.-Y. (2015). *Bebras International Computing Thinking Ability Test 2015 question Bank and detail* (in Chinese). Bebras. <https://bebras.csie.ntnu.edu.tw/>
- Lee, C.-M., Koh, J.-L., Lin, Y.-T., Chiang, T.-C., Lin, Y.-L., Jhu, D.-C., & Wang, Y.-Y. (2016). *Bebras International Computing Thinking Ability Test 2016 question Bank and detail* (in Chinese). Bebras. <https://bebras.csie.ntnu.edu.tw/>
- Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., & Werner, L. (2011). Computational thinking for youth in practice. *Acm Inroads*, 2(1), 32-37. <https://doi.org/10.1145/1929887.1929902>
- Lu, J.-M., Cai, S.-H., Lu, J.-J., & Li, Z.-H. (2009). *Puzzle Star (5) rectangular coordinates and graphics of system of linear equations in the unknowns* (in Chinese). Future.
- Lv, L., Zhong, B., & Liu, X. (2023). A literature review on the empirical studies of the integration of mathematics and computational thinking. *Education and Information Technologies*, 28(7), 8171-8193.

- Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, 6(1), 1-16. <https://doi.org/10.1186/s40594-018-0151-2>
- Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In *Engineering in pre-college settings: Synthesizing research, policy, and practices* (pp. 35-60). Purdue University Press. <https://doi.org/10.2307/j.ctt6wq7bh.7>
- Onal, H., Inan, M., & Bozkurt, S. (2017). A research on mathematical thinking skills: Mathematical thinking skills of athletes in individual and team sports. *Journal of Education and Training Studies*, 5(9), 133-139. <https://doi.org/10.11114/jets.v5i9.2428>
- Pai, K.-C., Kuo, B.-C., Liao, C.-H., & Liu, Y.-M. (2021). An application of Chinese dialogue-based intelligent tutoring system in remedial instruction for mathematics learning. *Educational Psychology*, 41(2), 137-152. <https://doi.org/10.1080/01443410.2020.1731427>
- Reichert, J. T., Barone, D. A. C., & Kist, M. (2020). Computational thinking in K-12: An analysis with mathematics teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, 16(6), 1-14. <https://doi.org/10.29333/ejmste/7832>
- 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. <https://doi.org/10.1080/10494820.2019.1612448>
- Snodgrass, M. R., Israel, M., & Reese, G. C. (2016). Instructional supports for students with disabilities in K-5 computing: Findings from a cross-case analysis. *Computers & Education*, 100, 1-17. <https://doi.org/10.1016/j.compedu.2016.04.011>
- Stacey, K. (2006). *What is mathematical thinking and why is it important?* ResearchGate. <https://reurl.cc/M8Ar7v>
- Tsai, C.-S., Chen, J.-J., Li, C.-F., & Jheng, M.-M. (2018). *i code* (in Chinese). <http://github.com/TsingfunLee/Blockly-games>.
- Tsai, M.-S. (2010). *The influence of scratch programming on the geometric concept and logical reasoning ability of junior five-year students* (in Chinese) [Unpublished master's thesis]. Taipei Municipal University of Education.
- Tseng, Y.-H. (2019). *Research on the teaching effect and attitude of the computational thinking of the third-grade students in the mathematics field* (in Chinese) [Unpublished master's thesis]. Shu-Te University.
- Wang, M.-H. (2009). *The research of integrating software agent mechanism into computer*

- programming course on senior high school students* (in Chinese) [Unpublished master's thesis]. National Taichung University of Education.
- Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, 49(3), 33-35. <https://doi.org/10.1145/1118178.1118215>
- Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical transactions of the royal society of London A: mathematical, physical and engineering sciences*, 366(1881), 3717-3725. <https://doi.org/10.1098/rsta.2008.01180>
- Yeşildere, S. (2007). Examination of students' mathematical thinking and reasoning processes. *Ankara University Journal of Faculty of Educational Sciences (JFES)*, 40(1), 181-213. [https://doi.org/10.1501/Egifak\\_00000000156](https://doi.org/10.1501/Egifak_00000000156)
- Zhong, B., Wang, Q., Chen, J., & Li, Y. (2016). An exploration of three-dimensional integrated assessment for computational thinking. *Journal of Educational Computing Research*, 53(4), 562-590. <https://doi.org/10.1177/0735633115608444>
- Zhong, C.-J., & Lu, T-H. (2015). The effect of cognitive and metacognitive strategy instruction on the word problem solving for elementary school students with mathematics difficulties (in Chinese). *Annual Journal of Special Education*, 2015, 111-134. <https://doi.org/10.6379/AJSE>

## Appendix: A Feedback Questionnaire

Class: \_\_\_\_\_ Seat number: \_\_\_\_\_ Gender: ☐ male ☐ female

Dear students:

This questionnaire is to understand everyone's opinions on the use of "Computational thinking  $\times$  Mathematics education" after learning. Please read it carefully, and then tick an answer that fits your idea, and tick it in the circle. Thank you for your patience and cooperation.!

		strongly agree	agree	disagree	strongly disagree
1	I had a great time studying the mathematics unit on plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2	I learned a lot of interesting things from the mathematics unit on plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3	I liked the mathematics unit on plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4	I like the school assignments in the mathematics units on plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5	I like to solve the problems in the mathematics unit on plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6	I look forward to taking the course on plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7	The mathematics unit on plane rectangular coordinates is among my favorite math units.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8	I like to use the programming method to determine plane rectangular coordinates.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9	Using the programming method has increased my interest in learning mathematics.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10	Using the programming method has increased my confidence in learning mathematics.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

---

11 How do you feel about learning mathematics using Computational Thinking  $\times$  Mathematical Education?

- ☐ The math class has become lively and interesting.
- ☐ Using a computer to learn math feels very novel and interesting.
- ☐ Using a computer has increased by focus on learning mathematics.
- ☐ I had difficulty using computers to solve math problems.
- ☐ Other suggestions: \_\_\_\_\_

---

12 Which method of mathematics teaching do you prefer and why?

- ☐ Computational Thinking  $\times$  Mathematical Education
- ☐ Traditional Teaching.

Why? please briefly explain your reason: \_\_\_\_\_

---

13 Please give your suggestions for learning mathematics through Computational Thinking  $\times$  Mathematical Education.

---



