A project entitled

Exploring the usefulness of Single Board Computer in computer lessons

Submitted by

Tsui Hok Sing Stanley

submitted to The Education University of Hong Kong

for the degree of *Bachelor of Education (Secondary) – Information and Communication Technology*

in May 2020

Declaration

I, *Tsui Hok Sing Stanley*, declare that this research report represents my own work under the supervision of *Dr. Lai Yiu Chi*, and that it has not been submitted previously for examination to any tertiary institution.

Signed ___________________

Tsui Hok Sing Stanley

6-5-2020

Table of Contents

List of Tables

List of Figures

Abstract

The Hong Kong Education Bureau has released the latest strategy on Information Technology Education in 2015. It emphasized on provoking Computational Thinking (CT) by utilization of coding. Thus, new visual and tangible programming tools, Single Board Computer (SBC), become an irreplaceable tool for this education reform.

This research involves two important goals. The first issue was to explore the usefulness of SBCs towards coding learning motivation and influence on learning experience in a computer lesson. The second aim was to measure the effectiveness of enhancing CT skills using SBCs. A mixed research method was used in this research, with a total of 14 undergraduate students with diverse major areas.

Pre- post- test and questionnaire were carried out among learners to evaluate the CT skills enhancement. Besides, the lesson design framework followed the 6E learning model to maximize the expected learning outcome. HaloCode was chosen based on unique AI features supported. Collected data were analyzed using Statistical Package for the Social Sciences (SPSS) software. This research used descriptive analysis, t-test, reliability analysis, and correlational analysis. For constructing a complete picture of this research, a semi-structured interview was also carried out to supplement the blindspot towards statistical data.

After the data analysis, several findings can be highlighted. Most of the learners became more motivated towards coding based on the joyful learning experience by using HaloCode. Additionally, their CT skills are significantly enhanced after the teaching intervention. They all welcomed to adopt SBC in coding because of the simplification of its design and learning experience.

Chapter 1. Introduction

1.1 Background

Global Education sectors are committing curriculum redesign since Computational Thinking (CT) is becoming a universal capability for students of the 21st century. It was confirmed by the statement from Jeannette Wing (2011) eight years ago: “Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (p. 1).

Hong Kong Education Bureau has released the newest strategy on Information Technology Education in 2015. It emphasized that it is crucial in provoking CT by utilization of coding (Education Bureau, 2015, p. 28). Meanwhile, new visual and tangible programming tools (figure 1), such as Single Board Computers (SBCs), have been developed to allow children to investigate their ideas before getting into university, which could also grow their multifaceted skills (Wong, Jiang & Kong, 2018).

Figure 1 – Example of visual and tangible programming tools - HaloCode and its online IDE (mBlock)

Chapter 2. Literature Review

2.1 What is Computational Thinking?

Computational thinking (CT) has a ubiquitous discussion about the ways of teaching technology to youngsters effectively. This term, CT, made famous by Wing (2006) but found from Papert (1980) who suggested the the-state-of-the-art methods of breaking down complex problems to become more achievable and solvable small tasks through the concepts such as "decomposition," "pattern recognition," "abstraction," and "algorithms," which also known as four significant areas of CT.

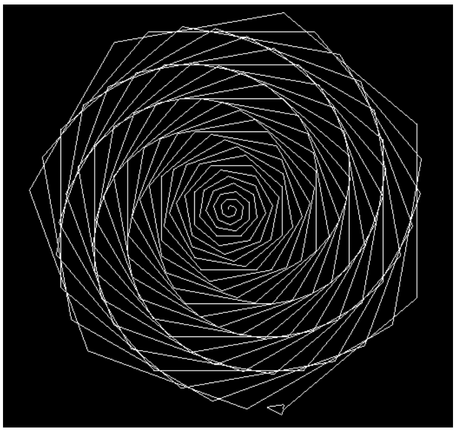


Figure 2 – Example Logo output

Before CT was defined, Papert initially worked with LOGO (1980) (figure 2). It is widely accepted that LOGO complied with the idea originated from Piaget's (1954) constructivism. This means the teacher should facilitate ideas to learners actively by constructing knowledge through real experience and the emphasis on "learn-by-doing."

According to the viewpoint of Kafai and Burke (2013), it proved that computational participation was a suitable medium to promote CT since it had the nature of showing artifacts that took the unreplaceable role throughout the learning process in computational participation. Thus, CT skills can be considered as a technique of problem-solving which required the construction building of artifacts through programming or 3D printing.

2.2 Major approaches in promoting STEM Education

According to the first strategy in *"Report on Promotion of STEM Education"* by the Education Bureau, two major approaches are mainly adapted, which are problem-based learning (PBL) and project-based learning (PjBL), respectively (Education Bureau, 2015, p.13). In most cases, the universal conclusion of two dominant approaches was PBL defined by ill-structured and relatively open-ended problems that deliver a realistic scenario in the learning process (Savin-Baden, 2000).

Natively, Boud and Feletti (2013) highlighted that PBL is a kind of educational strategy, which aims to consolidate the learning process by students' active engagement in finding answers by themselves. Therefore, Topalli and Cagiltay (2018) emphasized that PBL can hypothetically help learners to achieve in the introduction to the programming classes. Hopefully, it could boost their performance in projects. By contrast, PjBL was understood in terms of fixed tasks that the students have to perform step-by-step without creativity, which is predictable by the teacher in order to fit the lesson flow (Boud & Feletti, 2013). Consequently, most of the time, it adopted PBL in the programming lesson plan, in order to maximize the learning outcome of participants.

2.3 Relationship between CT and coding

Wong et al. (2015) conducted a wide-ranged quantitative questionnaire to review over forty schools in Hong Kong, which shows the tendency in the local schools to encourage STEM education. She found that over 85% of local schools consisted coding curriculum already, which mainly conduct in regular computer lesson hours. Additionally, it also filtered the core obstacles faced by a student in the coding lesson. For instance, they think coding lessons were not only abstract to them but also lacking with suitable examples and learning resources. In this research, it also catered to the obstacles specifically in order to overcome pain points of using traditional 2D-based programming lessons.

Three years later, Wong, Jiang and Kong (2018) organized a qualitative study on fourteen Hong Kong primary schools with group interviews and classroom observations. They also developed an interview protocol which was specially dedicated to kid below 16 years old. It can figure out the perception of youngsters in the process of learning programming. The results showed that pupils were usually engaging in CT activities and these learning materials and processes, which could enhance their generic skills such as creativity and practical problem-solving skills. Moreover, many research outcomes were showed that it was practical to use CT as a driver of programming skills (Tedre, 2017). Tedre (2017) also concluded that CT is not programming only, but it is the outcome of well-planned programming practice.

Noteworthily, it should be alerted that the interview above did not include any question, including professional terminology in CT skills (Wong et al., 2015; Wong, Jiang & Kong, 2018). For this reason, the following research procedure of this paper may introduce the general idea of CT skills to students before conducting the first lesson. It may able to raise their awareness of specific reflection in terms of CT skills in order to collect useful and accurate feedback from students in the interview sections.

Furthermore, all participants in that interview have had experience with CT skills in their primary schools. Which means a comparative study was impossible to carry out. Hence, in a follow-up study, this paper will avoid this bias on the research outcome, especially the research participants were not fresh on programming.

2.4 Common patterns

It is essential to generate challenging and meaningful tasks to promote the concept of CT while frequently aware of students' frustration (Lee et al., 2011). A thought-provoking problem should be treated as a stimulator for students' motivation enhancement. Thus, students must face real and stimulating problems based on their own experiences and interests.

Nowadays, most of the concept-oriented coding classes are using block-based commands languages, for example, MakeCode and Scratch platform. Either the teacher or the student only needs to drag and drop blocks. Comparing to old-fashioned text-based programming, it not only minimizing the cognitive load on students but also letting them pay more attention to the logical structures designed involved in programming (Kong, 2016). Henceforward, block-based coding tools were adapted to this research study in order to accelerate the learning processes of students.

Giving to The International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA), which are the well-known epicenter of ed-tech and a professional association whose mission to "empower, engage and advocate for K-12 CS teachers worldwide." They co-accepted the CT is a problem-solving process, including a collection of generic skills that are supported and enhanced by several dispositions or attitudes that are essential dimensions of CT (CSTA, 2016). More specifically, those problem-solving process occurs in the programming lessons, for example, debugging, reusing, and abstracting and modularization (Brennan and Resnick, 2012).

2.5 Single Board Computer for coding

In the literature, most of the researchers were building a connection between CT and programming lessons. One of the significant practices which are highly promoted across Spain, which used Arduino to accurately the learning curve in programming lessons (Rubio et al., 2014). Przybylla and Romeike (2014) demonstrated that physical computing could allow students to develop concrete, tangible products of the real world, which arise from the learners' imagination. Undoubtedly, the development of SBCs still needs significant improvement in order to handle the future needs of the rapidly changing world (Koorsse, Cilliers & Calitz, 2015). Existing educational SBCs, for example, micro:Bit, Arduino, and Raspberry Pi, are not adequate for employing one of the most advanced world trends, Artificial Intelligence (AI).

Furthermore, coding on the SBCs is fascinating for only a limited number of students, especially if they know they are not possible to create and invent their ubiquitous gadgets due to the limitation of specific STEM toolkit (Przybylla & Romeike, 2014). Therefore, a group of computer scientists from Google AI also advised that the global market should take the responsibility to cater to our needs (Abadi et al., 2016). We are still craving on the low-cost and easy-to-learn device, which is capable of handling "Machine Learning" and "Deep Learning" for actualizing AI applications.

These observations led to the development of HaloCode from MakeCode, which is an SBC with built-in wireless connectivity with reasonably affordable prices. It is designed for programming education, as it provides a compact design and integrating a broad selection of electronic modules. Pairing with block-based programming software mBlock (figure 1), Halocode offers handy experience AI and IoT technology with just a few clicks. Optimized hardware with a low-technical-cost programming platform makes creation easy and enjoyable.

Although Gibson and Bradley (2017) have confirmed that micro:Bit could improve the learning outcomes of the learner in programming lessons, while this research is using HaloCode with AI application, hence, the result may be a variance.

Chapter 3. Statement of Problem

Recently, most of the local schools are still adopting 2D Scratch in programming classes. It created the intention of evaluating the effectiveness of applying HaloCode and 2D Scratch in CT development lessons. The fundamental purpose of this paper is to investigate the degree of developing CT using physical SBC. Not only qualitative but also quantitative methods were adopted to make a comparison on the effectiveness of CT enhancement by conducting HaloCode and 2D Scratch lesson approach, respectively.

Based on the abovementioned objectives, three research questions were eventually formulated below:

1. Is using SBC in the computer lesson able to foster the learning motivation towards coding?
2. To what extend computational thinking skills of students able to enhance by using SBC in the computer lesson?
3. Do students achieve a better learning experience by using SBC in the computer lesson?

Chapter 4. Research Methodology

It is respectable to facilitate the understanding of the analysis section. A flowchart (figure 3) would be provided to illustrate the conceptual picture of this section.

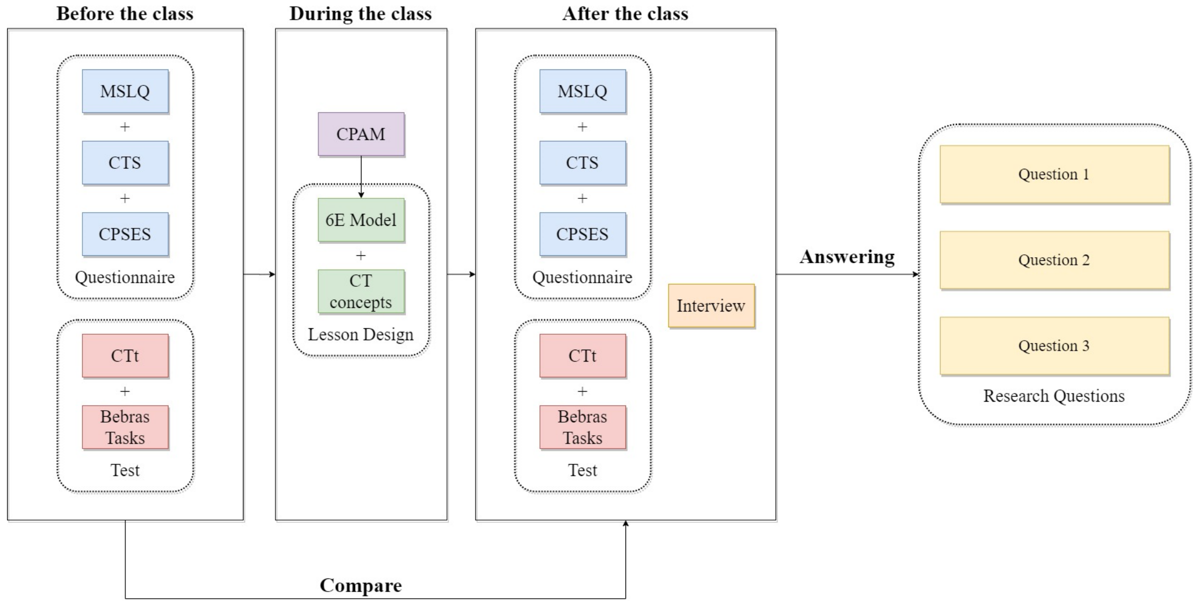


Figure 3 – Conceptual flowchart of the whole process of lesson intervention

4.1 Lesson Design

This research investigated the impact of CT skills improvement on learners. According to CSTA (2016), the lesson intended learning outcome in programming lesson should able to cater four primary goals, namely "formulating problems (decomposition)," "logically organizing and analyzing data (pattern recognition)," "representing data (abstraction)," and "algorithmic thinking (algorithms)." It is because scholars commonly accept this framework in related researches (Brennan & Resnick, 2012; CSTA, 2016; Kafai & Burke, 2013; Werner et al., 2012; Wing, 2011).

One of the first international scientific-educational organizations, the American Association for the Advancement of Science (AAAS), invented a fundamental teaching model since 1960. After a series of experiments, it concluded that the three most important steps were the essential elements of science-related education, namely "exploration, invention, and discovery." These three cornerstones became a framework adopted by Barry (2014) to finalize the 6E learning model initially developed by Burke (2014). This learner-centered teaching model would highlight the process of learners' spontaneous discovering and seeking scientific answers to cultivate learner's inquiring abilities. In the lesson design, it advocated the development of learning activities by the 6E model of inquiry learning, including engage, explore, explain, elaborate, enrich, evaluate. The framework of learning tasks was PBL design by integrating AI technology with the visual programming language.

By further utilizing the importance of STEM education and the 6E learning model, Tien and Yen (2019) recommended a blended learning framework (figure 4), which consists of two parts: classroom-led instruction in the inner circle and online inquiry learning activities in the outer circle. In the inner circle, teachers use the principles of "information perceiving" (Kolb, 2014) that are consistent with the concept of experiential learning to design teaching examples. In other words, learners ought to start from familiar experience, and gradually accumulate experience to develop into an abstract concept. Besides, teachers should provide clear guidance on procedures of "information processing" (Kolb, 2014) through explanations towards some casual examples. Scholars (Kolb, 2014; Tien & Yen, 2019) confirmed that would accelerate learners' accumulate their unique way to face everyday difficulties, which must consist of identifying problems, developing plans of problem-solving, taking actions, and evaluation. After the classroom-led instruction was completed, the spotlight should transfer to subsequent classroom and post-class online inquiry learning tasks.

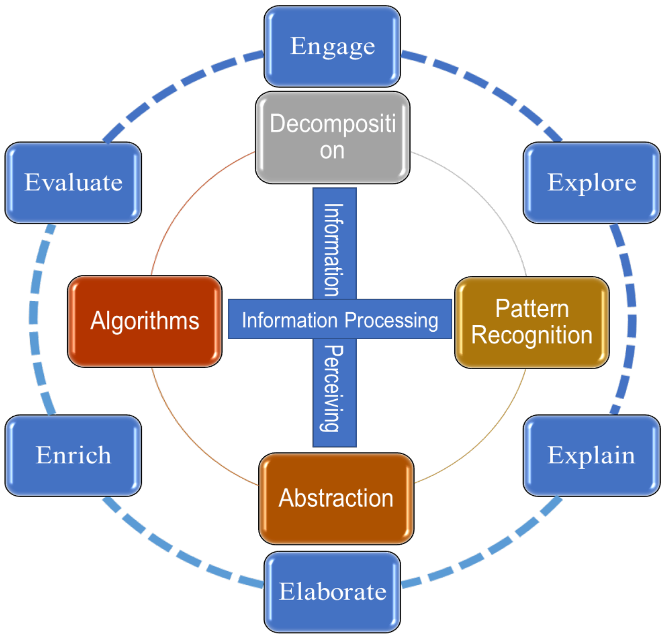


Figure 4 – Teaching framework after integrating CT with 6E learning model (Kolb, 2014; Tien & Yen, 2019)

Other than 6E, in order to analyze and evaluate more on computational practices and perspectives. Brennan and Resnick (2012) emphasized that the lesson should adopt the think-aloud protocol. It encouraged students to verbalize their thought processes while on-screen programming tasks in the interest of rationalizing their computational practices (Lye & Koh, 2014). Before starting to code, all participants were separately requested to describe each specific task solving procedure.

4.2 Lesson Instruments

4.2.1 Questionnaire

4.2.1.1) Computer Programming Self -Efficacy Scale (CTS) and Computational Thinking Scales (CPSES)

Korkmaz et al. (2017) suggested that questionnaires can determine the level of CT skills among learners. Appreciating the summative study conducted by Román-González et al. (2019), it evidenced a list of Computational Thinking assessment tools by different aspects. Such as "Computational Thinking Scales" (CTS) (Korkmaz et al., 2017) and "Computer Programming Self -Efficacy Scale" (CPSES) (Kurkul et al., 2017), these two reliable (Cronbach's $\alpha \geq 0.86$; Cronbach's $\alpha \geq 0.95$ respectively) scales are designed to measure the perceptions and attitudes towards CT and digital literacy. These scales mainly are evaluating non-cognitive and related soft skills such as self-confidence, creativity, teamwork. Thus, scholars (Korkmaz et al., 2017; Kukul et al., 2017; Román-González et al., 2019) classified these are "CT perceptions–attitudes scales," which has provided excellent adequacy in pre- and post-test (Table 1).

Table 1 – Chronological uses of the different types of CT assessment tools (Román-González et al., 2019)

	Before the intervention (pretest)	Along the intervention (progression)	Just after the intervention (posttest)	Sometime after the end of the intervention (retention and transfer)
Diagnostic tools	c	–	b	a
Summative tools	a	–	c	b
Formative–iterative tools	–	c	b	–
Data-mining tools	–	c	b	–
Skill transfer tools	a	b	b	c
Perceptions–attitudes scales	c	–	c	a
Vocabulary assessments	a	–	c	b

[a]Little adequacy, [b]Moderate adequacy, [c]Excellent adequacy, – No adequacy at all

Table 2 – Adequacy of different types of CT assessment tools regarding CT dimensions (Brennan & Resnick, 2012)

	Computational concepts	Computational practices	Computational perspectives
Diagnostic tools	c	a	–
Summative tools	c	a	–
Formative–iterative tools	b	c	a
Data-mining tools	b	c	a
Skill transfer tools	b	a	b
Perceptions–attitudes scales	–	a	c
Vocabulary assessments	–	a	c
[a]Little adequacy, [b]Moderate adequacy, [c]Excellent adequacy, – No adequacy at all			

Likewise, this test could also comply with the "Computational Perspective" and "Computational Practice" (Table 2) endorsed by Brennan and Resnick (2012). Subsequently, this research would use the translated version of CTS and CPSES with supplementing AI and SBC ideas to generate a set of Chinese questions, and they were questions 14 - 29 (based on CTS) and 30 - 46 (based on CPSES) respectively.

4.2.1.2) Motivated Strategies for Learning Questionnaire (MSLQ)

Moreover, only assessing CT and digital literacy would not provide a utilized response to the research questions 1. Hence, it would also adopt the "Motivated Strategies for Learning Questionnaire" (MSLQ) (Pintrich et al., 1991) (Cronbach's $\alpha \geq 0.87$) to evaluate learning motivation among university undergraduates. It is a self-report instrument intended to judge the motivation of university undergraduates and their use of diverse learning approaches for a tertiary course. Coincidentally, it matched with the primary research audiences, who are university students with multiple disciplines. This measurement model can divide into three main aspects, namely "Value," "Expectancy" and "Affective" components, to see the whole picture of students' learning motivation towards my pioneered AI courses. Since the lesson was conducted in Cantonese, it was preferred to denote to the translated version by 吳靜吉和程炳林 (1992) to create question 1 – 13 of the questionnaire.

Both questionnaires conducted before and after the intervention were answered anonymously in order to be protected students' privacy. Online Google form platforms were adopted to facilitate students to do the questionnaire afterschool. Total of 46 multiple choice questions about learning motivation and CT enhancement. Students are predicted to use less than 18 minutes to finish all questions.

More specifically, this questionnaire can give self-reported measures about the opinions of participants on the way of decision-making and applying related CT skills in the daily scenario.

For this study, this questionnaire consisted of 46 items with a 5-point Likert scale, which was promoted and revisited by Albaum (1997). By using a questionnaire design, it should able to gather quantitative data and utilized frequency distribution and means to analyze the data. The ranging is designed as " (1) *never*", " (2) *rarely*", " (3) *sometimes*", " (4) *generally*, " and " (5) *always*", which is perfectly fit with the original design of MSLQ, CTS, and CPSES. An indicative example of a question that has been adopted is the following: "我可以區分計算機科學，建築學和人工智能(AI)的概念。" CT enhancement through physical computing still is a contemporary educational issue which required an extensive exploration (Przybylla & Romeike, 2014). It is expected that the implementation of this research could disclose some casual links between CT improvement and SBCs.

In order to facilitate the understanding of the questionnaire design, it is better to summaries the correlation between those questions with different evaluate instruments in Table 3.

Table 3 – Question categorizations of interviews and question list

Major focus (research question)	Instrument	Questionnaire Question
1, 3	MSLQ	1 - 13
2, 3	CTS	14 - 29
2	CPSES	30 - 46

4.2.2 Pretest and Posttest

4.2.2.1) Computational Thinking Test (CTt)

Román-González et al. (2019) concluded that the Computational Thinking Test (CTt) is one of the best diagnostic assessment tools to examine the CT level of the subject. After they were revisiting their exploration in 2017, it is evident that it is suitable in the pure pre-test (e.g., without any prior programming experience) and post-test condition for validating the CT ability has increased or not (Román-González et al., 2017). Additionally, it also complies with "Computational Concepts" and "Computational Practices" promoted by Brennan and Resnick (2012) (Table 2). As it was predicted that some of the learners might lack the experience in any coding experience, it has become convincing tools in this research.

CTt is a multiple-choice instrument composed of 28 items that required students to finish within 45 minutes. Due to the time limitation of the lesson, only five questions would be selected in the pre- and post-test, respectively. Aiming to avoid severely affecting the reliability (Cronbach's $\alpha \geq 0.793$) of this tool, five questions on both tests were tightly obeyed by three dimensions, namely "Computational Concepts Addressed," "Style of Response Options" and

"Required Cognitive Task." In easy words, each question should address at least one computational concept (e.g., sequence, condition, and iteration), which difficulties are progressively nested. Also, those questions should show in visual arrow/ blocks form, which may include debugging and fill-in-the-blank style.

4.2.2.2) Bebras Tasks

Other than straight-forwarded algorithmic tasks, it was important to evaluate how students make use of CT skills to accommodate "daily" challenges. Thanks to Dagiene and Futschek (2008), they established "Bebras Tasks" to evaluate the capability of learners transferring CT skills onto different kinds of problems and daily circumstances. Initially, these tasks were extracted from "Beras International Contest," a competition launched in Lithuania since 2003, which was aimed at fostering the "Computational Perspective" of worldwide high school pupils. "Computational Perspective" is one of the critical elements of the new CT framework promoted by Brennan and Resnick (2012). Each year would launch a new set of Bebras Tasks, which encourage students to project their CT skills to solve "real-life" problems. Based on these characteristics, Román-González et al. (2019) have classified the "Bebras Tasks" as a CT skill transfer assessment tool. Thus, according to Table 1, this assessment is designed for testing after the end of the intervention.

Similarly, Boom et al. (2008) verified that Bebras Tasks is a justifiable (Cronbach's $\alpha \geq 0.93$) multiple-choice instrument composed of 25 items, which required students to finish within 50 minutes. Due to the time limitation of the lesson, only five questions would be selected in the pre- and post-test, respectively.

When using these tools, the pre-test sequence was tested according to the original sequence of CTt and Bebras Tests. During the post-test, in order to prevent students from memorizing the questions to affect the test results, the order of the questions and choices were randomized reset, without changing the content of the questions. One point was gained for each correct answer, which means the highest score of the pre- and post-test is 10 out of 10, while the lowest mark is 0 out of 10.

4.2.3 Creative Product Assessment Matrix (CPAM)

Furthermore, as the lesson design would include prototyping processes, it is suggested to adopt the Creative Product Analysis Matrix (CPAM) promoted by Besemer and O'Quin (1999). CPAM is a framework that commonly accepted to evaluate new product ideas during the development process. It consists of a high level of validity (Cronbach's $\alpha \geq 0.84$) as it would improve creative works in progress by focusing attention on the three dimensions (*Novelty*, *Resolution*, and *Elaboration and Synthesis*). When the nine subscale scores are objectively determined, the attention of learners may be given to strengthening lower-scoring attributes.

This scale was mainly used in the final lesson of the course design since this course was mainly delivered in Cantonese. A translated version by Hsiao et al. (2019) was employed (Table 4), and the full version of the CPAM can refer to Appendix A.

Table 4 – A translated version of CPAM (Hsiao et al., 2019)

指標	評分準則
原創性（Original）	作品是否自行構思創造而不是經由複製改編模仿衍生出來的作品
驚奇性（Surprise）	作品呈現出意想不到的資訊或效果
價值性（Valuable）	作品設計構想是否具有意義和價值
邏輯性（Logical）	作品設計構想是否合乎邏輯並且考慮到現實限制
有用性（Useful）	作品很大機會能夠在實際環境應用
可理解性（Understandable）	設計理念是否讓大眾清楚了解
基本品質（Organic）	作品是否能夠正常運作
精緻程度（Elegance）	作品在軟硬件兩大層面是否精簡易正確
良好手藝（Well-crafted）	作品在製作流程期間是否合標準及最終外觀是否美觀

4.2.4 interview

Other than those quantitative data, a semi-structured interview would be conducted to collect students' learning feedback and instructors' teaching feedback for qualitative data analysis. It is planned that the interview would consist of less than ten short open-ended questions about using SBC in coding class and CT enhancement. After feedbacks are collected, a triangulation and cross-case inductive analysis were conducted to evaluate the extent of reliability and consistency of the data analyses and results (Golafshani, 2003) (Table 5). After the data gathering activity from the think-aloud protocol, interviews were scheduled after finishing the entire coding classes. Students had the chance to express their opinion freely, in order to provide add-on feedbacks to the learning activities described in the previous questionnaires.

Table 5 – Protocol design of setting up the group interview in similar research (Golafshani, 2003)

Sub-Sections	Anticipated Duration
Briefing	2 minutes
Introduction of researchers	2 minutes
Ice-breaking	2 minutes
Interactive interview	6 minutes

This interview consisted of seven questions, and these questions were designed to complement quantitative research. This means those three research questions would also be catered to in a more subjective opinion by the interviewees. Interviews were conducted by Cantonese in order to maximize the effectiveness of the conversation. It was translated into English in the data analysis part already.

Chapter 5. Data Collection

5.1 Methodologies

This study collected and analyzed both qualitative and quantitative data.

The comparison was not only based on a questionnaire to measure the change of students' attitudes but also adapting think-aloud protocol in lesson design to collect the detail of problem-solving procedures of them (Lye and Koh, 2014). After that, a semi-structured interview was conducted to collect students' learning feedback for qualitative data analysis after the intervention; CT assessments would also be aligned for qualitatively comparing the performance of the participants.

Frankly, it is understood that setting up a Control Group and an Experimental Group to evaluate the research may be a suitable method. Nevertheless, due to the outbreak of COVID-19, it is impossible to organize many classes either on the teaching practice school or the University campus. This unfavorable disaster forced this study to be amended. In order to balance the risk of conducting face-to-face lessons, it could only confine a trial two-day workshop for 4 hours a day in the EdUHK library. It may slightly affect this research outcome, but it has already tried the best to uphold all pedagogical frameworks and the lesson design discussed throughout this essay. Eventually, fourteen undergraduates (age 17-25 with various disciplines) from The Education University of Hong Kong were involved in a two-day mini-workshop. After these two days, feedbacks from learners were collected by interview. All the classes were conducted in Extra Curriculum Activity (ECA) format.

5.2 Ethics Measures

The identity of students should always stay anonymous. Therefore, this research was strictly following the guidelines endorsed by the Human Research Ethics Committee (2015). Both questionnaires and interviews were not contained sensitive personal information of participants, including name and phone number. The hashed number was provided to students to identify the uniqueness of the collected data, such as using "453" to represent the first joiner, "258" to represent the second joiner, etc. All the collected data were stored in secured devices and will be destroyed when I graduated.

Chapter 6. Data Analysis

It is glad to simplify the understanding of the analysis section. A flowchart (figure 5) would be provided to illustrate the conceptual picture of this section.

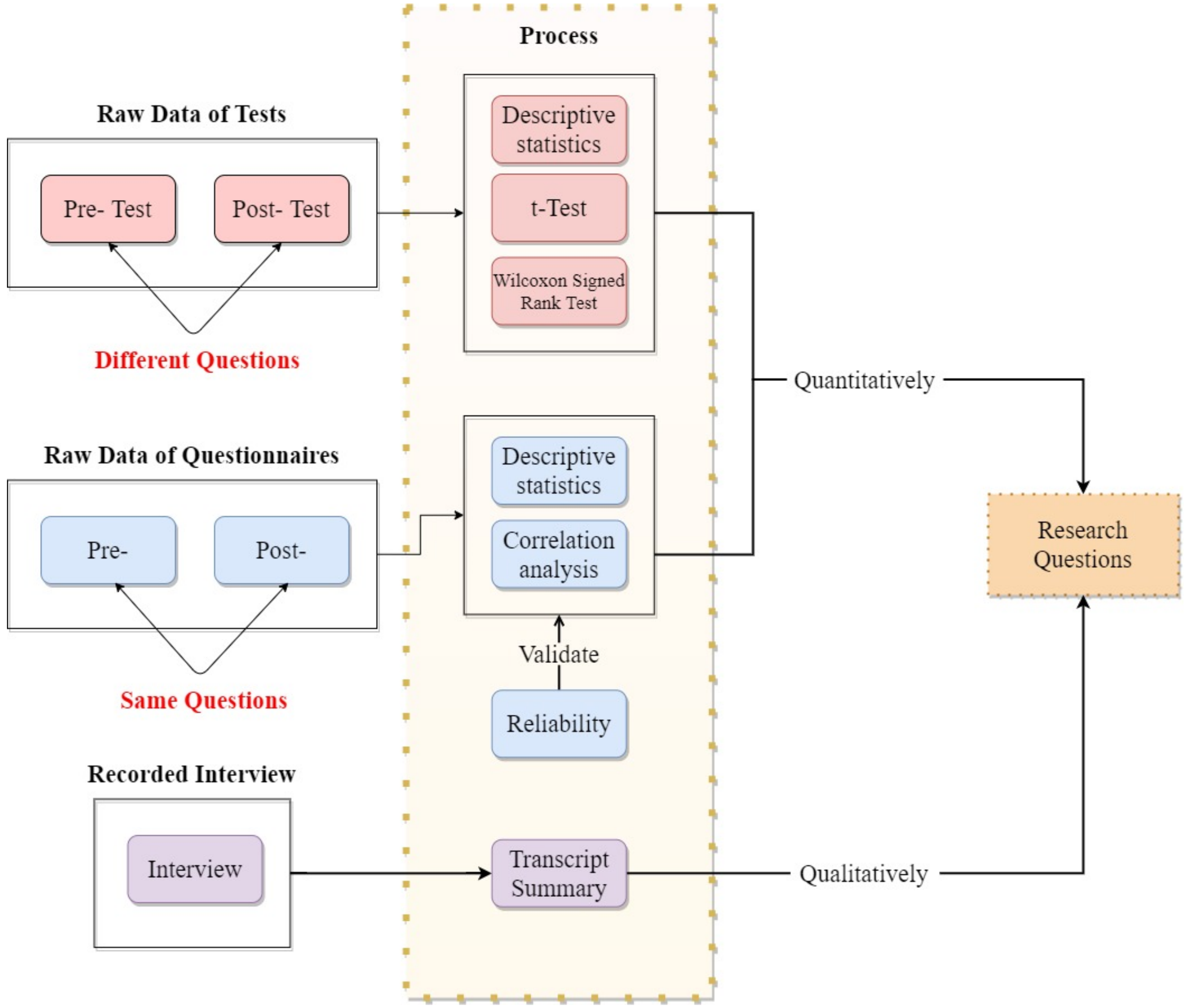


Figure 5 – Conceptual flowchart of raw data analysis

6.1 Quantitative Findings

6.1.1 Pre- post- Test

6.1.1.1) Descriptive statistics

Table 6 – Descriptive statistics from pre- post- test

Descriptive Statistics						
	N	Minimum	Maximum	Mean	Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
Pretest score	14	4	9	6.57	1.342	1.802
Posttest score	14	5	10	8.07	1.439	2.071

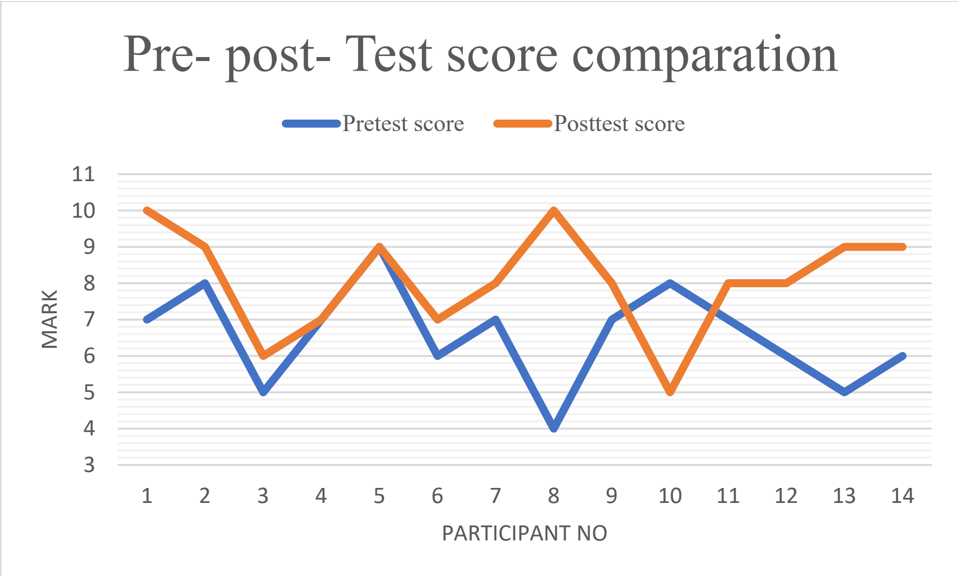


Figure 6 – Broken line chart of students' marks in pre- post-test

By observing Table 6, the total marks of both pre-test and post-test are 10. The mean score of the pre-test is 6.57, while that of the post-test is 8.07. It shows that there is an overall improvement after the intervention *(AI lessons designed by the 6E model).* As for the difference, the increments of absolute value and percentage are 1.5 and 22.8%, respectively. Moreover, by observing the figure 6, it was easy to observe 12 out of 14 (over 85%) student gain improvement in the post-test. One of them (number 8) even had a 150% improvement compared to the pre-test. It is assumed that the subjects are in a normal distribution as they were chosen from a normally distributed population.

The total marks of both pre-test and post-test are 10. The mean score of the pre-test is 6.57, while that of the post-test is 8.07. It shows that there is an overall improvement after the intervention (AI lessons designed by the 6E model). As for the difference, the increments of absolute value and percentage are 1.5 and 22.8%, respectively. Moreover, by observing the figure 7, it was straightforward to observe 12 out of 14 (over 85%) student gain improvement in the post-test. One of them (number 8) even had a 150% improvement compared to the pre-test. It is assumed that the subjects are in a normal distribution as they were chosen from a normally distributed population.

Also, the mean scores show that the subjects performed better after joining the intervention generally. It is expected that the intervention has a positive effect, and the post-test scores are higher than the pre-test score.

Therefore, the alternative hypothesis is that the post-test mean score is larger than the pre-test mean score (H1: $\mu > 1.5$), and so the null hypothesis is that the post-test mean score is equal to the pre-test mean score (H0: $\mu = 1.5$). In short, the above statistical information facilitated to make a response to the research question 2, learners' CT skill could be enhanced by near 15% with significant narrower learning diversities.

6.1.1.2) Paired samples t-Test

Also, the mean scores show that the subjects performed better after joining the intervention generally. It is expected that the intervention has a positive effect, and the post-test scores are higher than the pre-test score. Therefore, the alternative hypothesis is that the post-test mean score is larger than the pre-test mean score (H_1: $\mu > 1.5$), and so the null hypothesis is that the post-test mean score is equal to the pre-test mean score (H_0: $\mu = 1.5$). A 2-tailed paired T-test was done using the scores of both tests for all subjects. Below is the result (Table 7).

Table 7 – Paired samples t-Test of pre- post- test

Paired Samples Test							
	t	df	Std. Error Mean	Sig. (2-tailed)	Mean Difference	95% Confidence Interval	
						Lower	Upper
Pre – Post - test	2.669	13	.562	.019	1.500	.286	2.714

The conventional way of reporting the findings is to state the test statistic (*t*), degrees of freedom (df), and probability value (p). We can report our results as follows.

$$t(13) = 2.669; p < .05$$

The "Standard Error Mean" estimates the standard deviation (σ) of all the differences between sample means for samples of size $N = 14$ when the null hypothesis is true. It indicates the difference in the means we would expect by chance if the null hypothesis is true. Our mean difference is 1.5, which is much bigger than the standard error of the mean of .562, suggesting that the data does not support the null hypothesis. The calculated *t* value is the ratio of these two values:

$$t = \frac{1.5}{.562} = 2.669$$

This measure is often used as a supplementary or alternative indicator of statistical significance. A suggested way of reporting these findings is as follows:

Difference in means = 1.500 (95% CI: .286 to 2.714)

There is a statistically significant mean difference in the test scores at the 0.05 level. As a result, this SBC computer lesson leads to improvements in students' knowledge and skills.

6.1.1.3) 2-tailed Wilcoxon Signed-Rank Test

Apart from a 2-tailed paired T-test, the significance of improvement was examined using 2-tailed Wilcoxon Signed-Rank Test, which is a nonparametric test, due to the small sample size. Below is the result (Table 8).

Table 8 – 2-tailed Wilcoxon Signed-Rank Test

Test Statistics[a]	
	Pretest score - Posttest score
Z	-2.390[b]
Asymp. Sig. (2-tailed)	.017
a. Wilcoxon Signed Ranks Test	
b. Based on positive ranks.	

The result of this nonparametric test shows a *p*-value of 0.017. The significance level of this test is 0.05. The *p*-value is less than the significance level (i.e., $0.017 \leq 0.05$). Therefore, it can be said that the improvement is significant. To conclude, all statistical data yield the same outcome that the result is significant. In other words, the improvement between pre-test and post-test is significant overall. In short, the above statistical information could help to answer the research question 2. Their CT skills were enhanced by at least one-fifth with significant narrower learning diversities.

6.1.2 Questionnaire

6.1.2.1) reliability

It had integrated three types of questions from the questionnaire, namely from MSLQ (Question 1-13), CTS (Question 14-29), and CPSES (Question 30-46). Although they are highly reliable (Cronbach's $\alpha \geq 0.87$, ≥ 0.86 and ≥ 0.95 respectively) proven by different scholars (Kukul et al., 2017; Pintrich et al., 1991; Román-González et al., 2019). It may affect those reliabilities based on questions modification and integration. It is better to statistically prove the reliability of this questionnaire before further discussing the collected data. As 14 participants encountered in this research, thus 28 samples were recorded based on the pre- and post-questionnaire set. The results showed in Table 9.

Table 9 – Case Processing Summary

Case Processing Summary			
		N	%
Cases	Valid	28	100.0
	Excluded[a]	0	.0
	Total	28	100.0
a. Listwise deletion based on all variables in the procedure.			

The first part of the output provides a summary of the data. We can see that our data contains 28 cases (summation of pre- and post- questionnaire) and that the analysis is considering 100 % of the data.

The results of the reliability analysis were shown in the following table (Table 10). There were 46 questions in this study. Cronbach's alpha was 0.926, which was greater than 0.9. According to Tavakol and Dennick (2011), the questionnaire design indicated a scale of excellent reliability.

Table 10 – Reliability of the questionnaire

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.931	.926	46

After examining the reliability of the questionnaire, it is great to move on to the questionnaire result analysis section.

6.1.2.2) Descriptive statistics

For easy understanding, it is better to categorize these 46 questions by their primary focus (Table 11).

Table 11 – Question descriptions of the questionnaire

Questions	Major focus
1-13 (MSLQ)	Evaluating learning motivation among university under-graduate in the computer lesson
14-29 (CTS)	Measuring the perceptions and attitudes towards CT and digital literacy
30-46 (CPSES)	

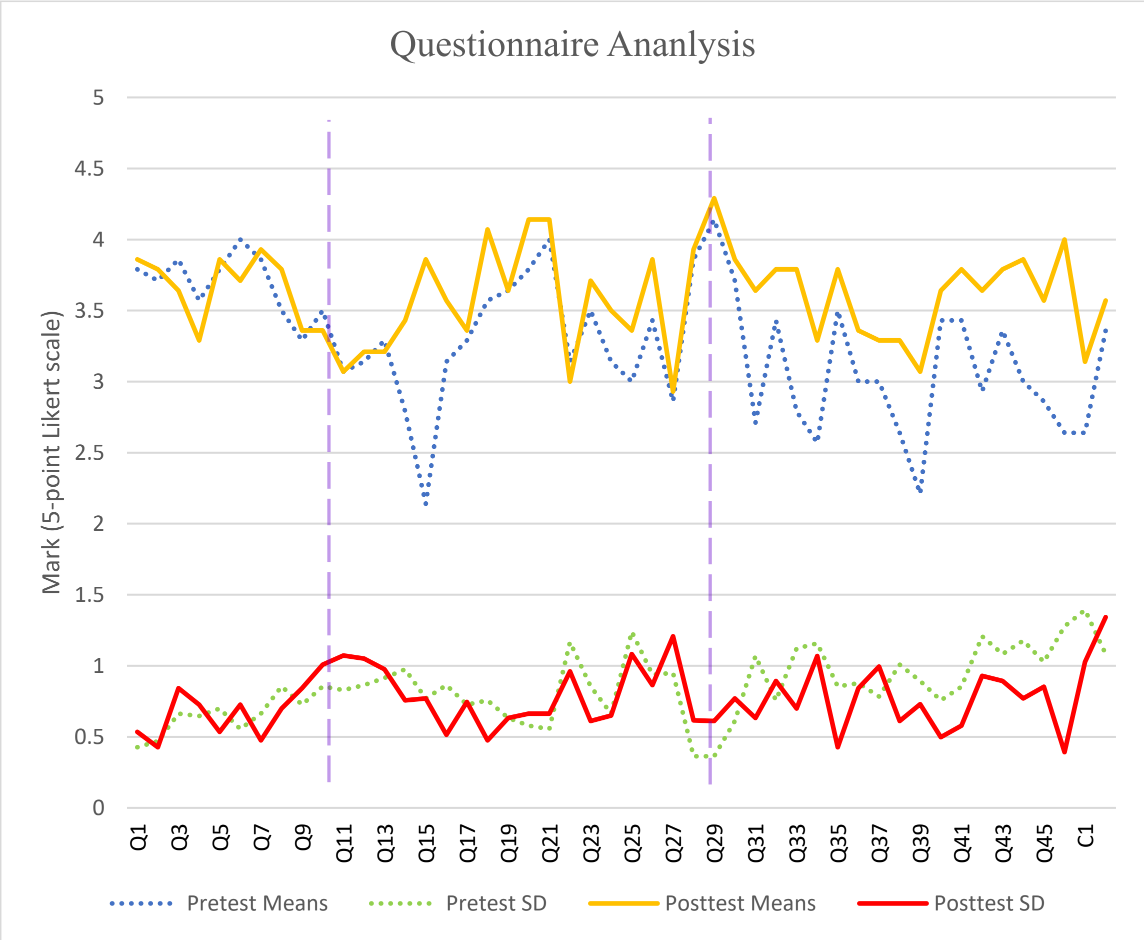


Figure 7 – Broken line chart of pre- and post- questionnaire analysis

For this study, this questionnaire consisted of 46 items with a 5-point Likert scale (figure 7), which was promoted and revisited by Albaum (1997). All the questions were designed based on MSLQ (Question 1-13), CTS (Question 14-29), and CPSES (Question 30-46), respectively. The purple dotted lines are also used to divide them into respective parts to exam them in a transparent way.

In the first portion (MSLQ), which focused on the learning motivation of the learners.

We could see the trend of pre- and post- questionnaire did not have a significant difference. Either the means and σ were very similar in the pre- and post- questionnaire. In short, the above statistical information could help to answer the research question 1, their learning motivation towards coding may not have a significant difference after the lesson intervention.

In contrast, the means difference in CTS and CPSES (Question 14-46), both of them are the tools to test the CT abilities, were significantly improved. The most noteworthy one should be question 15, "I understand how to apply Artificial Intelligence through the block coding platform." Its mean score boost from 2.14 to 3.86, which had more than 80% improvement after attending the pioneer class. Nearly all the means score of questions from CTS and CPSES are increased, while the average means score of them has increased by 14.9%. Still, the σ of CTS and CPSES were mainly decreased, which means the scores of individuals were closer to the mean score. Hence, the CT skills learning the difference between learners can assume to have a reduction after attending the lessons.

6.1.2.3) Correlation analysis

6.1.2.3.1) Pre- questionnaire

Before the computer lesson using HaloCode, it has carried out a questionnaire that is the same as the post- questionnaire. It is because it can be observed the change between pre- and post-intervention in order to analyze and draw some conclusions based on the changes.

From the correlation analysis, the summary results of the hypothesis test were shown below (Table 12). It showed that "major" had a strong and positive relationship ($r > 0.5$) on "coding experience," question 2, 19, 26, 27, C1(confidence towards the pre-test) and C2 (joy-fulness when using the computer), and it was significant ($p < 0.05$). Thus, it could assume that majoring in Science or Mathematic-related would have higher confidence in AI lessons. Similar patterns could also be recognized in the "Science Result" (Table 13) and "IT Result" (Table 14), while this time, they were proving the significant relationships on the actual academic performance in CT test. In other words, it can be concluded that higher academic achievements in Science-related subjects in the past could positively contribute to their learning motivation and CT skills. While most of the learners were lacking coding experience (non-IT discipline), thus, it was an excellent chance for me to observe their improvement after the intervention.

Table 12 – Correlations towards Major (Pre- questionnaire)

"Major" Correlations									
		Major	Coding Experience	Q2	Q19	Q26	Q27	C1	C2
Major	Pearson Correlation	1	.638*	.611*	.565*	.611*	.720**	.534*	.667**
	Sig. (2-tailed)		0.014	0.020	0.035	0.020	0.004	0.049	0.009
	N	14	14	14	14	14	14	14	14
*. Correlation is significant at the 0.05 level (2-tailed).									
**. Correlation is significant at the 0.01 level (2-tailed).									

Table 13 – Correlations towards Science Result (Pre- questionnaire)

"Science Result" Correlations					
		Science Result	Q6	Q20	Pretest score
Science Result	Pearson Correlation	1	-.676**	-.601*	.784**
	Sig. (2-tailed)		0.008	0.023	0.001
	N	14	14	14	14
**. Correlation is significant at the 0.01 level (2-tailed).					
*. Correlation is significant at the 0.05 level (2-tailed).					

Table 14 – Correlations towards IT Result (Pre- questionnaire)

"IT Result" Correlations																				
		IT Result	Coding Experience	IT Interested	Q8	Q9	Q11	Q12	Q13	Q14	Q15	Q16	Q19	Q23	Q27	Q32	Q33	Q42	Q44	C2
IT Result	Pearson Correlation	1	.745**	.645*	.664**	.606*	.573*	.536*	.659*	.534*	.601*	.723**	.603*	.664**	.537*	.551*	.609*	.681**	.551*	.696**
	Sig. (2-tailed)		0.002	0.013	0.010	0.022	0.032	0.048	0.010	0.049	0.023	0.003	0.022	0.010	0.048	0.041	0.021	0.007	0.041	0.006
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
**. Correlation is significant at the 0.01 level (2-tailed).																				
*. Correlation is significant at the 0.05 level (2-tailed).																				

Above and beyond, it is easy to observe that higher motivation on learning coding would contribute to the better learning outcome of CT skills. By spotting question 8-12 (Table 15) and 13 (Table 16), which is related to the learning motivation towards the lesson, it had many positive correlated not only in the learning motivation section (question 8-13), but also quite a lot in the attitudes towards CT(question 16, 18, 23, 26, 32, 34, 44 and 45). Therefore, if it could show shreds of evidence on proving their learning motivation towards coding was increased, it will also prove their CT skills were improved.

Table 15 – Correlations towards Q8-12 (Pre- questionnaire)

Q8-Q12 Correlations																
		Q8	Q9	Q10	Q11	Q12	IT Result	Q13	Q16	Q19	Q23	Q26	Q32	Q34	Q44	Q45
Q8	Pearson Correlation	1	.867**	.789**	.706**	.729**	.664**	.591*	.625*	.639*	.579*	.672**	.714**	.622*	.535*	.613*

	Sig. (2-tailed)		0.000	0.001	0.005	0.003	0.010	0.026	0.017	0.014	0.030	0.009	0.004	0.018	0.049	0.020
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q9	Pearson Correlation	.867**	1	.867**	.730**	.665**	.606*	0.447	.665**	.741**	0.496	0.484	.600*	0.340	0.360	0.471
	Sig. (2-tailed)	0.000		0.000	0.003	0.009	0.022	0.109	0.009	0.002	0.072	0.079	0.023	0.235	0.206	0.089
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q10	Pearson Correlation	.789**	.867**	1	0.489	0.520	0.474	0.295	0.416	.781**	0.474	0.384	0.476	0.389	0.382	0.438
	Sig. (2-tailed)	0.001	0.000		0.076	0.056	0.087	0.305	0.139	0.001	0.087	0.175	0.085	0.170	0.177	0.117
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q11	Pearson Correlation	.706**	.730**	0.489	1	.951**	.573*	.682**	.629*	0.492	0.489	.750**	.561*	0.435	0.316	0.374
	Sig. (2-tailed)	0.005	0.003	0.076		0.000	0.032	0.007	0.016	0.074	0.076	0.002	0.037	0.120	0.272	0.187
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q12	Pearson Correlation	.729**	.665**	0.520	.951**	1	.536*	.723**	0.485	0.522	0.520	.773**	.605*	0.527	0.302	0.371
	Sig. (2-tailed)	0.003	0.009	0.056	0.000		0.048	0.003	0.079	0.056	0.056	0.001	0.022	0.053	0.293	0.191
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
IT Result	Pearson Correlation	.664**	.606*	0.474	.573*	.536*	1	.659*	.723**	.603*	.664**	0.444	.551*	0.480	.551*	0.496
	Sig. (2-tailed)	0.010	0.022	0.087	0.032	0.048		0.010	0.003	0.022	0.010	0.111	0.041	0.082	0.041	0.071
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q13	Pearson Correlation	.591*	0.447	0.295	.682**	.723**	.659*	1	0.529	0.456	.886**	.564*	.589*	.706**	.572*	.702**
	Sig. (2-tailed)	0.026	0.109	0.305	0.007	0.003	0.010		0.052	0.102	0.000	0.036	0.027	0.005	0.032	0.005
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q16	Pearson Correlation	.625*	.665**	0.416	.629*	0.485	.723**	0.529	1	0.381	0.520	.583*	0.252	0.527	.681**	.631*
	Sig. (2-tailed)	0.017	0.009	0.139	0.016	0.079	0.003	0.052		0.178	0.056	0.029	0.384	0.053	0.007	0.015
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q19	Pearson Correlation	.639*	.741**	.781**	0.492	0.522	.603*	0.456	0.381	1	.639*	0.278	.666**	0.300	0.413	0.389
	Sig. (2-tailed)	0.014	0.002	0.001	0.074	0.056	0.022	0.102	0.178		0.014	0.337	0.009	0.298	0.142	0.170
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q23	Pearson Correlation	.579*	0.496	0.474	0.489	0.520	.664**	.886**	0.520	.639*	1	0.480	.595*	.699**	.688**	.788**
	Sig. (2-tailed)	0.030	0.072	0.087	0.076	0.056	0.010	0.000	0.056	0.014		0.082	0.025	0.005	0.007	0.001
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q26	Pearson Correlation	.672**	0.484	0.384	.750**	.773**	0.444	.564*	.583*	0.278	0.480	1	0.481	.678**	0.488	0.468
	Sig. (2-tailed)	0.009	0.079	0.175	0.002	0.001	0.111	0.036	0.029	0.337	0.082		0.082	0.008	0.077	0.092
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q32	Pearson Correlation	.714**	.600*	0.476	.561*	.605*	.551*	.589*	0.252	.666**	.595*	0.481	1	0.402	0.259	0.382
	Sig. (2-tailed)	0.004	0.023	0.085	0.037	0.022	0.041	0.027	0.384	0.009	0.025	0.082		0.154	0.370	0.178
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q34	Pearson Correlation	.622*	0.340	0.389	0.435	0.527	0.480	.706**	0.527	0.300	.699**	.678**	0.402	1	.847**	.850**
	Sig. (2-tailed)	0.018	0.235	0.170	0.120	0.053	0.082	0.005	0.053	0.298	0.005	0.008	0.154		0.000	0.000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q44	Pearson Correlation	.535*	0.360	0.382	0.316	0.302	.551*	.572*	.681**	0.413	.688**	0.488	0.259	.847**	1	.891**
	Sig. (2-tailed)	0.049	0.206	0.177	0.272	0.293	0.041	0.032	0.007	0.142	0.007	0.077	0.370	0.000		0.000
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Q45	Pearson Correlation	.613*	0.471	0.438	0.374	0.371	0.496	.702**	.631*	0.389	.788**	0.468	0.382	.850**	.891**	1
	Sig. (2-tailed)	0.020	0.089	0.117	0.187	0.191	0.071	0.005	0.015	0.170	0.001	0.092	0.178	0.000	0.000	
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 16 – Correlations towards Q13 (Pre- questionnaire)

Q13 Correlations																
		Q13	IT Result	Q11	Q12	Q17	Q22	Q23	Q26	Q31	Q32	Q33	Q34	Q42	Q44	Q45
Q13	Pearson Correlation	1	.659*	.682**	.723**	.563*	.824**	.886**	.564*	.720**	.589*	.665**	.706**	.578*	.572*	.702**
	Sig. (2-tailed)		0.010	0.007	0.003	0.036	0.000	0.000	0.036	0.004	0.027	0.010	0.005	0.030	0.032	0.005
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
*. Correlation is significant at the 0.05 level (2-tailed).																
**. Correlation is significant at the 0.01 level (2-tailed).																

Additionally, some noteworthy phenomenon is that CT skills may foster a better presentation ability. According to the wordings in question 32, “I can clearly explain my way of problem-solving and its included steps.” it is a CPSES testing question, which means they expected to have a higher ability on CT skills if they gain higher marks in this question. By observing Table 17, it showed that “question 32” had a strong and positive relationship ($r > 0.5$) on “Present Score” (carried out at the end of the course), and it was significant ($p < 0.05$). Thus, it could assume that higher CT skills should echo better presentation capability.

Table 17 – Correlations towards Q32 (Pre- questionnaire)

Q32 Correlations														
		Q32	IT Result	Q4	Q8	Q9	Q11	Q12	Q13	Q19	Q23	Q33	Q46	Present Score
Q32	Pearson Correlation	1	.551*	.562*	.714**	.600*	.561*	.605*	.589*	.666**	.595*	.570*	.649*	.539*
	Sig. (2-tailed)		0.041	0.036	0.004	0.023	0.037	0.022	0.027	0.009	0.025	0.033	0.012	0.047
	N	14	14	14	14	14	14	14	14	14	14	14	14	14
*. Correlation is significant at the 0.05 level (2-tailed).														
**. Correlation is significant at the 0.01 level (2-tailed).														

6.1.2.3.2) Post- questionnaire

After the teaching intervention, participates were required to do the same questionnaire again to measure the changing of their attitudes. Due to the word limit of this report, it will only focus on the noteworthy differences towards the pre- questionnaire.

First of all, by co-investigating the wording of question 1 (Table 18) and 10 (Table 19), which are “I am very interested in the content of this program.” and “I am sure I can master the skills or techniques taught in this program.” respectively. The correlations are not significant towards other factors in the pre- questionnaire. Interestingly, according to Table 18, it consisted of a significant positive correlation towards the CTS questions (Q14, 22, 23) and CPSES (Q26, 27, 32, 34). Therefore, this change proved that the course was fundamental and suitable for beginners to achieve the learning objectives easily. It could help learners become more confident about further explore coding to improve their CT skills. To further extend, this phenomenon aided to answer research questions 1 and 3, SBC is useful to foster learning motivation due to the gentle learning curve.

Table 18 – Correlations towards Q1 (Post- questionnaire)

Q1 Correlations													
		Q1	Q2	Q3	Q14	Q22	Q23	Q26	Q27	Q32	Q34	C2
Q1	Pearson Correlation	1	.869**	.733**	.544*	.749**	.572*	.618*	.699**	.737**	.750**	.766**
	Sig. (2-tailed)		0.000	0.003	0.044	0.002	0.033	0.018	0.005	0.003	0.002	0.001
	N	14	14	14	14	14	14	14	14	14	14	14
**. Correlation is significant at the 0.01 level (2-tailed).												
*. Correlation is significant at the 0.05 level (2-tailed).												

Table 19 – Correlations towards Q10 (Post- questionnaire)

Q10 Correlations														
		Q10	IT Result	Q2	Q8	Q11	Q12	Q13	Q14	Q22	Q34	Q35	Q45	Present Score
Q10	Pearson Correlation	1	.586*	.550*	.662**	.758**	.721**	.777**	.591*	.635*	.754**	.550*	.640*	.624*
	Sig. (2-tailed)		0.028	0.041	0.010	0.002	0.004	0.001	0.026	0.015	0.002	0.041	0.014	0.017
	N	14	14	14	14	14	14	14	14	14	14	14	14	14
*. Correlation is significant at the 0.05 level (2-tailed).														
**. Correlation is significant at the 0.01 level (2-tailed).														

Furthermore, by co-investigating, the wording of question 26 (Table 20) and 27 (Table 21), which are "It would great for me to work for Big Techs in my future career." and "I am sure I can master the skills or techniques taught in this program." respectively. The correlations are not significant towards other factors in the pre- questionnaire. Remarkably, according to Tables 22 and 23, it consisted of a significant positive correlation towards the MSLQ (Q1, 2, 3, 12, 13), CPSES (Q32, 34), and C2 (joyfulness when using the computer). Therefore, it could assume that joiners agreed that coding lessons using SBC could orient learners to become new blood of the IT industries in the future. To further extend this phenomenon support to answer research questions 1 and 3, they were happy to use SBC in a coding class, even foster them to code more in the future.

Table 20 – Correlations towards Q26 (Post- questionnaire)

Q26 Correlations										
		Q26	Q1	Q2	Q12	Q13	Q27	Q32	Q34	C2
Q26	Pearson Correlation	1	.618*	.537*	.544*	.587*	.727**	.755**	.713**	.672**
	Sig. (2-tailed)		0.018	0.048	0.044	0.027	0.003	0.002	0.004	0.008
	N	14	14	14	14	14	14	14	14	14
*. Correlation is significant at the 0.05 level (2-tailed).										
**. Correlation is significant at the 0.01 level (2-tailed).										

Table 21 – Correlations towards Q27 (Post- questionnaire)

Q27 Correlations												
		Q27	Major	IT Result	Q1	Q2	Q3	Q13	Q26	Q32	Q34	C2
Q27	Pearson Correlation	1	.635*	.547*	.699**	.716**	.654*	.537*	.727**	.770**	.733**	.882**
	Sig. (2-tailed)		0.015	0.043	0.005	0.004	0.011	0.048	0.003	0.001	0.003	0.000
	N	14	14	14	14	14	14	14	14	14	14	14
*. Correlation is significant at the 0.05 level (2-tailed).												
**. Correlation is significant at the 0.01 level (2-tailed).												

6.2 Interview Findings

For easy understanding, it is better to categorize these seven questions by three research questions and the actual question list (Table 22).

Table 22 – Question categorizations of interviews and question list

Major focus (research question)	Interview Questions
1	1, 2, 7
2	6
3	2, 3, 4, 5

Interview Question List (Translated)	
1	Before you use an SBC, do you like computer lessons? Why?
2	Do you think that using an SBC will improve your motivation to learn AI or coding? Why?
3	Do you want to use SBC in computer courses in primary and secondary schools in the future? Why?
4	What is the most impressive feature about HaloCode (and sensors)? Why?
5	What are the pros and cons of HaloCode (and sensors)? Why?
6	What should be improved throughout the entire computer course? Why?
7	Can you give three examples of how to improve the standard of living through the application of AI?

In question 1, most of the interviewees responded that they love computer lessons. It could let them be more creative and make something freely, which means higher flexibility in the lesson could be achieved. For example, some of them have learned Photoshop and Scratch before. They were interested in participating. Thus, we could understand that we have a great start point to attract more new-learners to experience coding. It would be great to find a good medium to foster their learning motivation towards coding.

In question 2, most of the interviewees agreed SBC would make the computer lesson more enjoyable. In the old day, the computer lesson always required students to follow the step of the teacher; while in this workshop, most of the time required them to think and make. Because of that, they can actualize their thoughts by some AI API host by Google. Moreover, they would prefer to interact with a material, rather than only seeing the output on the screen.

In question 7, due to the outbreak of COVID-19, the participants of the course are only limited to the undergraduate level. Therefore, they could only provide the bystander viewpoint in the question. They believe it is a positive and feasible solution to integrate SBC into local schools daily. As computer lessons should not always learning the outdated tech. If the school can afford it, children should have a chance to try a new tech that would be helpful for their future. Plus, they think pupils should like this learning medium more, as it was more interactive than the previous outdated computer curriculum.

To sum up, SBC is a great medium for a computer lesson. The research question 1 could also be supplemented. Based on respondents' reflections, the SBC computer lesson increased the learning motivation of students towards coding. The interactive feedback in an actual device was better than the virtual output on the screen. It is more energetic than traditional computer lesson content, which made students more engaged in the lesson.

In question 3, near all the learners, think that the most crucial function was calling Google API services. As it is out of their expectation that even a tiny SBC can perform this kind of high-tech functions. For instance, the face-recognition and voice-recognition features were impressive to be manipulated by themselves. They could train their custom AI to perform certain functions in the workshop. Some of them also mention the AI image descriptor is a powerful feature that could use in the educational field, while some personal privacy maybe encounters. This handy SBC benefited them to build their prototype easily.

In question 4, for the positive side, it could transfer the virtual feedback to an actual environment in an interactive way. A block-based coding environment also made AI applications achievable. Also, it had real-time and upload mode, which provided a feasible solution if we want to produce a standalone gadget (actualization). This feature helpful for fostering the creativity of learners.

For the cons, some of the participants return feedback towards the unstable wireless connection. Also, it only supported up to a simple 2.4Ghz WPA WIFI4 or below, which means it did not support IEEE 802.1x and WIFI 5 or above, which is commonly employed in the University environment. It may be problematic in the future.

In question 5, some participants reflect that as they had failed many times when they were trying to connect the HaloCode, thus they believe this technology may still be not sufficiently stable. Eventually, it even makes them feel depressed as they could not perform the function that they want. The steps were a bit not clear. The design section of our gadget should provide more guidelines for reference or even can give some limitations and circumstances for us, such as using in the library or hospital.

To conclude, students did achieve better learning experience from using SBC in the computer lesson. This leading to the answer research question 3. Based on respondents' reflections, they were impressed by the possibilities of SBC, from applying AI features to the actualizing their prototype, all by easy-to-learn drag-and-drop. At the same time, the lesson design should take care of the creativity pedagogical frameworks in order to foster the learning outcome more easily.

In question 6, although the quantitative data analysis has proved the improvement of CT skills of learners. Some of them had a slight misconception towards AI. It was glad that most of them could state at least two correct examples, such as Face ID Physical lock, real-time auto driving, and custom chatbot; But some of them were not aware or understood thoroughly on the definition of AI. Therefore, they may give some not related examples, like IKEA AR application, IoT devices, and airport self-check-in system. It may be encountered, given that the lesson design was highly compressed.

Chapter 7. Conclusion

7.1 Overview

To conclude, despite the limitations of the lesson durations, the research gives positive answers to the research questions. Applying SBC in the computer lesson can foster a noticeable amount of learning motivation towards coding. Although participants come from different major disciplines, the coding experience lets them step out of their comfort zone. It is a great entrance for new learners to start with block-coding and actual real-world feedbacks. The 8 hours workshop upheld the 6E model and including CT training tests and questionnaires. Major results returned positive contributions on enhancing CT skills, form 13% to near 23%, also noted with lower learning diversity between learners. Besides, the interview results show that learners are more enjoy using SBC in computer lessons than the traditional one. All in all, SBC is a great medium for computer lessons, hoping that it will further apply in local coding education in the foreseeable future.

7.2 Summary of findings

This research eventually provided various shreds of evidence to answer the three research questions stated in Chapter 3, respectively.

Research question 1: Is using SBC in the computer lesson able to foster the learning motivation towards coding?

Undoubtedly, the data analysis part in the MSLQ portion did not show there were significantly correlated between using SBC and increasing learning motivation. It may be since the ill-connection process between computer and HaloCode. Alternatively, by observing the responses from the interview, most of the joiners love and enjoy to use HaloCode to code with AI features. They would more engageable in the lesson based on the tangible interaction of HaloCode. Most importantly, they all agreed that SBC was a handy entrance for new-learners to actualize their prototype with block-based coding.

Research question 2: To what extend computational thinking skills of students able to enhance by using SBC in the computer lesson?

All findings from the instruments produced the consistent answers towards this research question – SBC will significantly enhance the CT skills of students. Not only over 20% of the mean score increased between the pre- and post-test, but also a near 15% improvement in the

CT skill measurement section (CTS and CPSES) in the questionnaire. Other than the quantitative analysis, comments were given by participants in the interview also helped to support the statistical findings. They reflected that they were more capable of building the prototypes with AI features by using HaloCode. The coding processes was easier than their expectations, the actual manipulation on coding (applying iteration, drawing flowchart, reusing global variables to accept the arguments, etc.) was not as difficult as they thought. Therefore, it is glad to conclude that this shockingly huge improvement on their CT skills was contributed by the application of SBC in coding class.

Research question 3: Do students achieve a better learning experience by using SBC in the computer lesson?

Students achieved a better overall learning experience by using SBC in this research intervention. According to their responses in interviews, they were highly impressed by the possibilities of HaloCode. It was straight forwarded for coding with AI features, which finally actualized their gadgets to a prototype. They expressed that they will welcome using SBC in coding classes, or even should further extend to the current Computer Literacy curriculum in local primary and secondary schools.

7.3 Limitations and Suggestions

1. Insufficient lesson hours

Since the outbreak of COVID-19, it forced to amend the planning and lesson design for many times. Originally, it has planned at least two iterations of this research, while the audience should be secondary students in my practicum school. However, this year, 2019-2020, have happened many unfavorable accidents, which directly lead to the long-term school suspension. Thus, it has changed the plan to 8 hours mini-workshops, break into two days, for different disciplines undergraduate students to experience using SBC to code with AI features.

2. Limited sample size may result in less accurate statistics

Just like I have mentioned above, the sample size of this pioneering workshop was smaller than expected. It is recommended to increase the sample size, says 40-50 joiners in total, which break them down evenly into Control Group and Experimental Group. Also noted that it would be more reasonable carrying out in real school setting.

3. Lacking limitations or guidance

Some participants reported that it was hard for them to suddenly generate some ideas which are useful in daily life, let along using the new-learned SBC to actualize their ideas. It is suggested that the lesson durations should be lengthened, also assisting students with some pedagogical frameworks, such as Multi-Area Creativity Educational Model (Cheng, 2020), in order to maximize the learning outcome of the lesson with smoother lesson pace.

4. Insufficient questions for the pre- post-test

Initially, CTt and Bebras Task included 30-40 questions in total. Nevertheless, due to the time limitation, it has randomly chosen 10 of each test with the corresponding type. It may have some negative influence on the reliability of the test. Moreover, according to figure 8 (Román-González et al., 2019), it is suggested to do some tests which are catering the high level of Bloom's taxonomy, such as Dr. Sctrach, while it may be more feasible given that I have a longer time for the test.

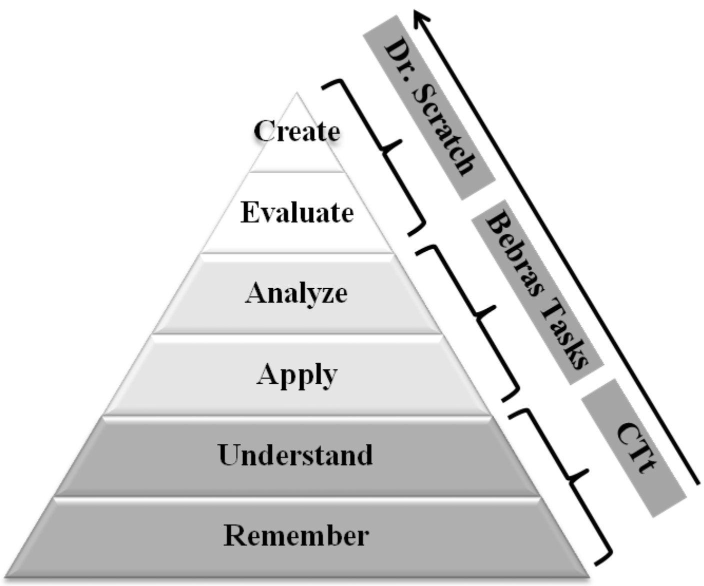


Figure 8 – Bloom's taxonomy and CT assessment tools (Román-González et al., 2019)

References

Abadi, M., Barham, P., Chen, J., Chen, Z., Davis, A., Dean, J., Devin, M., Ghemawat, S., Irving, G., Isard, M., Kudlur, M., Levenberg, J., Monga, R., Moore, S., Murray, D. G., Steiner, B., Tucker, P., Vasudevan, V., Warden, P., Wicke, M., Yu, Y., and Zheng, X. & Google Brain (2016). Tensorflow: A system for large-scale machine learning. In *12th {USENIX} Symposium on Operating Systems Design and Implementation ({OSDI} 16)* (pp. 265-283).

Albaum, G. (1997). The Likert scale revisited. *Market Research Society. Journal.*, *39*(2), 1-21.

Barry, N. (2014). The ITEEA 6E Learning by Design™ Model. *The Technology and Engineering Teacher, 73*(6), 14-19.

Besemer, S. P., & O'Quin, K. (1999). Confirming the three-factor creative product analysis matrix model in an American sample. *Creativity Research Journal*, *12*(4), 287-296.

Boom, K. D., Bower, M., Arguel, A., Siemon, J., & Scholkmann, A. (2018). Relationship between computational thinking and a measure of intelligence as a general problem-solving ability. *In Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education* (pp. 206-211).

Boud, D., & Feletti, G. (2013). *The challenge of problem-based learning*. Routledge.

Brennan, K., & Resnick, M. (2012). New Frameworks for Studying and Assessing the Development of Computational Thinking. *Proceedings of the 2012 Annual Meeting of the American Educational Research Association*. Vancouver: American Educational Research Association.

Burke, B. N. (2014). The ITEEA 6E Learning By Design™ Model: Maximizing Informed Design and Inquiry in the Integrative STEM Classroom. *Technology and Engineering Teacher, 73*(6), 14-19.

Cheng, V. MY. (2020). Models and Approaches for fostering creativity through STEM+A. In M.Y.V. Cheng et al. (Eds) *Developing Creativity through STEM+A learning* (ebook, chapter 3.1, Chinese). Published by The Education University of Hong Kong. China: Hong Kong.

Computer Science Teachers Association. (2016). Operational definition of computational thinking.

Education Bureau. (2015). *Report on the Fourth Strategy on Information Technology in Education*. Hong Kong.

Golafshani, N. (2003). Understanding reliability and validity in qualitative research. *The qualitative report*, *8*(4), 597-606.

Gibson, S., & Bradley, P. (2017). A study of Northern Ireland Key Stage 2 pupils' perceptions of using the BBC Micro: bit in STEM education. *The STeP Journal*, *4*(1), 15-41.

Hsiao, H. S., Chen, J. C., Lin, Y. W., & Tsai, H. W. (2019). Using a 6E Model Approach to Improve Students Learning Motivation and Performance about Computational Thinking. In Kong, S.C., Andone, D., Biswas, G., Hoppe, H.U., Hsu, T.C., Huang, R.H., Kuo, B.C., Li, KY, Looi, C.K., Milrad, M., Sheldon, J., Shih, J.L., Sin, KF, Song, KS, & Vahrenhold, J. (Eds.), *Proceedings of International Conference on Computational Thinking Education 2019* (pp. 122-126). Hong Kong: The Education University of Hong Kong.

Human Research Ethics Committee (2015). *EdUHK's Guidelines on Ethics in Research*. Hong Kong, China: The Education University of Hong Kong.

Kafai, Y. B., & Burke, Q. (2013). The social turn in K-12 programming: moving from computational thinking to computational participation *Proceeding of the 44th ACM technical symposium on Computer science education*, (pp. 603-608). Denver, Colorado, USA: ACM. doi:10.1145/2445196.2445373.

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Kong, S. C. (2016). A framework of curriculum design for computational thinking development in K-12 education. *Journal of Computers in Education*, *3*(4), 377–394. doi:10.1007/s40692-016-0076-z.

Koorsse, M., Cilliers, C., & Calitz, A. (2015). Programming assistance tools to support the learning of IT programming in south African secondary schools. *Computers & Education*, *82*(2), 162–178.

Korkmaz, Ö., Çakir, R., & Özden, M. Y. (2017). Avalidity and reliability study of the computational thinking scales (CTS). *Computers in Human Behavior*. https://doi.org/10.1016/j.chb.2017.01.005.

Kukul, V., Gökçearslan, Ş., & Günbatar, M. S. (2017). Computer Programming Self-efficacy Scale (CPSES) for Secondary School Students: Development, Validation and Reliability. *Educational Technology Theory and Practice, 7*(1), 158-179. doi:10.17943/etku.288493.

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., & Werner, L. et al. (2011). Computational thinking for youth in practice. *ACM Inroads*, *2*(1), 32–37. doi:10.1145/1929887.1929902.

Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? C*omputers in Human Behavior*, *41*, 51–61. doi:10.1016/j.chb.2014.09.012.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas.* Basic Books, Inc.

Piaget, J. (1954). *The construction of reality in the child.* New York, USA: Basic Books.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). *A manual for the use of the Motivated Strategies for Learning Questionnaire (Mslq)*. Ann Arbor, MI: National Center for Research to Improve Postsecondary Teaching and Learning.

Przybylla, M., & Romeike, R. (2014). Physical Computing and Its Scope--Towards a Constructionist Computer Science Curriculum with Physical Computing. Informatics in Education, 13(2), 241-254.

Román-González, M., Pérez-González, J. C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test. *Computers in Human Behavior*, *72*, 678-691.

Román-González, M., Moreno-León, J., & Robles, G. (2019). Combining assessment tools for a comprehensive evaluation of computational thinking interventions. In *Computational Thinking Education* (pp. 79-98). Springer, Singapore.

Rubio, M. A., Romero-Zaliz, R., Mañoso, C., & Angel, P. (2014). Enhancing an introductory programming course with physical computing modules. In *2014 IEEE Frontiers in Education Conference (FIE) Proceedings* (pp. 1-8). IEEE.

Savin-Baden, M. (2000). *Problem-based learning in higher education: Untold stories.* Buckingham: SRHE and Open University Press.

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education*, *2*, 53.

Tedre, M. (2017). Many paths to computational thinking. *In paper presented at the TACCLE 3 final conference, Brussels, Belgium.*

Topalli, D., & Cagiltay, N. E. (2018). Improving programming skills in engineering education through problem-based game projects with Scratch. *Computers & Education*, *120*, 64-74.

Tien, H. M. & Yen J.C. (2019). Computational Thinking in STEM Task Design: Authentic, Useful, Experiential, and Visual. In Kong, S.C., Andone, D., Biswas, G., Hoppe, H.U., Hsu, T.C., Huang, R.H., Kuo, B.C., Li, KY, Looi, C.K., Milrad, M., Sheldon, J., Shih, J.L., Sin, KF, Song, KS, & Vahrenhold, J. (Eds.), *Proceedings of International Conference on Computational Thinking Education 2019* (pp. 135-140). Hong Kong: The Education University of Hong Kong.

Werner, L., Denner, J., Campe, S., & Kawamoto, D. C. (2012). The fairy performance assessment: Measuring computational thinking in middle school. *In Proceedings of the 43rd ACM technical symposium on computer science education, SIGCSE '12* (pp. 215-220). New York, NY, USA: ACM.

Wing, J. (2011). Research notebook: Computational thinking—What and why. *The Link Magazine*, 20-23.

Wong, G. K., Cheung, H. Y., Ching, E. C., & Huen, J. M. (2015). School perceptions of coding education in K-12: A large scale quantitative study to inform innovative practices. *Proceedings of the 2015 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)* (pp. 5-10). IEEE. doi:10.1109/TALE.2015.7386007.

Wong, G., Jiang, S., & Kong, R. (2018). Computational thinking and multifaceted skills: A qualitative study in primary schools. In *Teaching computational thinking in primary education* (pp. 78-101). IGI Global.

吳靜吉和程炳林（1992）：激勵的學習策略量表之修訂。《測驗年刊》，39，59-78。

Appendices

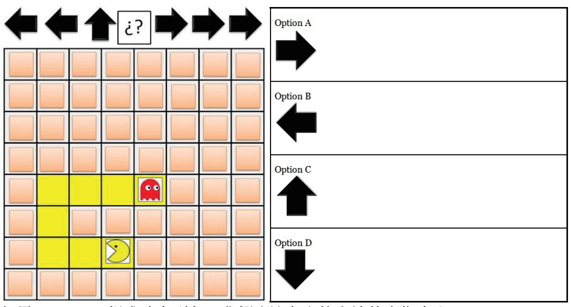
- Appendix A - Sample of Consent Form
- Appendix B - Pre-test
- Appendix C - Post-test
- Appendix D - Questionnaire
- Appendix E - Interview Questions
- Appendix F - Creative Product Assessment Matrix (CPAM)
- Appendix G - Lesson Slideshow
- Appendix H - Final Presentation Slideshow

Appendix A - Sample of Consent Form

Appendix B - Pre-test

學生編號：______________

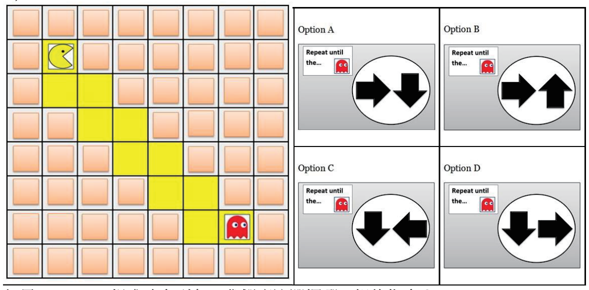
1)



如果 PACMAN 想成功食到鬼，我們應該在空格上填什麼指令？

☐

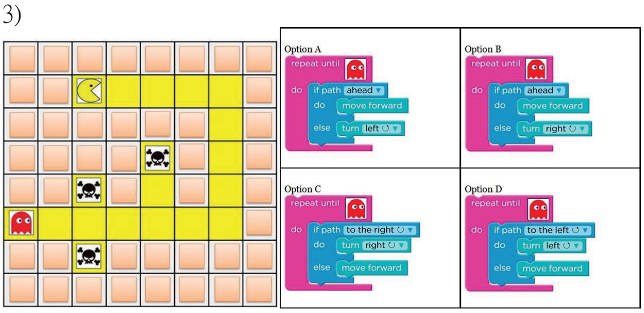
2)



如果 PACMAN 想成功食到鬼，我們應該選擇哪一組的指令？

☐

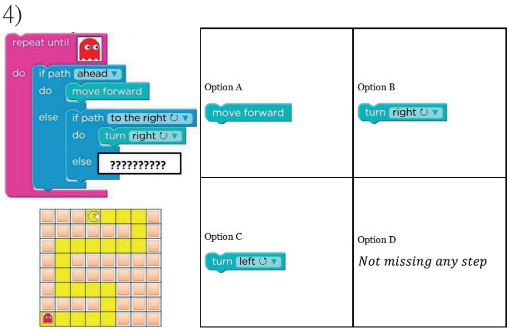
3)



如果 PACMAN 想成功食到鬼，我們應該選擇哪一組的指令？

☐

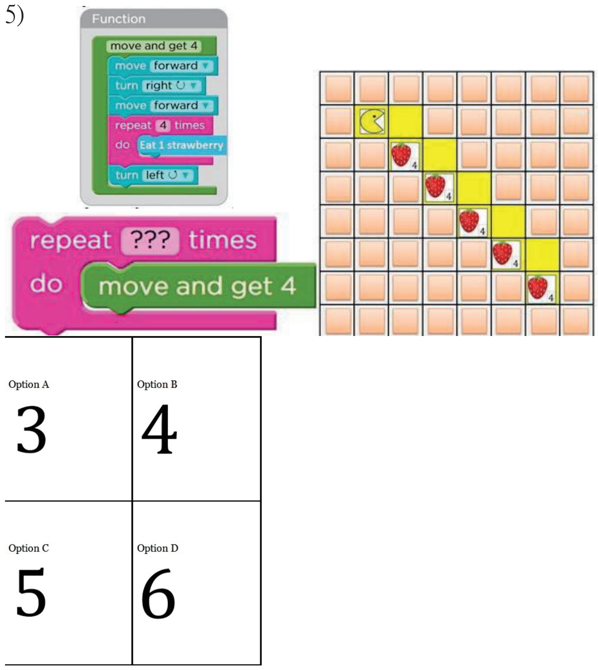
4)



如果 PACMAN 想成功食到鬼，我們應該在空格上填什麼指令？

☐

5)

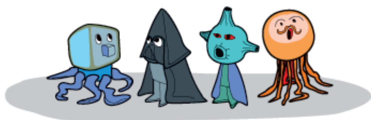


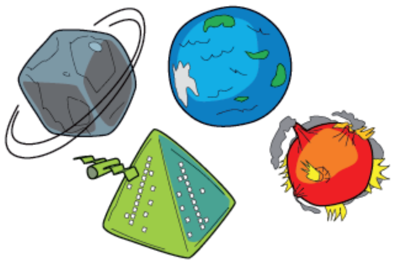
如果 PACMAN 想成功把全部草莓吃光，我們應該在空格上填什麼指令？

☐

6)

可愛的生物生活在新發現的行星。





根據什麼特徵可以為該生物分配一個行星？

A. 顏色
B. 旋轉的可能性
C. 形狀
D. 情感表達

☐

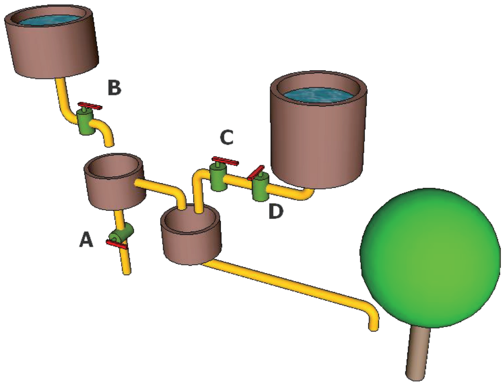
7)

園丁已經建造了一個管道系統來澆灌他的蘋果樹。

下圖包含四個水龍頭，分別為 A，B，C，D。

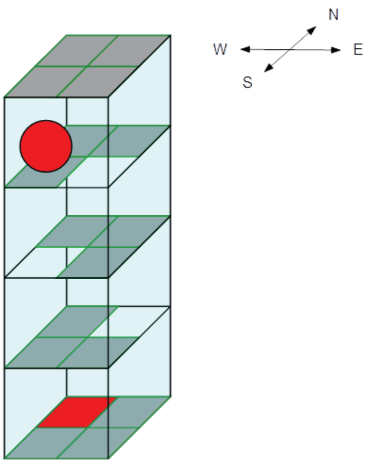
如果相應的水龍頭打開，我們就會視之為 true，如果關閉則為 false。

在這種情況下，才能成功灌溉蘋果樹？



A: A = false, B = true, C = false, D = false
B: A = true, B = true, C = false, D = false
C: A = true, B = false, C = false, D = true
D: A = false, B = false, C = false, D = true

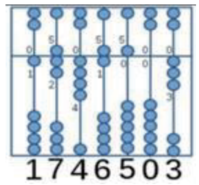
8)



以下哪一個移動順序才能把紅色球，最終移動至紅色區域？

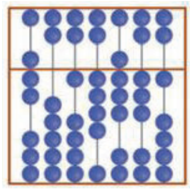
A: E, W, N, W, W
B: E, W, N, E, S, W
C: E, W, E, N, S, W
D: E, N, W, S, N, E, W

9)



以上是中國算盤的數字代表方法，上面例子代表 1746503；

參考上述例子，下圖代表什麼數字？



A. 3014431

B. 7514831

C. 7014831

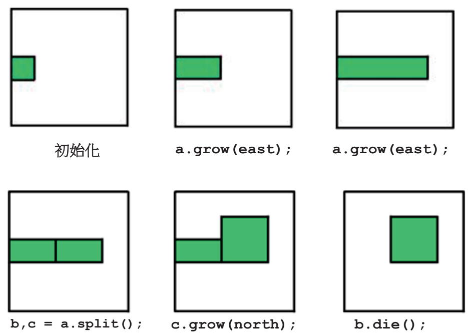
D. 3514431

10)

允行很喜歡種花，因此他發明基於花朵的興衰過程，模擬了一種簡單的程式編寫語言；

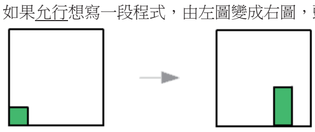
這種編寫語言只有三大函數，(function)，分別是 `grow(direction)`; `split()`;和 `die()`;

這種自製的語言會用以下六張圖片做演示；



****請切記正方形不能被切割，不能使用 split()**

如果允行想寫一段程式，由左圖變成右圖，頭 4 個步驟是什麼？



A. a.grow(east); a.grow(east); b,c = a.split(); b.die();
B. a.grow(north); a.grow(east); a.grow(east); b,c =a.split();
C. a.grow(east); a.grow(east); a.grow (north); a.die();
D. a.grow(east); b,c = a.split(); c.grow(north); c.grow(east);

自我評價

您的回答很重要，這份量表將會對老師的教學有所幫助，請務必認真作答，而問題的回答並沒有對錯之分，請依據您對每個題目的「第一個反應」來回答問題，不要考慮太久。

你覺得在這個測試裏表現如何？

	0	1	2	3	4	5	
信心極低	O	O	O	O	O	O	信心極高

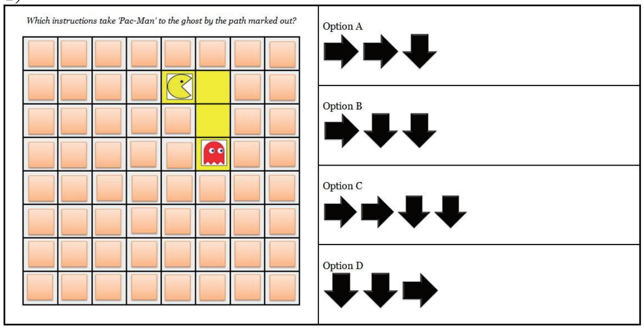
你使用電腦時，我覺得非常……？

	0	1	2	3	4	5	
抗拒	O	O	O	O	O	O	歡愉

Appendix C - Post-test

編號：________________

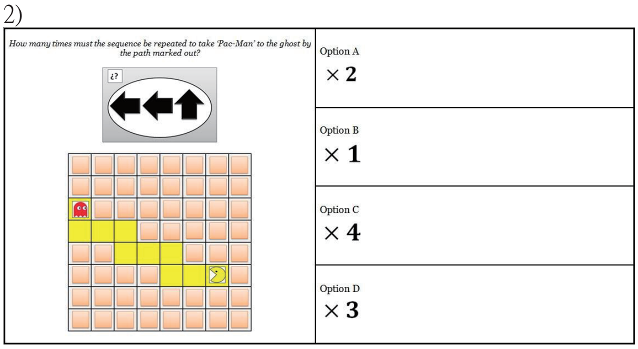
1)



如果 PACMAN 想成功食到鬼，我們應該選擇哪一組的指令？

☐

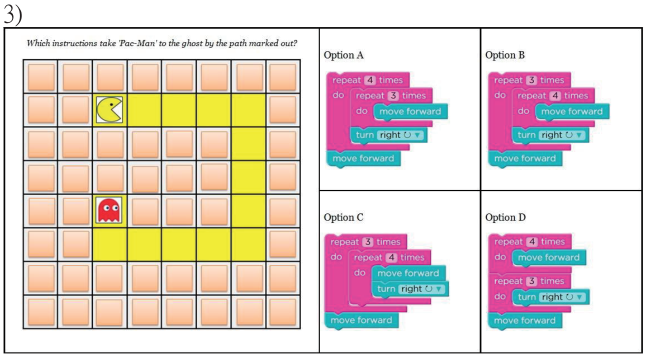
2)



如果 PACMAN 想成功食到鬼，應該把指令重複幾多次？

☐

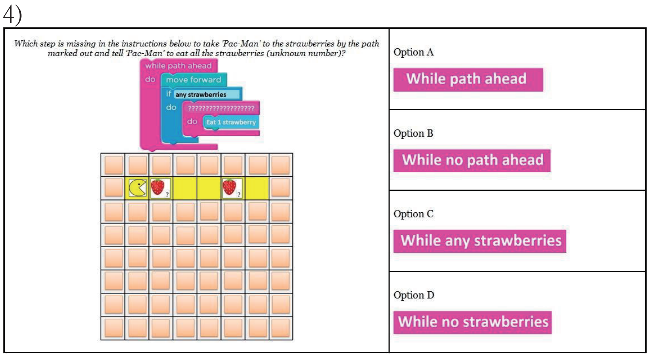
3)



如果 PACMAN 想成功食到鬼，我們應該選擇哪一組的指令？

☐

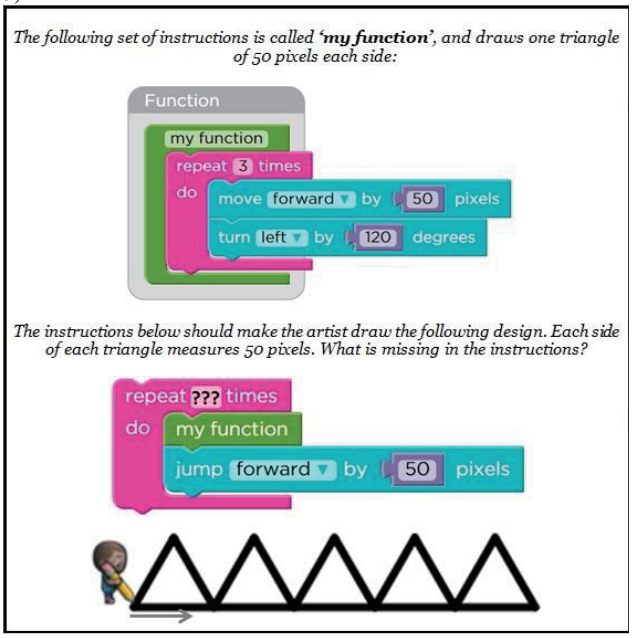
4)



如果 PACMAN 想成功把全部草莓吃光，我們應該在空格上填什麼指令？

☐

5)



A) 15
B) 5
C) 4
D) 3

☐

6)

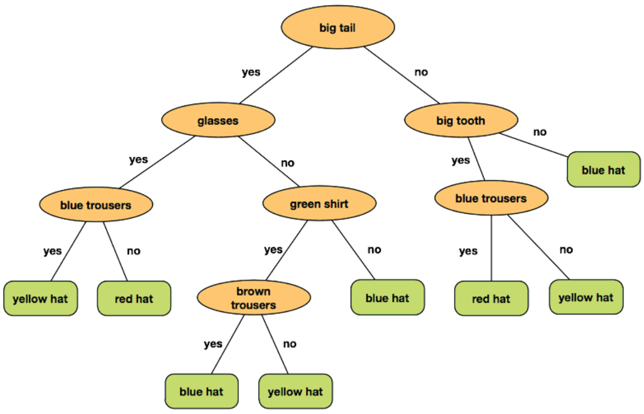
電腦上圖靈機的時代，會利用控制元件操控電腦 就像圖片中顯示，會有一連串的按鈕去代表相應的二進制數值，請問圖中的機器最多能夠展示幾多個不同的數值?

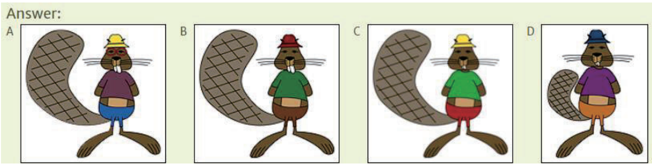
A. 8
B. 256
C. 128
D. 16

☐

7)

海狸喜歡複雜的規則系統，因此建立了新的穿著要求。根據以下的樹狀圖，哪個海狸 **沒有** 依從規矩穿著？





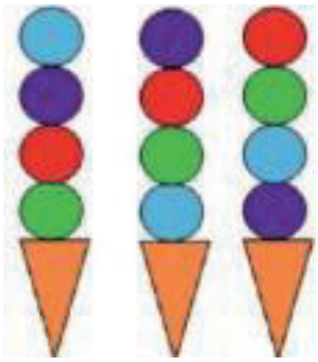
8)

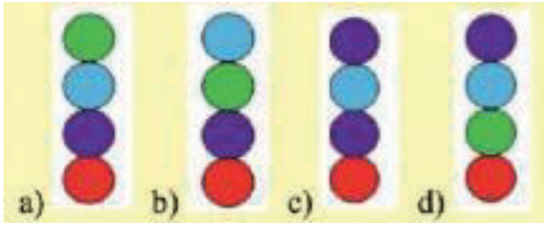
一心的爸爸是個工匠，一心生日的時候，爸爸發揮匠人精神把樹木切片變成小玩具，製成生日禮物送給一心。想請問以下哪個方法才能夠將圓珠帶出迷宮？

A: L, R, R, L, R, L
B: R, L, R, L, L
C: L, R, R, L, R
D: L, R, R, R, R, L

9)

雪糕機一定會依藏特定的次序生產雪糕球，圖中由左至右生產，請問下一支雪糕應該是什麼次序？





10)

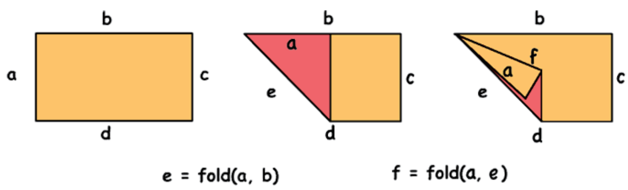
允行很喜歡摺紙，因此他基於摺紙的過程，發明了一種簡單的程式編寫語言，可以用來描述如何摺四邊都是直邊的紙;

這種編寫語言只有一個函數(function) -- **fold;**

這種自製的語言會用以下圖片做演示；

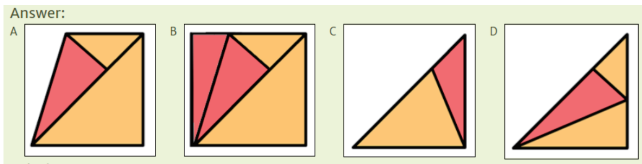
e = fold(a, b)→ 將 **a** 邊摺向 **b** 邊,從而產生新的 **e** 邊;

f = fold(a, e)→ 將 **a** 邊摺向 **e** 邊,從而產生新的 **f** 邊



如果允行拿了一張新紙，並執行了以下三個指令之後，最終會是什麼樣式？

e = fold(c, a); f = fold(c, d); g = fold(a, f)



Appendix D – Questionnaire

學生問卷

- 您的回答很重要，這份量表將會對老師的教學有所幫助，請務必認真作答。
- 問題的回答並沒有對錯之分，請依據您對每個題目的「第一個反應」來回答問題，不要考慮太久。
- 填寫時間為 15 分鐘，請不要遺漏任何一個題目，時間到時由老師統一收卷。

學生編號：	________			
主攻學科：	文科	商科	理科	
性別：	男	女		
編程經驗：	完全沒有	少	間中	豐富
教育程度：	初中	高中	大學	
每日網絡使用時長：	<1 小時	1-3 小時	3-6 小時	>6 小時
*數學*成績：	通常不合格	通常合格	通常高分	
你覺得*數學*這個學科：	無聊	既不無聊也不有趣	有趣	
*科學*成績：	通常不合格	通常合格	通常高分	
你覺得*科學*這個學科：	無聊	既不無聊也不有趣	有趣	
*資訊科技*成績：	通常不合格	通常合格	通常高分	
你覺得*資訊科技*這個學科：	無聊	既不無聊也不有趣	有趣	

	非常不同意	不同意	一般	同意	非常同意
1）我對本科目的內容很有興趣。	○	○	○	○	○
2）我喜歡本科目的內容。	○	○	○	○	○
3）我會在電腦課堂中積極學習。	○	○	○	○	○
4）學會本科目的內容對我是重要的。	○	○	○	○	○
5）我認為我可以在本科目所學到的應用到別的課程中。	○	○	○	○	○
6）我認為學習本科目的內容對我而言是有用處。	○	○	○	○	○
7）本科目可以激發我的思維。	○	○	○	○	○
8）我有信心我可以學會本科目所教的基本觀念。	○	○	○	○	○
9）我有信心在本科目的作業和考試表現優異。	○	○	○	○	○
10）我確定我能精通本科目所教的技能或技巧。	○	○	○	○	○
11）我確定我可以瞭解本科目中最困難的部分。	○	○	○	○	○
12）我有信心我能瞭解老師在本科目所教的最複雜的內容。	○	○	○	○	○
13）我總是在課後主動發掘電腦相關的知識。	○	○	○	○	○
14）我可以區分計算機科學，建築學和人工智能（AI）的概念。	○	○	○	○	○
15）我了解如何通過積木編程平台應用人工智能。	○	○	○	○	○
16）運算思維使我很容易理解訊息處理的概念。	○	○	○	○	○
17）我認為我擁有不俗的運算思維和解決問題能力。	○	○	○	○	○
18）我知道如何應用人工智能來改善我們的生活水平。	○	○	○	○	○
19）借助運算思維，我可以更容易地專注於解難流程。	○	○	○	○	○
20）我知道如何道德地使用人工智能（AI）技術。	○	○	○	○	○
21）我認為訓練運算思維是個漫長的過程，需要長期投入才能有所成。	○	○	○	○	○
22）我不會因為看見複雜的使用介面而感到苦惱。	○	○	○	○	○
23）運算思維提高了我對軟件和機器人的興趣和好奇心。	○	○	○	○	○

	非常不同意	不同意	一般	同意	非常同意
24）單板電腦有助提升我的運算思維能力。	○	○	○	○	○
25）我認為每人從小就必須接受編程教育。	○	○	○	○	○
26）如果未來能夠在一些科技巨擘當中工作是件美事。	○	○	○	○	○
27）我對新高中 ICT 課程感興趣。	○	○	○	○	○
28）如果可以，我想利用我的技術去造福社會。	○	○	○	○	○
29）政府應喚起大眾對於科技的關注，並大力支持並鼓勵科技行業的長遠可持續發展。	○	○	○	○	○
30）我可以通過多種的解決方案解決同一個問題。	○	○	○	○	○
31）我可以正確運行自己開發的程序。	○	○	○	○	○
32）我可以清晰地解釋我解決問題的方法，以及每一個步驟。	○	○	○	○	○
33）我選擇最適合的知識來解決編程問題。	○	○	○	○	○
34）課後我會主動探討編程知識。	○	○	○	○	○
35）我盡量會使用最高效率的方法解決問題。	○	○	○	○	○
36）我能夠長期維護並改善自己的設計。	○	○	○	○	○
37）我有能力偵錯（debug）。	○	○	○	○	○
38）在解決問題的時候，我知道還有多久才能完工。	○	○	○	○	○
39）我會在網絡上分享我自己設計的程式。	○	○	○	○	○
40）我能夠把大問題分解成多個容易解決的小問題，之後逐一擊破。	○	○	○	○	○
41）我能夠理解流程圖。	○	○	○	○	○
42）我可以使用「循環」（迭代）的概念來簡化編程任務，即重複一個（些）動作。	○	○	○	○	○
43）我可以應用運算符號完成編程任務，例如: 使用 >（大於）或 <（小於）之類的作出條件比較。	○	○	○	○	○
44）我可以應用「function」（功能/ 函數）來完成編程任務。	○	○	○	○	○
45）我可以重用現有代碼以構建自己的程序。	○	○	○	○	○
46）我可以從日常生活中提出可以利用電腦思維解決的問題。	○	○	○	○	○

Appendix E - Interview Question

面試問題

1）在未使用單板計算機（SBC）之前，您是否喜歡電腦課？為什麼？

2）您認為通過單板電腦*有沒有*提升你應用人工智能（AI）/ coding 學習動機？為什麼？

3）HaloCode (and sensors) 令你最深印象的是什麼？為什麼？

4）HaloCode (and sensors) 的優點和缺點是什麼？為什麼？

5）你認為整個電腦課程最需要改善的地方是什麼？為什麼？

6）你可以舉三個通過應用人工智能（AI）來改善生活水平的例子嗎？

7）您希望將來在中小學的電腦課程中使用單板電腦（SBC）嗎？為什麼？

Appendix F - Creative Product Assessment Matrix (CPAM)

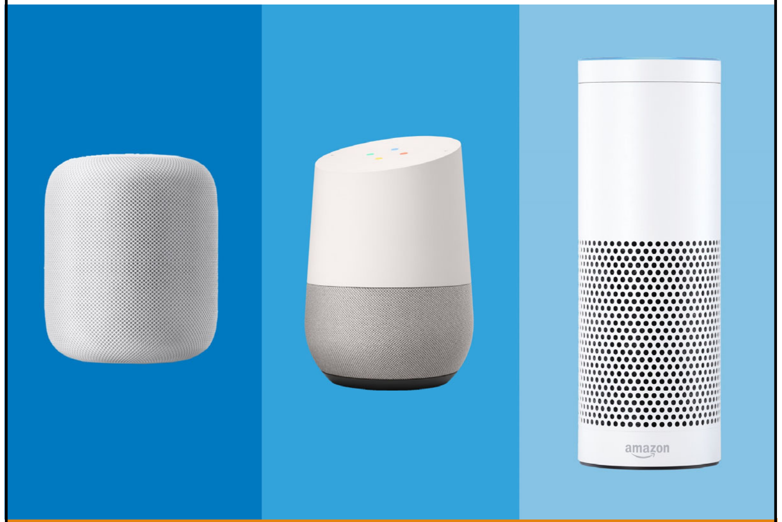
指標	評分準則
原創性（Original）	作品是否自行構思創造而不是經由複製改編模仿衍生出來的作品
驚奇性（Surprise）	作品呈現出意想不到的資訊或效果
價值性（Valuable）	作品設計構想是否具有意義和價值
邏輯性（Logical）	作品設計構想是否合乎邏輯並且考慮到現實限制
有用性（Useful）	作品很大機會能夠在實際環境應用
可理解性（Understandable）	設計理念是否讓大眾清楚了解
基本品質（Organic）	作品是否能夠正常運作
精緻程度（Elegance）	作品在軟硬件兩大層面是否精簡易正確
良好手藝（Well-crafted）	作品在製作流程期間是否合標準及最終外觀是否美觀

向度	指標	分數
創新性（Novelity）	原創性（Original）	1 ☐ ☐ ☐ ☐ ☐ 5
	驚奇性（Surprise）	1 ☐ ☐ ☐ ☐ ☐ 5
解決方案（Resolution）	價值性（Valuable）	1 ☐ ☐ ☐ ☐ ☐ 5
	邏輯性（Logical）	1 ☐ ☐ ☐ ☐ ☐ 5
	有用性（Useful）	1 ☐ ☐ ☐ ☐ ☐ 5
	可理解性（Understandable）	1 ☐ ☐ ☐ ☐ ☐ 5
製作與統合（Elaboration & Synthesis）	基本品質（Organic）	1 ☐ ☐ ☐ ☐ ☐ 5
	精緻程度（Elegance）	1 ☐ ☐ ☐ ☐ ☐ 5
	良好手藝（Well-crafted）	1 ☐ ☐ ☐ ☐ ☐ 5

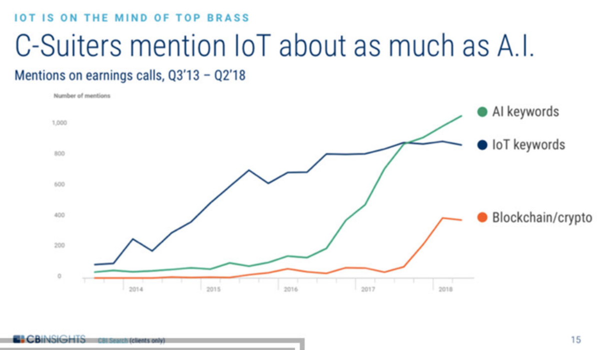
Appendix G - Lesson Slideshow

人工智能編程課程

LESSON 1



無可限量的 AI 未來



以上的說法貌似都不太對，那人工智能的本質到底是什麼？

Artificial Intelligence =AI

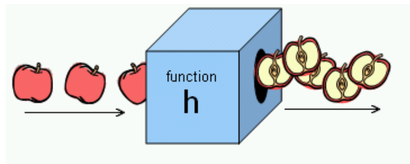
=人工智能

人工

亦稱智械 機器所表現出
來的智慧。通 通電腦程式來呈現
人類智慧的技術 樣的智慧系統是否
能夠實現，以 學、神經科學、
機器人學及 進步 為人類的無
數職業也 代。

以下理解僅個人簡化後的簡介，是非常的**不嚴謹和不科學**的！！！

但是對於初學者，姑且先這樣理解吧。



AI是一個函數(function)

只是此功能不同於我們的人寫的，它是通過大規模的培訓模式*(DATASETS + TRAIN MODEL)*產生

現有的程式，都通過不斷的IF...else...，的方式事先寫好，當下次遇到相同的輸入時，匹配上了IF，自然就輸出結果了。

IF Input  Then output Cat

IF Input  Then output Dog

AI function和現有function之間有什麼區別?

現有認貓function

Input  output **cat**

AI function和現有function之間有什麼區別?

AI認貓function

Training Data
This is cat

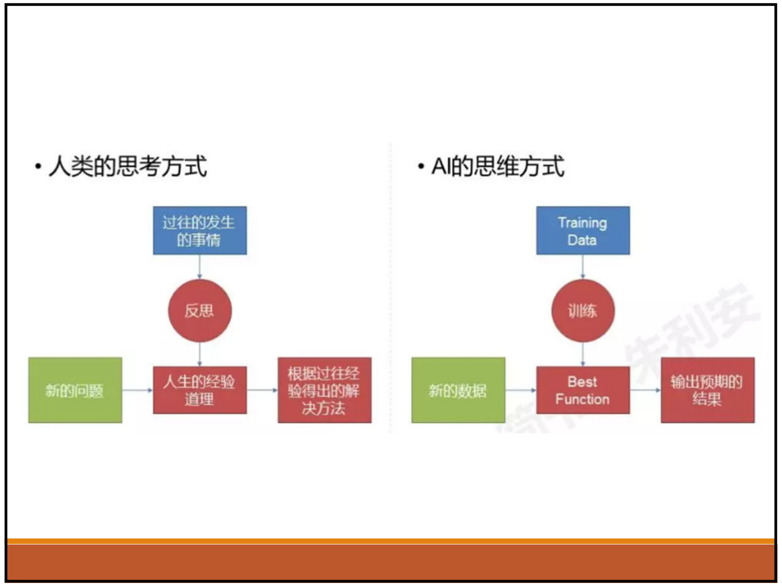
AI

AI function和現有function之間有什麼區別?

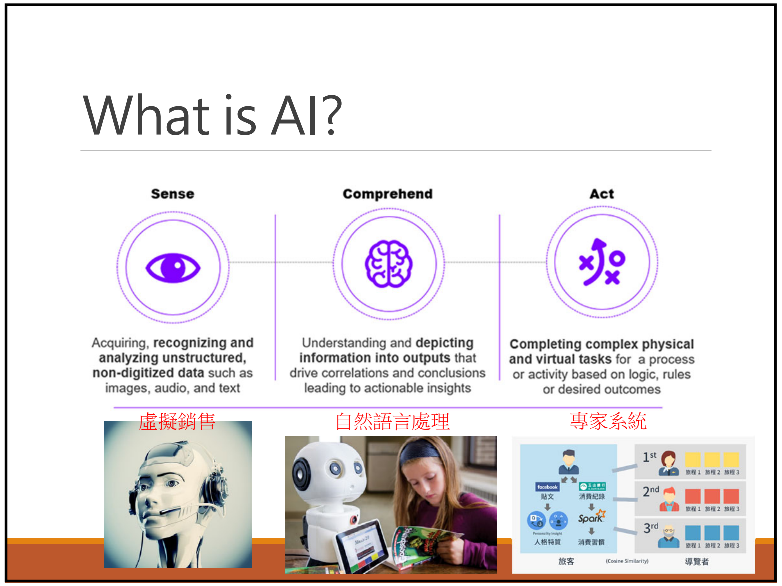
AI認貓function

AI

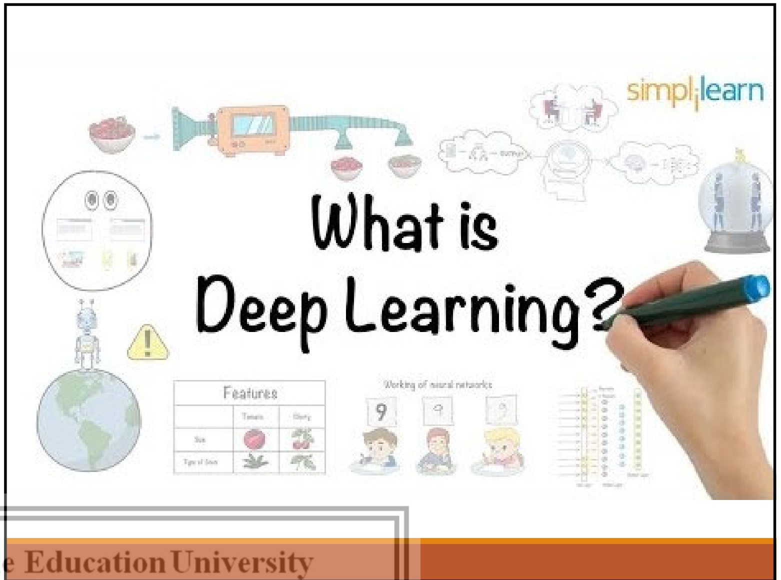
Input  output **Cat (properly)**



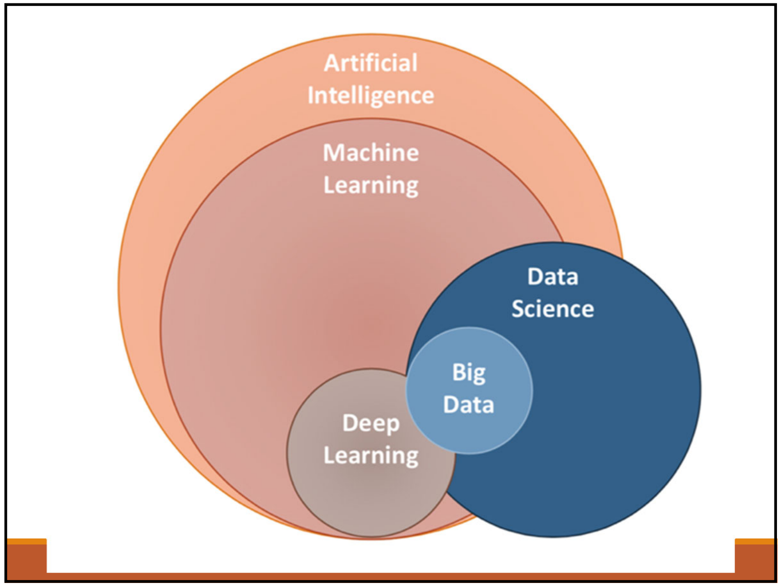
• 人类的思考方式
过往的发生的事情
反思
新的问题
人生的经验道理
根据过往经验得出的解决方法
• AI的思维方式
Training Data
训练
新的数据
Best Function
输出预期的结果



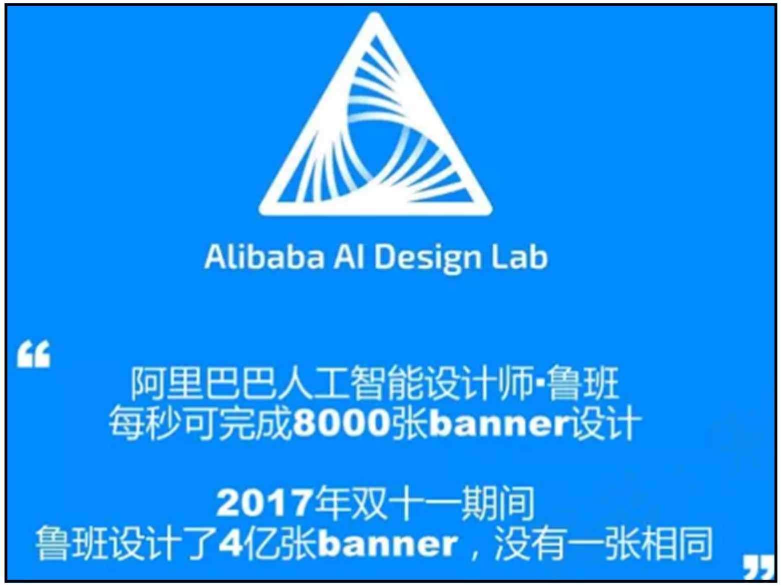
What is AI?
Sense
Comprehend
Act
Acquiring, recognizing and analyzing unstructured, non-digitized data such as images, audio, and text
Understanding and depicting information into outputs that drive correlations and conclusions leading to actionable insights
Completing complex physical and virtual tasks for a process or activity based on logic, rules or desired outcomes
虛擬銷售
自然語言處理
專家系統



simplilearn
What is Deep Learning?
Features

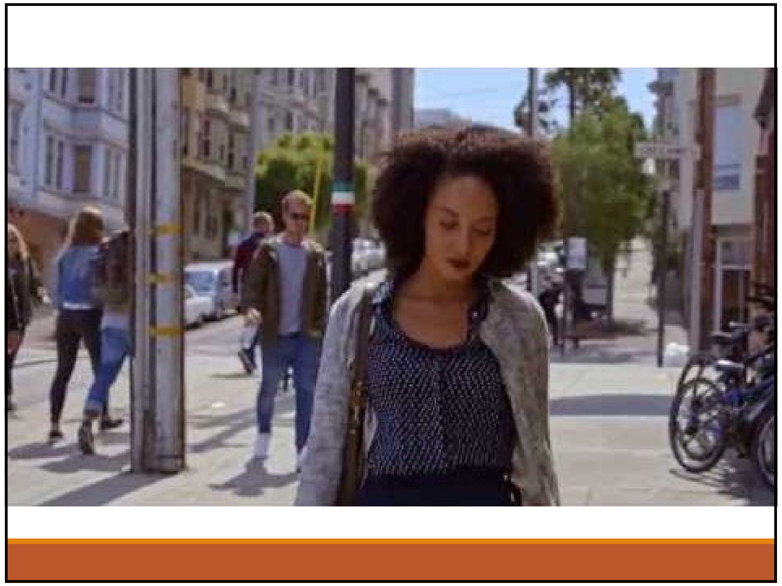


Artificial Intelligence
Machine Learning
Data Science
Big Data
Deep Learning


Alibaba AI Design Lab
“
阿里巴巴人工智能设计师·鲁班
每秒可完成8000张banner设计
2017年双十一期间
鲁班设计了4亿张banner，没有一张相同
”


“鲁班” AI设计系统
Output
春季上新
线下同款
同步发售
F鲁班（原始素材，风格，...）
Input
风格背景元素
修饰元素
配色
构图
原始素材

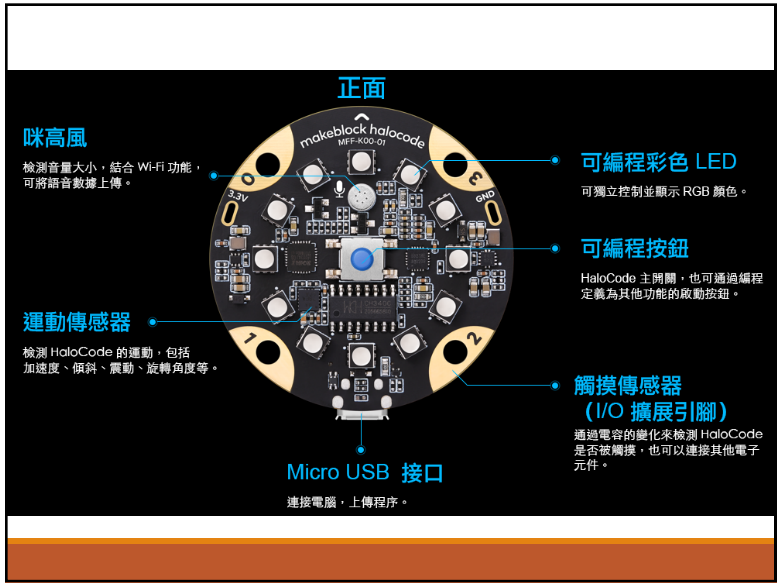

THERE IS SOMETHING TRULY AMAZING



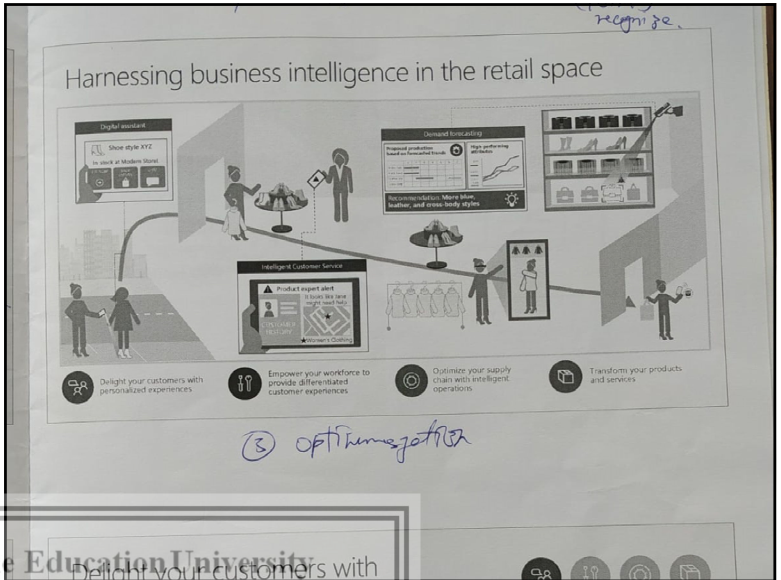

網紅、KOL末日？
01
生活
liliankan
roserosemama
La Porte HK
Instagram
正式取消Like數
「鼓勵 Engagement」


Redefining the
QSR Experience


OUTDOOR
ADVERTISEMENT STAND
BILL-
-BOARD
MOCKUP PSD


正面
咪高風
檢測音量大小，結合 Wi-Fi 功能，可將語音數據上傳。
makeblock halocode
可編程彩色 LED
可獨立控制並顯示 RGB 顏色。
可編程按鈕
HaloCode 主開關，也可通過編程定義為其他功能的啟動按鈕。
運動傳感器
檢測 HaloCode 的運動，包括加速度、傾斜、震動、旋轉角度等。
觸摸傳感器
(I/O 擴展引腳)
通過電容的變化來檢測 HaloCode 是否被觸摸，也可以連接其他電子元件。
Micro USB 接口
連接電腦，上傳程序。


Hong Kong's low-fare airline
HK express
由 UNWIRE.HK 發佈
104,827 次觀看
分享
實試KFC點餐機
食雞真係咁難？
-1:44
HD


Harnessing business intelligence in the retail space
Delight your customers with personalized experiences
Empower your workforce to provide differentiated customer experiences
Optimize your supply chain with intelligent operations
Transform your products and services

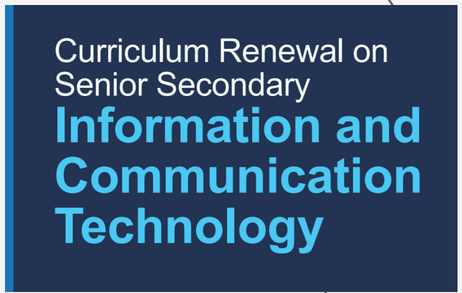

全球首宗
01 新聞
UBER
自動駕駛車
撞死人
美加路面測試緊急暫停
unmanned platforms.
b. Establishes guidelines designed to minimize the probability and consequences of failures in autonomous and semi-autonomous weapon systems that could lead to unintended engagements.

Appendix H - Final Presentation Slideshow

Exploring the usefulness of Single Board Computer in computer lessons

Tsui Hok Sing Stanley

Introduction



- The Hong Kong Education Bureau (2015 & 2019) → Latest strategy on ITE & 2025 ICT Curriculum Renewal on NSS curriculum

→ Highly emphases on improving Computational Thinking (CT) by coding

Agenda

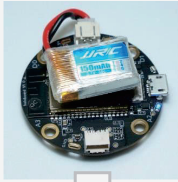
Research Aim & Questions	01
Literature Review	02
Research Methodology	03
Findings	04
Limitation	05
Conclusion	06

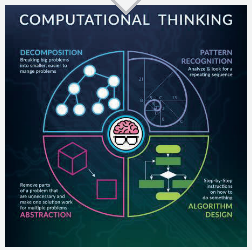
"Computational thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent"

—Jeannette Wing (2011, p.1)

Relationship between CT and SBC

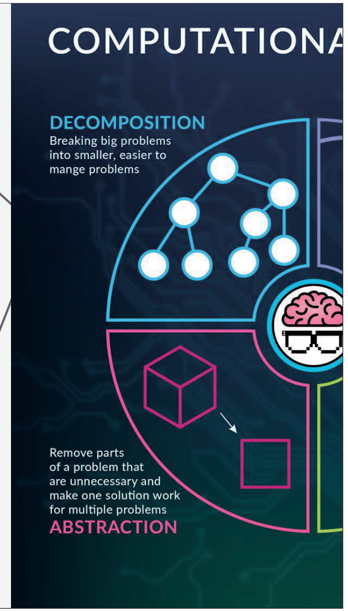
- new visual and tangible programming tools
  ➔ Single Board Computer
- Provoking CT by coding (Wong, Jiang & Kong, 2018)
- Irreplaceable tool for coding education reform





02

Literature Review



01

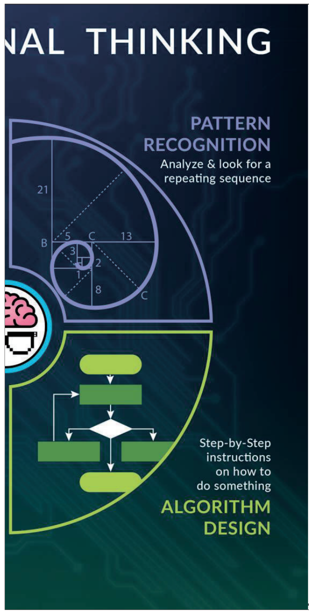
Research Aim & Questions

- Exploring the usefulness of Single Board Computer → Coding

RQ1 Is using SBC in the computer lesson able to foster the learning motivation towards coding?

RQ2 To what extend computational thinking skills of students able to enhance by using SBC in the computer lesson?

RQ3 Do students achieve a better learning experience by using SBC in the computer lesson?

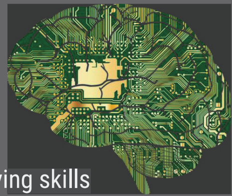


What is Computational Thinking?

Problem-solving process (CSTA ,2016)

1) Decomposition
2) Pattern recognition
3) Abstraction
4) Algorithms

Relationship between CT, coding & SBC

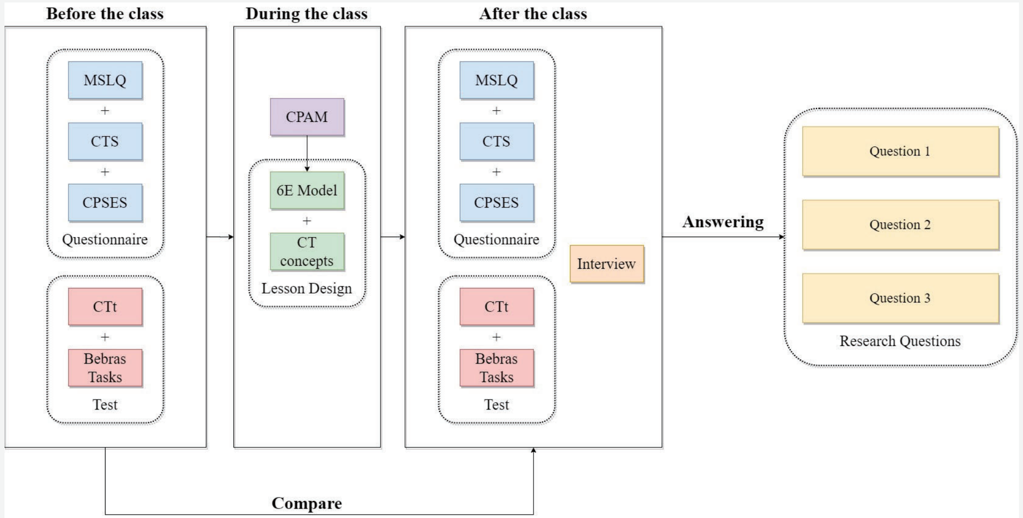


CT activities
→ enhance generic skills such as creativity and practical problem-solving skills
→ use CT as a driver of programming skills (Tedre, 2017)

85% of local schools consisted coding curriculum already
Core obstacles → abstract + lacking learning resources (Wong et al., 2015)

- Physical computing could foster development of students (Koorsse, Cilliers & Calitz, 2015)
- "Machine Learning" and "Deep Learning" in block-based → HaloCode (AI features implementation)

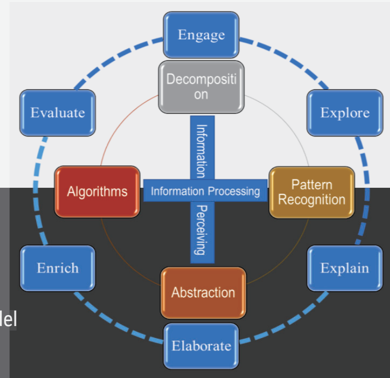
Research Methodology



03

Research Methodology

Lesson Design (Kolb, 2014; Tien & Yen, 2019)



6E Model

Learner-centered teaching model

Cultivate learner's inquiring abilities

(Barry, 2014)

CT

Formulating problems

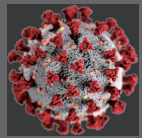
Logically organizing and analyzing data

Representing data

Algorithmic thinking

(Brennan & Resnick, 2012; CSTA, 2016; Kafai & Burke, 2013; Werner et al., 2012; Wing, 2011)

Outbreak of COVID-19



- Control Group and an Experimental Group → impossible
- Balance the risk of conducting face-to-face lessons
- trial two-day workshop for 4 hours a day in the EdUHK library

- 14 undergraduates (age 17-25 with various disciplines) from The Education University of Hong Kong were involved

Research Instrument - Questionnaire

1. Motivated Strategies for Learning Questionnaire (MSLQ) (Question 1-13)
2. Computational Thinking Scales (CTS) (Question 14-29)
3. Computer Programming Self -Efficacy Scale (CPSES) (Question 30-46)

Cronbach's α≥ 0.86; 0.95; 0.87 respectively

CTS and CPSES are evaluating non-cognitive and related soft skills such as self-confidence, creativity, teamwork.

MSLQ to evaluate learning motivation.

Creative Product Assessment Matrix (CPAM)

- Cronbach's α≥ 0.84
- To evaluate new product ideas during the development process
- For peer evaluation in the final presentation
- Assist 6E model (evaluate)

A translated version of CPAM (Hsiao et al., 2019)

指標	評分準則
原創性（Original）	作品是否自行構思創造而不是經由複製改編模仿衍生出來的作品
驚奇性（Surprise）	作品呈現出意想不到的資訊或效果
價值性（Valuable）	作品設計構想是否具有意義和價值
邏輯性（Logical）	作品設計構想是否合乎邏輯並且考慮到現實限制
有用性（Useful）	作品很大機會能夠在實際環境應用
可理解性（Understandable）	設計理念是否讓大眾清楚了解
基本品質（Organic）	作品是否能夠正常運作
精緻程度（Elegance）	作品在軟硬件兩大層面是否精簡易正確
良好手藝（Well-crafted）	作品在製作流程期間是否合標準及最終外觀是否美觀

MSLQ (Pintrich et al., 1991)

1）我對本科目的內容很有興趣。
2）我喜歡本科目的內容。
3）我會在電腦課堂中積極學習。
4）學會本科目的內容對我是重要的。
5）我認為我可以在本科目所學到的應用到別的課程中。

CTS (Korkmaz et al., 2017)

18）我知道如何應用人工智能來改善我們的生活水平。
19）借助運算思維，我可以更容易地專注於解難流程。
20）我知道如何道德地使用人工智能（AI）技術。
21）我認為訓練運算思維是個漫長的過程，需要長期投入才能有所成。
22）我不會因為看見複雜的使用介面而感到苦惱。

CPESE (Kurkul et al., 2017)

35）我盡量會使用最高效率的方法解決問題。
36）我能夠長期維護並改善自己的設計。
37）我有能力偵錯（debug）。
38）在解決問題的時候，我知道還有多久才能完工。
39）我會在網絡上分享我自己設計的程式。
40）我能夠把大問題分解成多個容易解決的小問題，之後逐一擊破。
41）我能夠理解流程圖。

5-point Likert scale

Research Instrument - Test

1. Computational Thinking Test (CTt) (Question 1-5)
2. Bebras Tasks (Question 6-10)

Cronbach's α≥ 0.793 and 0.93 respectively

CTt is one of the best diagnostic assessment tools to examine the CT level of the subject.

Bebras Tasks can evaluate how students make use of CT skills to accommodate "daily" challenges.

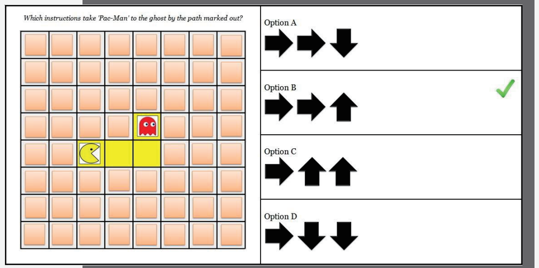
Research Instrument - Interview

Major focus (research question)	Interview Questions
1	1, 2, 7
2	6
3	2, 3, 4, 5

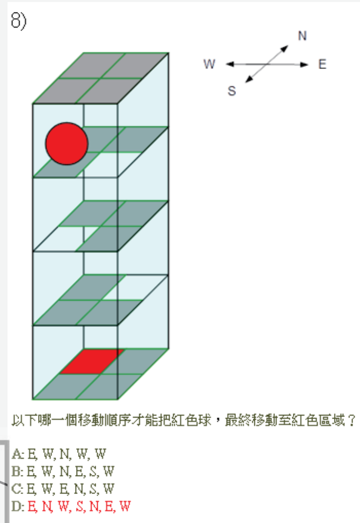
7 questions

- Before you use an SBC, do you like computer lessons? Why?
- Do you think that using an SBC have improved your motivation to learn AI or coding? Why?
- What is the most impressive feature about HaloCode (and sensors)? Why?
- What are the pros and cons of HaloCode (and sensors)? Why?
- What should be improved throughout the entire computer course? Why?
- Can you give three examples of how to improve the standard of living through the application of AI?
- Do you want to use SBC in computer courses in primary and secondary schools in the future? Why?

CTt



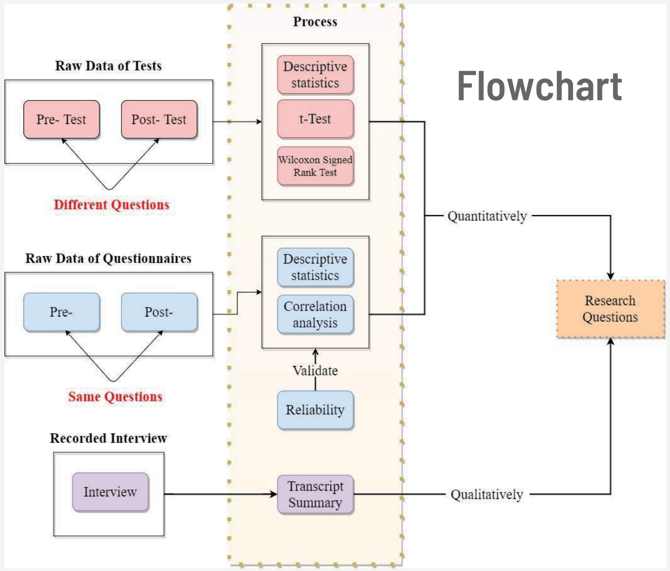
Bebras Tasks



04

Findings

Flowchart

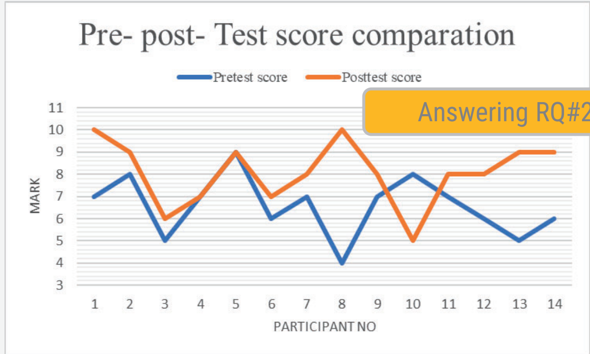


Findings in Tests

Paired samples t-Test of pre- post- test

Paired Samples Test

	t	df	Std. Error Mean	Sig. (2-tailed)	Mean Difference	95% Confidence Interval Lower	95% Confidence Interval Upper
Pre – Post - test	2.669	13	.562	.019	1.500	.286	2.714



Answering RQ#2

Subjects were chosen from a normally distributed population

Paired Samples Test (2 tailed)

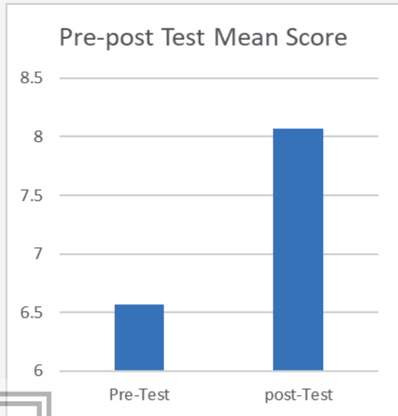
- *p*-value = 0.019
- Significance level = 0.05

p-value < significance level → The result is significant

Findings in Tests

Mean
Pre-test: 6.57 /10
Post-test: 8.07 /10

Difference
Absolute value: +1.5
% change: +22.8%



Answering RQ#2

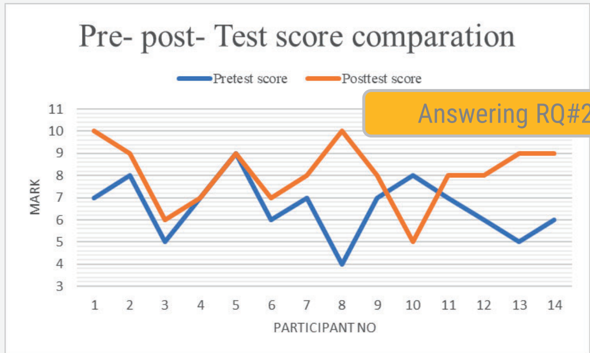
Findings in Tests

2-tailed Wilcoxon Signed-Rank Test

Test Statistics[a]

	Pretest score - Posttest score
Z	-2.390[b]
Asymp. Sig. (2-tailed)	.017

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.



Answering RQ#2

2-tailed Wilcoxon Signed-Rank Test

- *p*-value = 0.017
- Significance level = 0.05

p-value < significance level → The result is significant

Findings in Questionnaire

Reliability of the questionnaire		
Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.931	.926	46

Reliability Test

- Cronbach's Alpha Based on Standardized Items = 0.926

Cronbach's Alpha > 0.9 → Excellent reliability

Findings in Questionnaire (pre- and post-)

"Major" Correlations

		Major	Coding Experience	Q2	Q19	Q26	Q27	C1	C2
Major	Pearson Correlation	1	.638*	.611*	.565*	.611*	.720**	.534*	.667**
	Sig. (2-tailed)		0.014	0.020	0.035	0.020	0.004	0.049	0.009
	N	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

"Science Result" Correlations

		Science Result	Q6	Q20	Pretest score
Science Result	Pearson Correlation	1	-.676**	-.601*	.784**
	Sig. (2-tailed)		0.008	0.023	0.001
	N	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

"IT Result" Correlations

		IT Result	Coding Experience	IT Interested	Q8	Q9	Q11	Q12	Q13	Q14	Q15	Q16	Q19	Q23	Q27	Q32	Q33	Q42	Q44	C2
IT Result	Pearson Correlation	1	.745**	.645*	.664**	.606*	.573*	.536*	.659*	.534*	.601*	.723**	.603*	.664**	.537*	.551*	.609*	.681**	.551*	.696**
	Sig. (2-tailed)		0.002	0.013	0.010	0.022	0.032	0.048	0.010	0.049	0.023	0.003	0.022	0.010	0.048	0.041	0.021	0.007	0.041	0.006
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

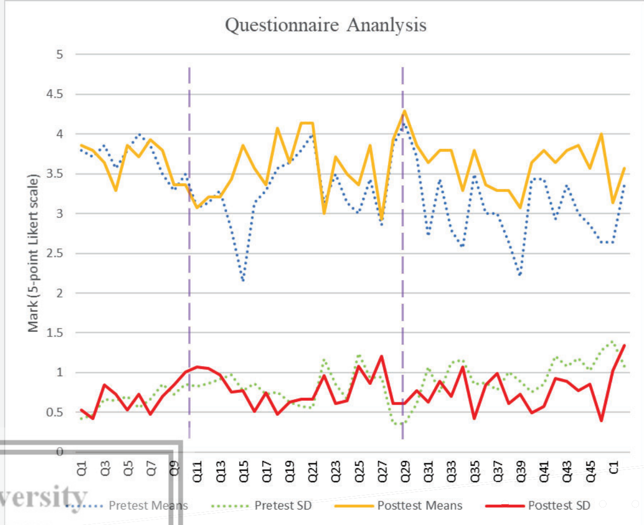
**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Excellent chance for me to observe their improvement after the intervention

Findings in Questionnaire

Questions	Major focus
1-13 (MSLQ)	Evaluating learning motivation among university undergraduate in the computer lesson
14-29 (CTS) 30-46 (CPSES)	Measuring the perceptions and attitudes towards CT and digital literacy



Answering RQ#1, 2, 3

Findings in Questionnaire (pre- and post-)

Q8-Q12 Correlations

		Q8	Q9	Q10	Q11	Q12	IT Result	Q13	Q16	Q19	Q23	Q26	Q32	Q34	Q44	Q45
Q8	Pearson Correlation	1	.867**	.789**	.706**	.729**	.664**	.591*	.625*	.639*	.579*	.672**	.714**	.622*	.535*	.613*
	Sig. (2-tailed)		0.000	0.001	0.005	0.003	0.010	0.026	0.017	0.014	0.030	0.009	0.004	0.018	0.049	0.020
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

Q13 Correlations

		Q13	IT Result	Q11	Q12	Q17	Q22	Q23	Q26	Q31	Q32	Q33	Q34	Q42	Q44	Q45
Q13	Pearson Correlation	1	.659*	.682**	.723**	.563*	.824**	.886**	.564*	.720**	.589*	.665**	.706**	.578*	.572*	.702**
	Sig. (2-tailed)		0.010	0.007	0.003	0.036	0.000	0.000	0.036	0.004	0.027	0.010	0.005	0.030	0.032	0.005
	N	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

If learning motivation on coding ↑ = CT skills ↑

Answering RQ#1, 2

Findings in Questionnaire (pre- and post-)

Q32: I can clearly explain my way of problem-solving and its included steps.

Q32 Correlations

		Q32	IT Result	Q4	Q8	Q9	Q11	Q12	Q13	Q19	Q23	Q33	Q46	Present Score
Q32	Pearson Correlation	1	.551*	.562*	.714**	.600*	.561*	.605*	.589*	.666**	.595*	.570*	.649*	.539*
	Sig. (2-tailed)		0.041	0.036	0.004	0.023	0.037	0.022	0.027	0.009	0.025	0.033	0.012	0.047
	N	14	14	14	14	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

"Present Score" (carried out at the end of the course)

- Peer assessed by CPAM

Answering RQ#2

Higher CT skills should echo better presentation capability

Findings in Questionnaire (difference between pre and post)

Q26: It would great for me to work for Big Techs in my future career.

Q26 Correlations

		Q26	Q1	Q2	Q12	Q13	Q27	Q32	Q34	C2
Q26	Pearson Correlation	1	.618*	.537*	.544*	.587*	.727**	.755**	.713**	.672**
	Sig. (2-tailed)		0.018	0.048	0.044	0.027	0.003	0.002	0.004	0.008
	N	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the

**. Correlation is significant at th

Q27: I am sure I can master the skills or techniques taught in this program.

Q27 Correlations

		Q27	Major	IT Result	Q1	Q2	Q3	Q13	Q26	Q32	Q34	C2
Q27	Pearson Correlation	1	.635*	.547*	.699**	.716**	.654*	.537*	.727**	.770**	.733**	.882**
	Sig. (2-tailed)		0.015	0.043	0.005	0.004	0.011	0.048	0.003	0.001	0.003	0.000
	N	14	14	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Answering RQ#1, 3

- They were happy to use SBC in a coding class, even foster them to code more in the future

Findings in Questionnaire (difference between pre and post)

Q1 Correlations

		Q1	Q2	Q3	Q14	Q22	Q23	Q26	Q27	Q32	Q34	C2
Q1	Pearson Correlation	1	.869**	.733**	.544*	.749**	.572*	.618*	.699**	.737**	.750**	.766**
	Sig. (2-tailed)		0.000	0.003	0.044	0.002	0.033	0.018	0.005	0.003	0.002	0.001
	N	14	14	14	14	14	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Q1: I am very interested in the content of this program.

Q10: I am sure I can master the skills or techniques taught in this program.

Q10 Correlations

		Q10	IT Result	Q2	Q8	Q11	Q12	Q13	Q14	Q22	Q34	Q35	Q45	Present Score
Q10	Pearson Correlation	1	.586*	.550*	.662**	.758**	.721**	.777**	.591*	.635*	.754**	.550*	.640*	.624*
	Sig. (2-tailed)		0.028	0.041	0.010	0.002	0.004	0.001	0.026	0.015	0.002	0.041	0.014	0.017
	N	14	14	14	14	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Answering RQ#1, 2, 3

- SBC is useful to foster learning motivation due to the gentle learning curve

Interview Findings

Major focus (research question)	Interview Questions
1	1, 2, 7
2	6
3	2, 3, 4, 5

Interview Question List (Translated)

1	Before you use an SBC, do you like computer lessons? Why?
2	Do you think that using an SBC have improved your motivation to learn AI or coding? Why?
3	What is the most impressive feature about HaloCode (and sensors)? Why?
4	What are the pros and cons of HaloCode (and sensors)? Why?
5	What should be improved throughout the entire computer course? Why?
6	Can you give three examples of how to improve the standard of living through the application of AI?
7	Do you want to use SBC in computer courses in primary and secondary schools in the future? Why?

Summary of Interview Findings

Answering RQ#1

Q1 → love computer lesson → more creative and make something freely
- great to find a good medium to foster their learning motivation towards coding

Q2 → SBC is enjoyable → actualize their thoughts by some AI API host by Google
- prefer to interact with a material, rather than only seeing the output on the screen

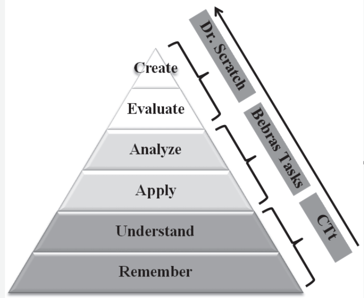
Q7 → positive and feasible solution to integrate SBC into local schools
- pupils should like this learning medium more

Limitations

Insufficient lesson hours

Limited sample size may result in less accurate statistics

Insufficient questions for the pre- post- test



(Román-González et al., 2019)

Summary of Interview Findings

Answering RQ#3

Q3 → Google API services is the most impressive
- benefited them to build their prototype

Q4
Pros: transfer the virtual feedback to an actual environment in an interactive way
Cons: did not support IEEE 802.1x and WIFI 5 or above

Q5 → failed in the connection
- provide more guidelines for reference

Conclusion

1. **Foster a noticeable amount of learning motivation towards coding**
2. **Positive contributions on enhancing CT skills, form 13% to near 23% + reduced learning diversity between learners**
3. **Enjoy using SBC in computer lessons than the traditional one**

- **SBC is really useful in computer lesson!**

↑ learning motivation + ↑ CT skills + ↑ coding learning experience

References

Barry, N. (2014). The ITEEA 6E Learning by Design™ Model. The Technology and Engi-neering Teacher, 73(6), 14-19.

Brennan, K., & Resnick, M. (2012). New Frameworks for Studying and Assessing the De-velopment of Computational Thinking. Proceedings of the 2012 Annual Meeting of the American Educational Research Association. Vancouver: American Educational Re-search Association.

Computer Science Teachers Association. (2016). Operational definition of computational thinking.

Education Bureau. (2015). Report on the Fourth Strategy on Information Technology in Edu-cation. Hong Kong.

Kafai, Y. B., & Burke, Q. (2013). The social turn in K-12 programming: moving from com-putational thinking to computational participation Proceeding of the 44th ACM technical symposium on Computer science education, (pp. 603-608). Denver, Colorado, USA: ACM. doi:10.1145/2445196.2445373.

Koorsse, M., Cilliers, C., & Calitz, A. (2015). Programming assistance tools to support the learning of IT programming in south African secondary schools. Computers & Educa-tion, 82(2), 162–178.

Korkmaz, Ö., Çakir, R., & Özden, M. Y. (2017). Avalidity and reliability study of the com-putational thinking scales (CTS). Computers in Human Behavior. https://doi.org/10.1016/j.chb.2017.01.005.

Kukul, V., Gökçearslan, Ş., & Günbatar, M. S. (2017). Computer Programming Self-efficacy Scale (CPSES) for Secondary School Students: Development, Validation and Reliability. Educational Technology Theory and Practice, 7(1), 158-179. doi:10.17943/etku.288493.

Pintrich, P. R., Smith, D. A. F., Garcia, T., & McKeachie, W. J. (1991). A manual for the use of the Motivated Strategies for Learning Questionnaire (Mslq). Ann Arbor, MI: Nation-al Center for Research to Improve Postsecondary Teaching and Learning.

Tedre, M. (2017). Many paths to computational thinking. In Paper presented at the TACCLE 3 final conference, Brussels, Belgium.

Werner, L., Denner, J., Campe, S., & Kawamoto, D. C. (2012). The fairy performance as-sessment: Measuring computational thinking in middle school. In Proceedings of the 43rd ACM technical symposium on computer science education, SIGCSE '12 (pp. 215-220). New York, NY, USA: ACM.

Wing, J. (2011). Research notebook: Computational thinking—What and why. The Link Magazine, 20-23.

Wong, G. K., Cheung, H. Y., Ching, E. C., & Huen, J. M. (2015). School perceptions of cod-ing education in K-12: A large scale quantitative study to inform innovative practices. Proceedings of the 2015 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE) (pp. 5-10). IEEE. doi:10.1109/TALE.2015.7386007.

Q&A