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Development and Evaluation of an Internet of Things Project for Preservice Elementary School Teachers

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Abstract: Programming education is gaining more attention in elementary schools, especially through the use of visual programming tools and development boards. However, the elementary school teacher education in Taiwan allows only limited time periods for training in visual programming and the use of development boards. Development boards are ideal for creating internet of things (IoT) projects, and project-based learning (PBL) is an effective teaching strategy in programming education to promote active learning. Therefore, to sustainably cultivate 21st-century teachers, this study developed an IoT PBL activity for preservice elementary school teachers in Taiwan, so as to improve their attitude toward programming and to enhance their content knowledge of programming teaching, including in computational thinking concepts and knowledge concerning the micro:bit and IoT. This project aimed to engage preservice elementary school teachers in using the micro:bit and electronic modules to create cardboard games with IoT features. A preliminary evaluation was conducted within a teacher education course to verify the project's feasibility. Consequently, the preservice elementary school teachers participating in this project could develop various IoT cardboard games through teamwork. Their scores on the assessments of computational thinking concepts, development board knowledge, and attitude toward programming showed significant improvement after the project activity. They also expressed highly positive feedback on the project. These findings verify that the proposed PBL activity could be feasible for elementary teacher education.

Keywords: internet of things education; project-based learning; teacher education; computational thinking; technology education; programming education; development boards

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1. Introduction

Computational thinking (CT) refers to an individual's thinking while using computers to analyze and solve problems [1]. CT, as proposed by [2], is not only essential for computer engineers but also important for children. It is recognized as an essential skill for people in the 21st century. Many countries have included CT training as a key objective for K-12 education [3,4]. Programming, being regarded as the most direct and effective means of CT learning [5], has thus gained increasing attention in many countries and has been incorporated into their curricula for K-12 students at the elementary school (ES) level or higher [6].

Visual programming software is a suitable tool for teaching programming to ES students because it mitigates the need to learn complex textual syntax [7,8]. It enables a learner to create a program by simply dragging and stacking graphical objects representing program instructions [9]. A common practice in programming education is to learn programming by designing games using visual programming software such as Scratch [10]. Moreover, the price of microcontroller development boards (e.g., Arduino) has recently decreased. In 2016, the United Kingdom adopted the micro:bit in its mandatory programming curriculum for ES [11]; these developments have contributed to the rise of visual programming software, such as MakeCode(v5.0), as tools that help teach ES students to control the micro:bit, enabling them to develop creative interactive devices in class.

Nevertheless, a lack of teacher training can challenge the implementation of ES programming education [12]. For example, in Taiwan's latest K-12 curriculum update, the government has included CT as a core objective of technology education and recommended the learning of visual programming languages in grades 3 to 4 and development boards in grades 5 to 6 [13]. To prepare for the new curriculum, ES teachers must receive preservice training to teach visual programming and development board control. However, Taiwan's current ES educational system leaves limited time for such training, as ES teachers must receive training on various subjects. The ES curriculum reform thus poses a significant challenge to Taiwan's ES teacher education.

To address this challenge and enhance preservice ES teachers' programming content knowledge, this study developed a two-credit course for Taiwan's ES teacher education. MakeCode and micro:bit were employed in the course to ensure that preservice teachers' skills conform to the latest trends in programming education. The micro:bit development board has several in-built components—including light-emitting diodes (LEDs), buttons, and an accelerometer—and can be connected to various electronic components [11]. Thus, the micro:bit can be used by students in various projects, from the development of simple pedometers to the remote control of toy cars [14]. Furthermore, project-based learning is widely used in programming-related courses and is a meaningful teaching method that encourages active student learning [15,16]. This study adopted PBL as the teaching method for this training course.

Following the recent advancement of the internet of things (IoT), various new development boards incorporating an internet connection, including ESP32, have been introduced to address the needs of IoT products and projects [17]. The micro:bit can also be used to develop IoT products if connected to a wi-fi module. The micro:bit is not yet commonly used for IoT projects in ES courses. However, in response to the IoT era, the present study developed PBL activities in which preservice ES teachers developed cardboard games with IoT capabilities in groups to equip them with the necessary content knowledge for teaching future ES programming courses using micro:bit.

Based on the above, to address the Taiwanese ES curriculum's increasing emphasis on programming education, this study designed an IoT project for sustainably preparing preservice ES teachers so as to improve their attitude toward programming and enhance their content knowledge on teaching programming, including knowledge regarding CT and micro:bit. To examine the effectiveness of this experimental course, preservice ES teachers were recruited as participants, and their performance and learning results were preliminary evaluated for future improvement and course promotion. This study addressed the following questions:

- How to use PBL to guide students in completing IoT projects?
- Can PBL strategies help preservice ES teachers complete an IoT project?
- Can the proposed IoT project activity improve preservice ES teachers' CT and knowledge of development boards?
- Can the proposed IoT project activity improve preservice ES teachers' attitudes toward programming?
- Can preservice ES teachers have positive feelings about their participation in this IoT project activity?

2. Literature Review

2.1. Programming Education

Programming is widely considered to be effective for students seeking to develop CT skills [10]. Countries such as the United Kingdom, Finland, Japan, and South Korea have made programming education compulsory in their ES curricula [6]. At the ES level, visual programming languages have become the most common means of programming education because they mitigate the need to learn complex text-based programming languages [8]. Scratch, for example, which is a popular visual programming software tool, presents programming commands as graphical objects. It allows users to construct a program by simply dragging and stacking the objects; such a programming language is known as block-based programming due to its resemblance to the process of building blocks [9]. Another advantage of Scratch is its simple procedure for developing computer games. Therefore, using Scratch to develop computer games has become a common strategy for teaching programming [10]. The benefits of Scratch in students' CT development have also been verified extensively in research [18,19].

An alternative strategy to teaching programming with visual programming software is to connect this software to a microcontroller development board. This strategy originated from the United Kingdom's adoption of the micro:bit development board in its ES programming curriculum in 2016 [11], with another block-based programming software (MakeCode) employed for visual programming. The micro:bit is a development board that is about the size of a credit card and has various built-in components, including light, movement, magnetic, and button sensors. It can enable students to learn about programming and sensors while they make their own physical creations. For example, the micro:bit has been used to design a watch, a cardboard robot through connection to an external servomotor, a remote-control car [14], shadow art creations with cut-out figures [20], and headband- and plushie-based wearables [21]. Researchers have also demonstrated the positive effect of the micro:bit on students' CT [12,22]. Therefore, this study selected the visual programming software MakeCode and the micro:bit development board as the programming skills that preservice ES teachers in Taiwan must learn.

2.2. IoT Education

The term IoT was coined by Kevin Ashton in 1999 [23]. IoT equipment is defined as anything that can collect information and send it to the internet, be programmed, contingently respond to various situations, receive information through the internet, and communicate with other IoT devices [24]. IoT can extend the internet into the real-world environment and improve daily life by enabling the connection of everyday items to the virtual internet environment; it can collect information and send it to the internet while allowing the remote control of devices [25]. The advent of the IoT era has prompted the education sector to emphasize IoT skills training. Abichandani et al. [26] built upon the IoT four-layer model developed by [27] and proposed that IoT courses should be designed based on four dimensions: sensing, network, service, and interface layers.

Abichandani et al. [26] found that the sensing layer of an IoT architecture is the most crucial component relating to IoT education and should be the critical focus when introducing K-12 students to the IoT concept. Sensing-layer education may teach students to integrate low-cost development boards—such as the Arduino, the micro:bit, and Raspberry Pi—with low-cost electronic components, including temperature, humidity, movement, and distance sensors. Education regarding IoT network layers may focus on introducing students to general wired or wireless communication and the message queue telemetry transport (MQTT) communication protocol commonly used in IoT devices. Education regarding the IoT service layer architecture centers on teaching students how cloud services, such as Google Cloud, can store and access IoT data, notify users, and send emails or other messages. The IoT's interface layer architecture can enable users to interact with and control IoT services. Therefore, education regarding this layer should focus on learning to design user interfaces and message displays on IoT devices. To ensure that preservice ES teachers can acquire knowledge on all four dimensions of the IoT architecture, the present study used the four-layer IoT model to develop the IoT project activity. In this project, preservice ES teachers were asked to use the micro:bit to develop IoT-based cardboard games. Education regarding the four-layer components was implemented as follows. Regarding the sensing layer, preservice ES teachers learned about the micro:bit development board and various sensors. For the network layer, preservice ES teachers used the MQTT protocol to send messages to the cardboard games they had developed. Regarding the service layer, preservice teachers learned how game scores could be stored on the ThingSpeak cloud service. For the interface layer, they used an MQTT-based interface to control their cardboard games.

Abichandani et al. [26] reviewed 60 IoT education articles and found that most IoT practices involve students learning actively and solving real-world problems with IoT technology. They also found that PBL is commonly employed in college IoT education. For example, Kortuem et al. [28] incorporated visual programming software and development boards into an open university's computer science introductory course to teach students about IoT. They reported that, at the end of the course, 75% of the students could develop projects on various themes, including music and online weather stations, and that many students with no previous programming experience had successfully acquired programming skills. Mäenpää et al. [29] employed the PBL strategy and asked students to develop IoT devices for a greenhouse. Using low-cost Arduino development boards, the students successfully developed IoT devices capable of monitoring the greenhouse's temperature, humidity, and airflow, and several students described this process as an eye-opening learning experience. Nonetheless, few researchers have examined IoT education for teacher education courses. Thus, this study employed IoT PBL activity in a teacher education course to improve preservice ES teachers' IoT knowledge and skills.

2.3. Project-Based Learning

PBL is based on constructivist theory, aiming for students to actively construct knowledge through learning-by-doing [30]. PBL typically provides students with a real-world task to solve, usually involving collaboration, and results in the creation of an artefact upon completion [31]. Thus, PBL offers opportunities for students to actively construct knowledge or develop skills to solve real-world tasks, or to understand how the knowledge they have learned can be applied in the real world [32,33]. PBL is now widely recognized as a learner-centered, meaningful teaching method that fosters active and deep learning, as well as collaborative planning and hands-on engagement [15,34]. Recently, PBL has gained increasing importance in K-12 education to develop the skills needed for the 21st century [35].

Chiu [16] found that PBL has been widely applied in computer science courses, such as tasks involving programming for robotics design, compiler design, big data mining, and game design. Students not only gain practical programming skills but also have the opportunity to collaborate on project management. Chiu also found that applying PBL in computer science courses yields positive outcomes, such as improving students' motivation and skill acquisition. PBL is often associated with CT, as programming is an effective method for enhancing students' CT skills. For example, Yang et al. [32] suggested that PBL is one of the most commonly used teaching methods to promote CT skills. Hsu et al. [36] found that, among 13 teaching strategies used to teach CT skills, PBL is one of the most popular. As discussed above, PBL is a meaningful teaching strategy that promotes active learning and is well-suited for teaching programming and CT skills. This study thus adopted PBL as the teaching strategy to develop programming and CT skills for preservice ES teachers.

Many studies have proposed methods for implementing PBL. For example, Duck [37] outlined a five-stage process for implementing PBL: (1) project launch: teachers and students establish the goals, format, and audience for the project; (2) reading and research: students gather information and build necessary knowledge for the project; (3) writing and research: students plan and design their project; (4) revision and editing: students receive feedback on their initial project results from teachers, peers, or experts and make revisions; (5) presentation and celebration: students present their final project results to a specific audience and celebrate their achievements. Hugerat [38] proposed six stages for implementing PBL in science learning: (1) pre-preparation stage: the teacher shows a video, experiment, or relevant story to engage students' motivation; (2) preparation for the project stage: the teacher explains the project's goals and tasks to students and assigns them tasks to complete the project; (3) planning for the project: the teacher divides students into groups, each group plans the resources, skills, and materials needed for the project; (4) project implementation: students conduct experiments and record their research observations and findings; (5) post-project stage: each group presents their project results to the class; (6) assessment and evaluation: the teacher and students discuss and evaluate the students' completed projects. Jalinus et al. [34] proposed three main stages for implementing PBL in vocational education: (1) skill competency debriefing: students are motivated to tackle real-world tasks and provided with skill training to gain a basic understanding of the instructional materials and learning content; (2) project work: students are assigned a project task related to real-world issues and learning content, and they develop and execute the project; (3) evaluation: students present their project outcomes and initiate discussion with the teacher and peers. In this study, the PBL activities are related to vocational education and require preservice ES teachers to undergo skill training to understand basic knowledge of visual programming and development boards before carrying out the project. Hence, this study adopted the approach of Jalinus et al. [34] and divided the PBL activities into three main stages.

3. Methods

To determine the feasibility of the proposed IoT project, this study offered the proposed activity to students enrolled in an ES teacher education course. The study employed a one-group pre-test-post-test quasi-experimental design for the outcome assessment. Specifically, a group of participants was asked to complete a pre-test and post-test before and after receiving the activity, respectively, to determine whether this activity improved their CT, knowledge regarding development boards, and attitude toward programming. This study also examined how they felt about the activity. The following subsections detail the IoT project, participants, experimental procedures, and research instruments.

3.1. The IoT Project

This study designed a PBL activity based on a two-credit elective course for preservice ES teachers enrolled in the teacher education program of a Taiwanese university. The course was offered in the summer of 2021. The schedule of the designed activity primarily followed the three-step PBL model proposed by Jalinus et al. [34]: skill competency debriefing, project work, and evaluation. The skill competency debriefing stage involved introducing the preservice ES teacher participants to IoT and providing an overview of the project objectives while teaching them how to use development boards, electronic components, and related materials for their project. For example, participants were taught how to use the MakeCode visual programming language to control the micro:bit's built-in LEDs, buttons, and light sensors and how to manage external liquid-crystal displays (LCDs), ultrasonic devices, servomotors, buttons, infrared obstacle avoidance sensors, and wi-fi modules. They also learned about the MQTT protocol for sending IoT messages and the ThingSpeak cloud database. The activity stage lasted eight weeks and aimed to teach them the skills necessary to engage in an IoT project. In the next stage regarding project work, the participants worked in groups on IoT projects, following a set of requirements. Specifically, they were required to develop a cardboard game with IoT capabilities; the game must enable players to transmit their username through the internet from their phone or computer and must upload a player's username and game score to the ThingSpeak cloud database when they finish playing the game. This activity stage lasted seven weeks. The participants were first guided in collecting data and proposing project ideas before they began working on their projects. In the final evaluation stage, which lasted one week, each group gave a project presentation. Their peers and the course lecturer then provided feedback about how to improve the project.

In the PBL activity, each group was provided with the equipment materials, as shown in Figure 1. Groups were asked to employ additional materials, such as cardboard, for designing and constructing their game. Each group decided on the type of cardboard game device they want to develop, and used Dupont wires to connect electronic components, such as ultrasonic sensors, servo motors, IR obstacle detection sensors, or LCDs, to the micro:bit development board, depending on the functions of their gaming device. They then used MakeCode to write programs and upload them to the micro:bit to receive distance data from ultrasonic sensors, detect objects with IR obstacle detection sensors, control the servo motor's operation, or display messages on the LCD. Additionally, the micro:bit can be connected to a wi-fi module, allowing students to use MakeCode to upload players' game scores to the ThingSpeak cloud database or receive messages from internet-connected devices, such as smartphones.

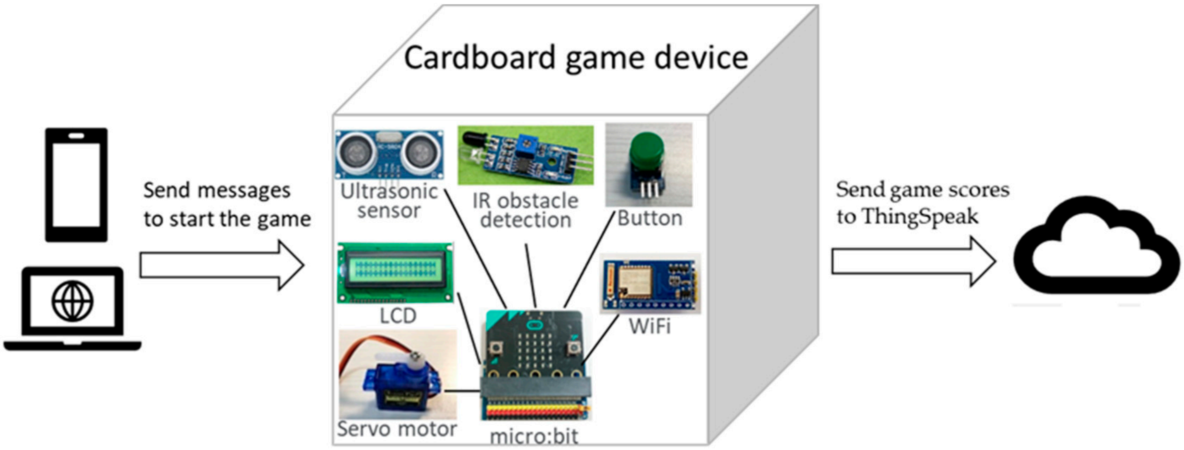

Figure 1. The equipment provided for the PBL activity and the illustration of an IoT cardboard game.

3.2. Participants

This study employed purposive sampling to select students enrolled in an introduction to technology course within an elementary school teacher education program at a university in Taiwan as the research participants. In most Taiwanese teacher education curricula, Mandarin Chinese and mathematics are the only compulsory specialized education courses; the remaining courses are optional. This resulted in only 15 students enrolling in the technology-related elective course that was the focus of this study. Of the 15 preservice ES teachers, 11 were women, and 4 were men. The participants were in their third year of university or above, and some were graduate students. Eleven had some experience with Scratch, but the other four had no experience at all. None of the participants had any experience with MakeCode or development boards before enrolling in this course. They were divided into five groups of three for the project work.

3.3. Research Procedure

The experimental course lasted 17 weeks, with two 50 min weekly sessions. During the first week, the participants were asked to complete a pre-test comprising a CT assessment, a development board knowledge assessment, and a programming attitude scale. The remainder of the course proceeded with eight weeks of skill competency debriefing activities, seven weeks of project work activities, and one week of evaluation, plus a post-test and a survey regarding the participants' perception of the project.

3.4. Research Instruments

3.4.1. CT Assessment

To investigate the project effectiveness in improving the participants' CT, this study developed a 10-question assessment on MakeCode programming, covering seven CT concepts proposed by Brennan and Resnick [39]: sequences, loops, events, parallelism, conditionals, operators, and data. The first seven questions correspond to a CT concept and the remaining three cover multiple concepts. Each question has a highest possible score of 10 points, totaling 100 for the full score. Figure 2 displays the data-related question from the

CT assessment. Figure 3 presents a question that combines the data, operators, and loops concepts under CT. This assessment was reviewed by an expert in programming education to confirm the appropriateness of the questions, and the KR-20 reliability coefficient is 0.66.

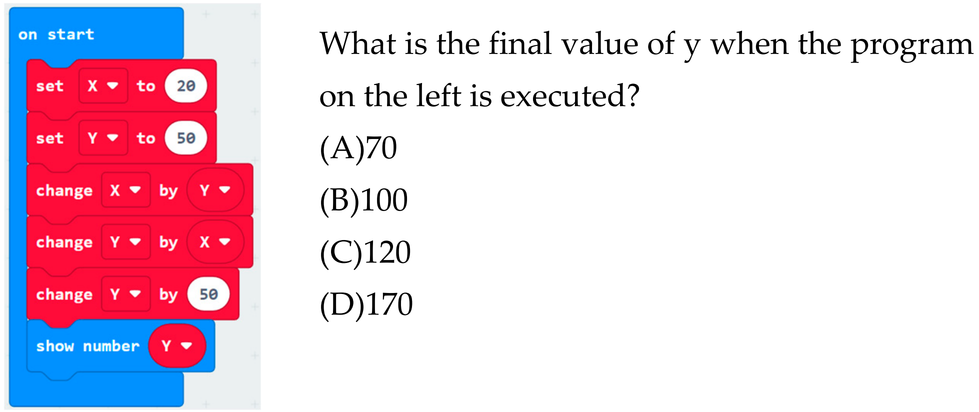

Figure 2. Assessment question about the data concept.

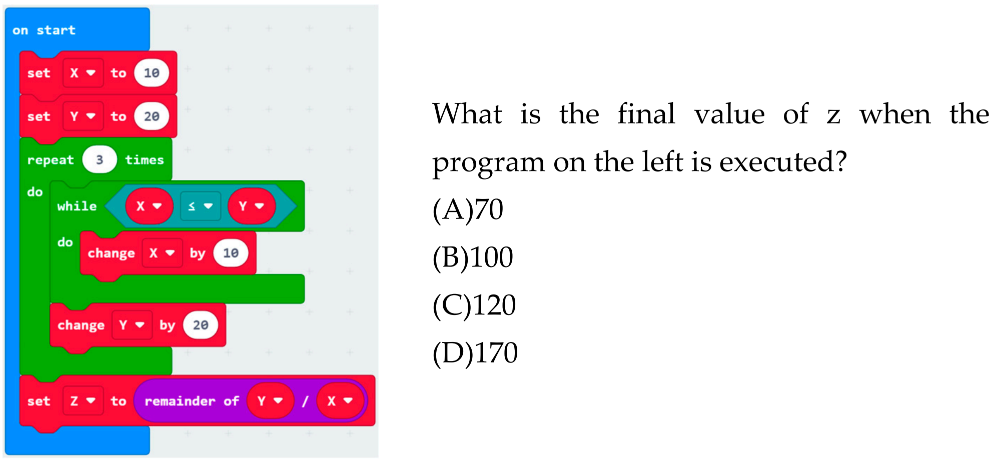

Figure 3. Assessment question combining the concepts of data, operators, and loops.

3.4.2. Development Board Knowledge Assessment

This study developed an assessment to explore the effect of the proposed IoT project on the participants' knowledge of development boards, which was implemented in the pre-test and post-test. The assessment is composed of 20 multiple-choice questions that cover knowledge related to the proposed IoT project; the full score is 100. Of the 20 questions, 11 pertain to knowledge about micro:bit; for example, "Which one of the following is not a sensor built into the micro:bit?" Four questions concern knowledge of external electronic components; for example, "What is the maximum number of alphanumeric lines that an external LCD1602 module can display?" The other five questions are related to IoT knowledge; for example, "MQTT is a common protocol in IoT devices. What is the common thing to which all IoT devices are subscribed to facilitate MQTT-based communication?" The assessment was reviewed by an expert in IoT education to confirm the appropriateness of the questions, and the KR-20 reliability coefficient is 0.65.

3.4.3. Computer Programming Attitude Scale

This study adapted the computer programming attitude scale developed by Tsai et al. [40] to evaluate the participants' attitudes toward programming. The participants completed this scale before and after the IoT project. The scale is composed of four subscales—confidence, preference, usefulness, and gender—and each subscale contains four items rated on a 5-point Likert scale ranging from 1 (strongly disagree) to

5 (strongly agree), totaling 16 items. An example item from the confidence subscale is, "I am confident that I can become good at programming." An example of a preference subscale question is, "Learning programming is fun." An example from the usefulness subscale is, "I believe that everyone should have some understanding of programming." An example from the gender subscale is, "Programming is appropriate for both boys and girls." The attitude scale has a Cronbach's α of 0.89.

3.4.4. Participation Perception Scale

An 11-item scale was modified from Tsai et al. [40] to investigate the participants' perception of the proposed IoT project. The items are rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The questions address the participants' perception of learning and participation in the project (see Table 5). The scale has a Cronbach's α of 0.86.

4. Results

4.1. Project Outcome

Table 1 displays photographs and explanations of the IoT cardboard games that the preservice ES teacher developed using the micro:bit and external electronic modules, including wi-fi modules. All games could upload usernames and game scores to a cloud database. Users could start a game by sending their username from a computer or phone through an internet connection. The preservice ES teachers, regardless of whether they had experience with development boards or IoT knowledge, could develop IoT devices through teamwork after the PBL activity. This result confirms that the IoT project activity is feasible.

Table 1. The project results.

Group	Game Machine	Description
1		The game was inspired by a basketball arcade game. A player starts by using a phone or computer to send their username to the micro:bit through MQTT. Once the micro:bit has received their username, it displays a prompt on an LCD instructing the player to push three buttons on the device to start the game. The player shoots a ball in any of the three holes to score 1 (closest) to 3 (farthest) points—the more points a player scores, the higher their ranking. An infrared sensor is installed at each hole to determine whether a ball enters the hole. The final score is uploaded through wi-fi to a ThingSpeak cloud database.
2		The game was inspired by pinball and is played with marbles. A player starts by using a phone or computer to send their username to the micro:bit through MQTT. Once the micro:bit has received their username, it displays a prompt on an LCD and concurrently sets off a buzzer to instruct the player to start the game. The player uses a plunger to shoot a marble and then catches the marble by using a small box before it falls to the bottom. The player who catches the most marbles within 60 s wins. An infrared sensor is installed in the box, detecting whether a marble passes through. The player's final score is uploaded through wi-fi to a ThingSpeak cloud database.

Table 1. *Cont.*

Group	Game Machine	Description
3		The game was inspired by soccer. A player uses a phone or computer to send their username to the micro:bit through MQTT. Once the micro:bit has received its username, it sets off a buzzer to instruct the players to start the game. Each game is played with two players, one of whom is the shooter and the other the goalkeeper. The shooter is awarded 1 point when they successfully shoot the table tennis ball into the hole inside the goal. In each game, the shooter has 5 balls to shoot within 25 s. An infrared sensor is installed at the hole to detect whether a ball enters the hole. The final score is uploaded through wi-fi to a ThingSpeak cloud database.
4		The game was inspired by pinball. A player starts by using a phone or computer to send their username to the micro:bit through MQTT. Once the micro:bit has received their username, it displays a prompt on an LCD instructing the player to push button A to start the game. The player drops a marble from the top and uses the wheel below to maneuver the marble into the "Moon" bottle. A player is awarded 1 point if the marble falls into the "Moon" bottle, but 1 point is deducted from the total score if it falls into the "Earth" bottle instead. The player who achieves the highest score within the shortest time, with the three marbles provided in each game, wins. Infrared sensors are installed above the openings of the "Moon" and "Earth" bottles to detect whether the marble enters the respective bottle. The final score is uploaded through wi-fi to a ThingSpeak cloud database.
5		The game is a two-player soccer game. Players start by using a phone or computer to send their usernames to the micro:bit through MQTT. Once the micro:bit has received their usernames, it displays a prompt on an LCD instructing the players to push a button to start the game. Each player pushes the ball with a doll to get the ball into the hole on the opposite side. A player is awarded 1 point when they hit the ball into the other's hole. The first player to be awarded 3 points wins. An infrared sensor is installed at each hole to detect whether a ball enters the hole. The final score is uploaded through wi-fi to a ThingSpeak cloud database.

All five IoT games developed by the participants employed the gaming mechanism of aiming a ball into a hole. An infrared sensor was installed at the hole to determine whether a ball had entered the hole. A player's score was then calculated appropriately. Two of the games were based on soccer, two were based on pinball, and one was based on basketball. Every group incorporated the button, LCD, and infrared sensing modules introduced in the PBL course into their project. However, none of the groups employed an ultrasound sensor, which was also introduced in the course. Another component introduced in the course, the servomotor, was used only by Group 3 in their mechanism for starting a game.

4.2. Results of CT Assessment

Table 1 presents the CT assessment results. The preservice ES teachers had an average score of 46.00 (N = 15, SD = 17.65) before the project activity and an average score of 63.33 (N = 15, SD = 19.15) after the project activity. A paired-sample t-test yielded the result $t(14) = 3.52$ ($p < 0.05$, Cohen's $d = 0.91$). This indicates that the post-test result was significantly higher than the pre-test result and that the effect size was large. This finding suggests that the proposed project may effectively improve preservice ES teachers' CT knowledge.

An investigation into the individual assessment items revealed that the preservice ES teachers had some CT concepts of events and conditionals before the project activity as shown in Table 2. This led to limited improvement in the items corresponding to these two concepts. In contrast, they had little understanding of the sequence, parallelism, data, operator, loops, and mixed concepts of CT before the project activity. After the project, they had significantly improved results on items related to sequences, parallelism, data, and loops. However, the results for the operator-related and multi-concept items had limited improvement. Thus, the proposed project may benefit the participants' learning of the CT concepts of sequences, parallelism, data, and loops. However, the preservice ES teachers still performed unfavorably regarding some items in the post-test, namely, operators, data, and loops—despite significant improvement in their scores—and the multi-concept items.

Table 2. CT assessment results.

	Average	Sequences	Events	Parallelism	Conditionals	Data	Operators	Loops	Multiconcept
Pre-test	46.00	4.67	9.33	7.33	8.67	0	5.33	0	10.67
Post-test	63.33	8.67	10.00	10.00	8.67	3.33	5.33	4	13.33
t	3.52 *	2.45 *	1.00	2.26 *	0.00	2.65 *	0.00	3.06 *	0.78
Cohen's *d*	0.91	0.63	0.26	0.58	0.00	0.68	0.00	0.79	0.20

* $p < 0.05$.

4.3. Results of Development Board Knowledge Assessment

Table 3 presents the results of the development board knowledge assessment. The preservice ES teachers' average score in the evaluation was 35.00 ($N = 15$, $SD = 11.34$) before and 65.00 ($N = 15$, $SD = 15.35$) after the project activity. A paired-sample *t*-test yielded the result $t(14) = 6.67$ ($p < 0.05$, Cohen's $d = 1.72$). This indicates that the post-test result was significantly higher than the pre-test result and that the effect size was large. This finding suggests that the proposed project activity may effectively improve preservice ES teachers' knowledge of development boards.

Table 3. Development board knowledge assessment results.

	Average	Micro:bit	External Electronic Component	IoT
Pre-test	35.00	21.33	6.33	7.33
Post-test	65.00	33.67	12.33	19.00
t	6.68 *	3.91 *	4.94 *	7.00 *
Cohen's *d*	1.72	1.01	1.28	1.80

* $p < 0.05$.

An investigation into the items regarding each knowledge domain (the micro:bit, external electronic components, and the IoT) revealed that the preservice ES teachers had little knowledge of the three domains before completing the project but a significantly greater understanding of all three domains after the project, as shown in Table 3. These assessment results verified the project's effectiveness in enhancing the preservice ES teachers' knowledge in all three domains, particularly the IoT domain. The assessment results for the micro:bit and external electronic components, however, indicate that room for improvement remains despite this significant progress.

4.4. Results of Attitudes Toward Computer Programming

Table 4 presents the results of the computer programming attitude assessment. The preservice ES teachers had an average score of 3.78 ($N = 15$, $SD = 0.31$) before and 3.90 ($N = 15$, $SD = 0.42$) after the project activity. A paired-sample *t*-test yielded the result $t(14) = 1.58$ ($p > 0.05$). This suggests that their attitude was not significantly different before compared with after the project. In other words, the proposed project activity may not be able to significantly change the mindset of preservice ES teachers regarding computer programming. However, the participants had an overall positive attitude toward programming and a slightly improved attitude after participating in the project.

Table 4. Results for attitude toward computer programming.

	Average	Confidence	Preference	Usefulness	Gender
Pre-test	3.78	3.12	3.72	4.03	4.25
Post-test	3.90	3.22	3.57	4.47	4.35
t	1.58	0.78	−1.01	5.25 *	0.90
Cohen's d	0.41	0.20	0.26	1.38	0.23

* $p < 0.05$.

To obtain in-depth insight, this study examined the programming attitude assessment results for the four subscales separately (see Table 4). The only significant improvement was in the score for the usefulness subscale. Therefore, the proposed project may effectively improve preservice ES teachers' attitudes toward computer programming concerning its usefulness. Furthermore, the participants reported an overall positive attitude in all subscales of programming before and after the project, but their confidence regarding programming was generally low.

4.5. Results of Participation Perception

Table 5 presents the results for the participation perception scale. The average score given by preservice ES teachers on all items of the participation perception scale was 4.76, and the average scores given by participants for each question were four or higher. This indicates that the preservice ES teachers were satisfied with the project activity. Regarding their experience in the learning process, they positively evaluated the knowledge offered during the course about the programming, development boards, electronic components, and IoT. Regarding their participation experience, most preservice ES teachers reported feelings of fun and achievement while participating in the project.

Table 5. Participation perception results.

Item	Content	Average Score
1	The project activity was fun.	4.53
2	I put a lot of effort into the project activity.	4.80
3	I learned about the micro:bit development board from the project activity.	4.87
4	I learned about MakeCode programming from the project activity.	4.87
5	I learned about external electronic modules from the project activity.	4.87
6	I learned to control the micro:bit with MakeCode during the project activity.	4.93
7	I learned about IoT from the project activity.	4.80
8	I learned how to store IoT messages in ThingSpeak through the project activity.	4.73
9	I learned about MQTT from the project activity.	4.73
10	Seeing the IoT game machine we developed gave me a sense of accomplishment.	4.67
11	I would love to create an even better IoT project if I had the chance.	4.53
	Average score	4.76

Moreover, the preservice ES teachers primarily responded positively to an open-ended question at the end of the participation perception scale. Some examples of their responses were, "I gained a lot from the course," "I felt happy and accomplished when I finished the project and hope that I can put the knowledge and skills I have learned on this course into use in my future teaching practice and even combine them with different subjects," "The project-making process was fun. I usually play games developed by others, and now I can design basic games myself for my students, which gives me a sense of accomplishment," "Working on the project familiarized me with the micro:bit and IoT," and "I really learned a lot, although some parts of the course were challenging; I hope I'll be able to put some of the things I learned into my teaching practice." However, some participants also provided suggestions for improving the project activity. For example, one participant stated: "We only had so much class time, so we basically finished our project outside of class, meaning that we would not be able to ask for help and get an instant response from the teacher like we would in class. That made the project-making process much longer than we had expected." Others expressed the following: "Given the limited time we had, the project was not as perfect as we wanted it to be; the project would have been a lot better if we had had more time," "We did not have enough class time, which left us minimal time for actual work on the project in class," and "The wi-fi module was unstable; sometimes, we wouldn't be able to connect to the internet or would see garbled text on the LCD in our first test after loading our program from the micro:bit." Most of the suggestions concerned the insufficient class time allocated to project making and the instability of external components such as the wi-fi module and LCD. These suggestions can provide a basis for future improvement of the project activity.

5. Discussion

There is an increasing emphasis on programming education in ES, particularly regarding visual programming and development boards. As such, this study designed an IoT project that can be incorporated into the ES teacher education program to enhance preservice teachers' content knowledge related to programming. A preliminary evaluation was conducted to verify the proposed project's feasibility.

The results indicate that, despite having no experience with the MakeCode visual programming software, micro:bit, electronic components, or IoT technology, the preservice ES teachers who were enrolled in the course all completed their projects as per the course requirements. Their ability to develop various IoT cardboard games verified the feasibility of this project. This indicates that the project is suitable for the ES teacher education curriculum. The three steps of PBL—skill competency debriefing, project work, and evaluation—were implemented during this project. The preservice ES teachers learned basic skills relating to visual programming and micro:bit use, worked on a project in groups, and presented their group project for evaluation. Five IoT cardboard games were developed and integrated into physical and virtual environments. This involved collecting game scores, uploading them to a cloud database, and communicating with other devices. The results also verify that the PBL steps proposed by Jalinus et al. [34] are feasible; they can guide preservice ES teachers from no experience with IoT to completing an IoT project themselves. The proposed project differs from other micro:bit-based project activities [14,20,21] in that the wi-fi modules were incorporated into the projects, which increased the complexity of the project-making process. Thus, the results of this study also indicate that combining a micro:bit with a wi-fi module for students to develop IoT application projects is feasible for micro:bit-based projects. However, the types of games designed in the participants' projects were similar. This suggests that the groups used only a limited selection of the available electronic components. Future courses could incorporate an appropriate teaching strategy, such as teaching design thinking skills, to spark students' creativity.

This study aimed to incorporate the proposed project activity into the ES teacher education curriculum and thereby equip preservice ES teachers with the programming skills necessary for teaching programming courses at an ES level. The participants showed significant improvements in the CT assessment after the project activity, particularly regarding CT concepts of sequences, parallelism, data, and loops. This finding has verified that the proposed project could be effective in helping preservice ES teachers develop CT skills. This is consistent with previous research that found that incorporating the micro:bit into classes can enhance students' CT knowledge [12,22]. However, the preservice ES teachers exhibited unfavorable results for items related to the CT concepts of data, operators, and loops—which are particularly challenging for beginner-level programming [41,42]—as well as on the multi-concept items. This indicates that their understanding of CT must be further improved. A possible solution would be to focus more on these complex CT concepts at the skill competency debriefing stage of the project activity. The proposed project also enhanced the participants' knowledge regarding development boards and IoT, as evidenced by their significantly improved results in assessing development board knowledge. Nevertheless, their scores regarding the development boards and electronic component items remained relatively low because they had no prior experience with development boards. A potential solution would be to focus more on these knowledge domains in the skill competency debriefing stage of the project activity. Overall, the proposed project activity improved the preservice ES teachers' knowledge of visual programming and development board applications and can be improved and adjusted in the future.

The project also slightly changed the participants' attitude toward programming. Although the overall score for the attitude scale did not significantly increase, the score for the usefulness subscale did. The participants felt more positively about the need for everyone to learn programming and felt more strongly about the importance of programming after the project. This finding concurs with previous research [43,44] in that the micro:bit can improve students' attitudes toward computer programming. Nonetheless, the attitude assessment in the present study revealed a generally low confidence level among the participants regarding their ability to program, which is consistent with the finding reported by Tsai et al. [40]. Consequently, some improvements are necessary for future courses, such as increasing the course length to more than one semester to enhance preservice ES teachers' confidence in computer programming.

The benefits of the proposed project activity were supported by the preservice ES teachers' responses to the participation experience scale. Most participants acknowledged that the course helped them learn about programming, development boards, and IoT. However, the participants' feedback also suggests areas where this activity can be further improved. For example, it was suggested to arrange a three-credit course, if allowed by the teacher education institutions, so the students would have more class time to work on their projects. Furthermore, in the future, it may be worth trying to use development boards with built-in wi-fi, such as ESP32. This could facilitate smoother development for students working on projects related to the IoT.

6. Conclusions

To enhance Taiwanese preservice ES teachers' content knowledge regarding programming, this study developed an IoT project activity based on the emphasis of ES programming curricula in advanced countries worldwide and Taiwan. This project aimed to enable preservice ES teachers to use the micro:bit and external electronic components to develop cardboard games with IoT features. To preliminarily verify its feasibility, the activity was offered to students enrolled in an ES teacher education course. The preservice ES teachers participating in this project were able to develop various IoT cardboard games through teamwork. Their scores on the CT, development board knowledge, and attitude toward programming assessments were significantly improved after the project activity. Furthermore, participants reported that their perception of participating in the project was highly positive. These findings verify that the proposed project activity could be feasible and effective in improving preservice ES teachers' content knowledge and attitude regarding computer programming.

The proposed IoT project activity could provide a reference for ES teacher education courses. In the future, more class time should be provided to the participants to work on their projects. Furthermore, additional training activities could be incorporated into the project to reinforce the participants' knowledge regarding the CT concepts of variables, operations, loops, and development boards. Moreover, employing various teaching strategies to inspire the participants' creativity in project development should also be further explored. Other limitations of this study include its small sample size. Larger samples and more rigorous research are required for a more in-depth understanding of the learning outcomes of this project activity.

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