

Online Learning Using Block-based Programming to Foster Computational Thinking Abilities During the COVID-19 Pandemic

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Abstract—The COVID 19 pandemic has affected global education. In Thailand, all educational institutions temporarily closed to prevent the spread of COVID-19. However, teaching and learning still need to be continued. It is necessary to switch the learning activities to online learning. In this study, we designed online learning activities for developing computational thinking (CT) of students and carried out an experiment with 90 participants (first-year students enrolled in a Bachelor of Education Program in educational technology and communications at King Mongkut's University of Technology Thonburi). At the beginning of the experiment, all participants were asked to take a CT test to measure their CT. The test is consistent with other CT tests under validation. During the sessions, all participants were taught by Thinkable. After the experiment, they took the CT test again. The results show that by improving CT through block-based programming projects, students' performance improved significantly. In conclusion, block-based programming and working in pairs are combinations that can potentially help students to perform better, in turn affecting their performance in projects.

Keywords—Block-based programming, computational thinking, computational thinking components, COVID-19, online learning, working in pairs

1 Introduction

The recent global pandemic was caused by the appearance of the coronavirus in December 2019, which was discovered in Wuhan, the capital city of Hubei, China. The World Health Organization (WHO) announced the outbreak as a Public Health Emergency of International Concern (PHEIC) on the 30th of January 2020 and as a pandemic on the 11th of March 2020 [1]. During the outbreak, all educational institutions temporarily closed to prevent the spread of COVID-19 and reduce the risk of infection to students [2]. The closing down of the world economy affected students and instructors across the globe [3]. However, the pandemic has presented a challenge to educational institutions to improve their modes of course delivery and to transfer

their attention to emerging technologies [4]. Universities across different countries have measures for all instructors to switch from classroom teaching (face to face) to various forms of online learning amid the COVID-19 pandemic [5]. Preparation for teaching and learning in the COVID-19 crisis is an essential duty of all parties, especially instructors. A critical challenge is how to design online learning to attract students' attention because they always lack focus during online classes. Some instructors have had to provide the educational apps, platforms, and resources to facilitate student interaction, motivation, and learning [6, 7].

Access to good quality education for all Thai students is the highest concern of the Thai Ministry of Education. During a pandemic, it is understandable that educational institutions have to come to a halt; learning, however, should not. Hence, seeking ways to resume teaching and learning activities with maximum efficiency—as far as the context allows—is a priority. The problems that the crisis has generated have to be resolved, but the circumstances have presented a timely opportunity to revamp the Thai educational system. Guidelines have been published for teaching and learning during the pandemic. They are based on the 4 Ons: online, on-air, on-demand, and onsite. If educational institutions are not in an epidemic-prone area, they are allowed to open. Everybody has to follow the pandemic prevention measures: having one's temperature taken at screening points, wearing a mask, staying six feet away from others, and washing one's hands often. Educational institutions should provide blended (i.e., face to face and online) learning. For example, arrangements should be made for students from different levels to switch days and periods when they come to class while dividing those in the same class into two groups: one studies online, while the other studies face to face. Students' willingness and convenience should always be taken into consideration. Educational institutions in epidemic-prone areas have to remain closed until the pandemic is over. In the meantime, they should provide online teaching using e-learning and video conferencing [8].

The world is changing very rapidly because of technological advancements. The world economy is being transformed, and more and more workers are being replaced by robots and artificial intelligence (AI). Consequently, human resource management should focus on encouraging the acquisition of the hard and soft skills that are and will be needed in the current and future job markets [9]. Various technologically advanced countries have been developing their students' capabilities in this regard. One of the most valuable skills globally is computational thinking (CT) [10]. Thailand has developed a national socio-economic and educational development plan for human resources with an eye to the job market of the future. Higher education institutions must produce graduates who are highly specialized in different fields [11]. Thailand is concentrating on digital technology as a solid foundation for future business and as the main driving force in educational reform. It is critical that students develop CT, which is an analytical way of thinking and approaching problems imaginatively, systematically, and in the abstract. It is not just about coding, since programming languages are in a state of constant flux; what is more important is that students learn to think associatively. However, CT requires appropriate teaching methods and tools. Because the instructor is one of the main influences on the student, they have to integrate their teaching approach with the technologies that are available [12].

A member of our research team is an instructor who teaches innovation in educational technology and mass communication. He had a desire to encourage their stu-

dents' CT because he realized that CT is an essential skill in the 21st century. Providing students with CT will also strengthen students' confidence in their ability to problem-solve. There are various approaches to cultivating CT, such as block-based programming and games design [13, 14, 15, 16, 17], educational robotics [18, 19, 20, 21], e-learning [22], and board games [23, 24]. From the survey, most students in this class had no prior experience with programming, and block-based programming is considered as an alternative to foster CT because text-based coding is not easy for beginners to start coding and the language syntax is a barrier for students to better understand CT concepts [25]. Furthermore, block-based languages have a pallet of commands, making memorizing commands unneeded; therefore, it is easy for novices [26].

Computer programming is an essential skill for students in the digital era. Through it, they can learn to solve problems systematically and develop computational and logical thinking skills [27]. Block-based programming is one of the most popular ways to improve CT. A growing number of classrooms are incorporating it into their materials. It uses colors and shapes and drag-and-drop features to support novice programmers [28]. Block-based programming environments help students to learn CT concepts (e.g., sequences, loops, parallelism, events, conditionals, operators, and data) [25]. Block-based programming can stimulate students' interest, show them how to build real-life applications, and give them a sense of accomplishment.

The purpose of this study is to provide empirical evidence that can help to answer a set of research questions: What are the CT abilities of the participants after online learning activities? What are the CT abilities of the participants who have different genders after online learning activities? What are the CT abilities of the participants who have different performances (high, medium, and low) after online learning activities? This paper is organized as follows: Section 2 reviews background literature on CT and online learning during the COVID-19 pandemic; Section 3 outlines the methodology, including the participants, procedure, and measuring tool; Section 4 presents the results of the experiment; and Section 5 summarizes the discussion and conclusion.

2 Literature Review

2.1 Computational thinking

CT is a key skill in the 21st century that is essential to everyone, not just a programming skill used only by programmers or computer scientists [29]. CT can be integrated with a variety of subjects, but most teachers are familiar with bringing CT to apply with programming teaching [30, 31]. There are different definitions of CT. For example, Denning [32] defined CT as a method to solve problems through algorithmic thinking. Denning and Tedre [33] proposed that CT is a skill that involves the conceptual skills and practices for designing computations that get computers to work for us and explaining the world as a complicated information process. Kafai and Burke [34] explained CT is the ability to think and analyze problems more systematically. Wing [35] emphasized that CT is a way of human thinking to solve problems rather than copying the computer's thinking mode. Wing also proposed four compo-

nents of CT: decomposition, pattern recognition, abstraction, and algorithm design. The definitions of CT components are as follows:

1. Decomposition: Separating something into smaller parts to be easier to manage [36]
2. Pattern recognition: Noticing patterns, trends, and regularities of data [36]
3. Abstraction: Focusing on crucial information and ignoring unnecessary details [36, 37]
4. Algorithm Design: Designing a step-by-step procedure for solving problems [36, 37]

From 2011 to 2020, most CT studies were related to computer programming. The most popular teaching tool that teachers used for CT instructional design was block-based programming because most teachers believed that using blocks in coding can remove syntax error, which is an obstacle for students to better understand the principal programming concepts [25], and block-based programming is suitable for students who are just starting to practice coding or who had no prior experience with programming. Examples of teaching tools for improving the CT of students include Scratch, Thinkable, App Inventor, Alice, LEGO, and code.org. When block-based programming was conducted with the participants, CT concepts (e.g., sequences, Loops, conditionals, events, parallelism, and operators) were developed. One of the most recent studies was conducted in 2020 by Pérez-Marín et al. [16] to develop CT concepts in 132 primary students, whose ages ranged between 9 and 12 years. At the beginning of the experiment, all students took three tests, including a validated test to measure CT, a knowledge of programming and CT concepts test created ad hoc, and a new test to measure CT created for students. During the experiment, all students were taught CT and programming through the Scratch (MECOPROG). After six weeks, they took those same three tests again. The results showed that all levels of students improved their knowledge of CT and programming. However, fifth-grade students improved their performance in all tests, while fourth-grade students can understand programming and CT concepts more than fifth- and sixth-grade students.

The experiment was conducted with computer engineering, software engineering, and information systems engineering students in 2018 by Topalli and Cagiltay [25], whose purpose was to better understand the effect of enriched introduction to the programming course on students' performances. The results showed that teaching through real-life game development projects in Scratch helps students find solutions for real-life problems that they face during their algorithm design. Additionally, the Scratch environment helps them not only eliminate the syntax problems but also in the design and development of algorithms.

In this course, the students need to create applications to complete the course. We use Thinkable as a teaching tool because it is a drag-and-drop mobile app builder that enables anyone to create beautiful apps. The students can build complex apps with Thinkable by dragging and dropping different logical components. Using these building blocks resembles Scratch but is more specific for creating apps.

2.2 Online learning during the COVID-19 pandemic

Due to the COVID-19 pandemic, many educational institutions around the world were closed to prevent the spread of COVID-19 [2]. This situation led to the transition from the traditional classroom (face to face) to online learning [38]. Both instructors and students face unfamiliar learning conditions. Instructors who lack the ability to use online platforms must spend more time preparing to teach, whereas students need to study by themselves more than they would in face-to-face classes. However, to ensure the continuity of learning, many instructors have tried to use online classes through platforms like Zoom, Google Meet, and Cisco Webex [6]. The challenge is how instructors will design interesting online classes because the students have low concentration [39]. The instructor plays a key role in online classes [40]. Heuer and King [41] defined the role of the instructor in online classes as a planner making a clear instructional plan, a coach supporting students to learn, a facilitator giving the students space to allow creativity, and a communicator delivering content effectively.

Formative assessment is as crucial as online learning activities' design because it improves student engagement and promotes learning performance [42, 43, 44]. The online formative assessment could be implemented with asynchronous and synchronous learning. Asynchronous learning can be delivered via a learning management system (i.e., Moodle), providing assignments, discussions, tests, etc. Assignments can help students practice by themselves, whereas instructors can create discussion topics and allow students to communicate and collaborate. Moreover, tests can identify gaps in knowledge and help students form a big picture of the content [45].

Apart from asynchronous learning, synchronous learning can be delivered via live streaming (i.e., Zoom and MS Teams). Using educational technology to create virtual classrooms at a scheduled time led students to enjoy real-time interaction with their instructors and peers [46]. Formative assessments in live streaming are discussions, evaluations from instructors and peers, and real-time quizzes [45]. However, synchronous learning requires high-speed Internet connection, and unstable Internet connection influences learning performance [47], whereas asynchronous learning does not provide real-time activities, so students may experience decreased motivation and engagement [48]. Therefore, in this study, we provided a combination of synchronous learning (live streaming meetings via Zoom) and asynchronous learning (learning management system via Moodle) for making an effective online class.

3 Methodology

We conducted an experiment for three months. The course is named Innovation in Educational Technology and Mass Communication. We originally designed learning activities with a focus on face to face, but we needed to transition to online learning in the COVID-19 situation.

3.1 Participants

A sample group consisted of 90 freshmen attending the Department of Educational Communications and Technology of King Mongkut's University of Technology

Thonburi (KMUTT), Thailand. All participants enrolled in the Innovation in Educational Technology and Mass Communication course. This quasi-experimental research followed a one-group pre-test–post-test design because the human research ethics committees of KMUTT had concerns about students’ equality; all students should receive the same treatments and assessments. Hence, we could not have a control group. In this study, we classified the students into three groups: high-, medium-, and low-performing students. The students’ classification details are shown in Table 1. They were asked to fill in personal information in Google Form. Personal information included name, surname, nickname, student ID, gender, and grade point average (GPA). All respondents' information will be kept confidential.

Table 1. Students’ classification

| GPA | Level of Performers |
|----------------|---------------------|
| 3.01 to 4.00 | High |
| 2.01 to 3.00 | Medium |
| Less than 2.01 | Low |

3.2 Procedure

Due to the coronavirus outbreak (COVID-19) and infection control policy, the university temporarily closed to prevent the large gathering of people. The instructors needed to provide online teaching that combined synchronous learning (video conferencing) and asynchronous learning (e-Learning). Each session, the instructors assigned students to study in Moodle before discussion in an online classroom, in which everyone can share ideas and participate in real time. We asked students to take the pre-test in Google Form. After completing the test, we informed students that they need to create a project to complete the course. The project involves creating applications with Thinkable, which the instructors assigned to work as a pair. The course was three hours long per week. Table 2 shows the online classroom activities conducted via Zoom, the cloud-based video conferencing platform. In addition to online learning in the classroom, the students can also review additional content in the learning management system (Moodle) provided by the instructors. At the end of the course, the students were asked to take the CT test again.

Table 2. Online classroom activities

| Week | Online class-room activity | Detail |
|------|---|---|
| 1 | The formulation of expected learning outcomes | The instructors informed the students of the expected learning outcomes in this course for helping the students prepare a plan to access teaching materials and information from various sources to obtain information on the problems encountered in real life that leads to the origin and significance of the project. The instructors must also connect content with real-world situations and encourage the students to apply their knowledge to analyze and connect to the problems they face in life or society. |
| 2 | Pre-test and introduction to CT | The instructors asked the students to take the CT test, which was provided in Google Form. After that, the instructors clarified the importance of CT and CT components. To increase students' engagement and motivation, the instructors used Kahoot to create a quiz "Introduction to CT" for students. They took this quiz to find the winner of the game. |
| 3 | Designing the project theme | The instructors and the students discussed and identified real problems in today's society. Then the instructors and the students defined the theme of the project. Most students had the same opinion that COVID-19 was an interesting topic. The instructors explained that the students must work in pairs to create an application with Thinkable to complete the course. |
| 4 | Introduction to Thinkable | The instructors introduced how to use Thinkable to students. The contents included the Thinkable component, design page, blocks page, and live test. |
| 5 | Thinkable workshop | The instructors demonstrated how to create a rock-paper-scissors game step by step. The students followed the teacher's demonstration. After completing the workshop, the students captured their blocks page and posted it in the classroom Facebook group. Blocks are shown in Figure 1. |
| 6 | Formulating the project proposal | The students made the project proposal that consists of problems and solutions, framework, and the duration of the production. |
| 7 | Flowchart practice | The instructors taught students about flowchart symbols and creating a flowchart in draw.io. After that, the instructors assigned the students to create a flowchart showing the process of deciding what symptoms get tested for COVID-19. |
| 8 | Flowchart Thinkable application | Each pair of students created an application flowchart and reported on the progression plan. The applications must relate to the COVID-19 situation. |
| 9-10 | Let's make the project | Each pair of students built an application. The students contacted each other via online communication channels such as video conferences and social media. If students encounter problems they cannot solve by themselves, they immediately notify the instructors. |
| 11 | Presentation | The students demonstrated their own Thinkable application. After that, they uploaded their project to the YouTube channel for anyone who is interested in building an application using Thinkable. Some examples of the Thinkable applications are shown in Figure 2. |
| 12 | Evaluation | The instructors commented to the students about their presentations and assessed the applications according to the rubric score. |
| 13 | Post-test and reflection | At the end of the course, the students were asked to take the CT test again. Then the instructors allowed the students to reflect on their online learning experience via a post-it note on a wall in Padlet because some students may not be able to fully express their opinions. Writing anonymous comments may give the instructors a big picture of past learning activities. |

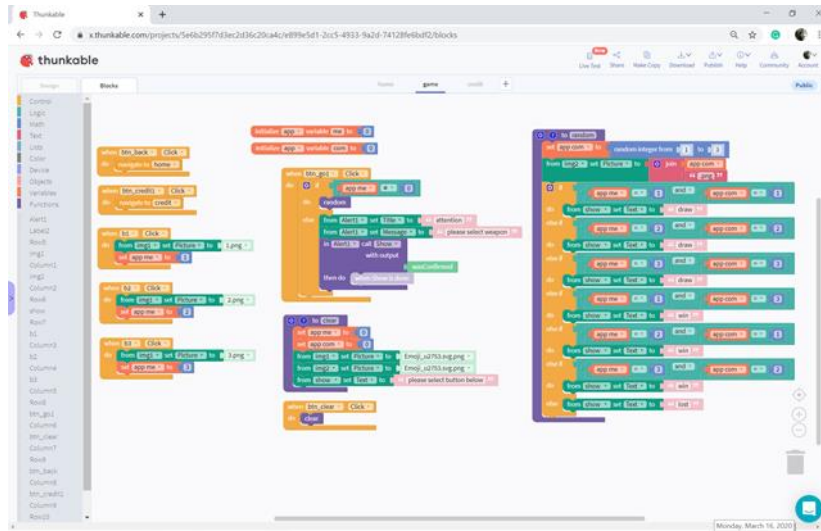


Fig. 1. Blocks of rock–paper–scissors game in Thinkable

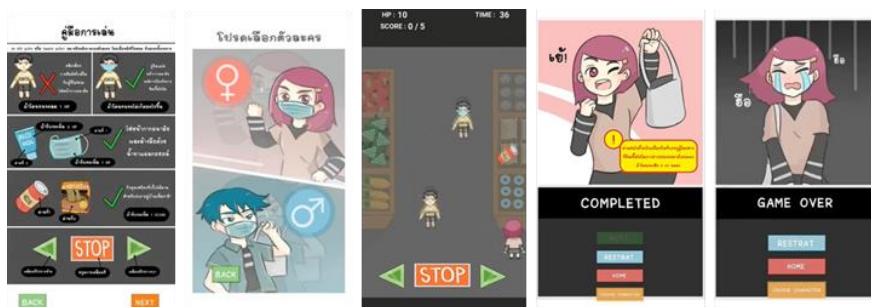


Fig. 2. Thinkable applications examples

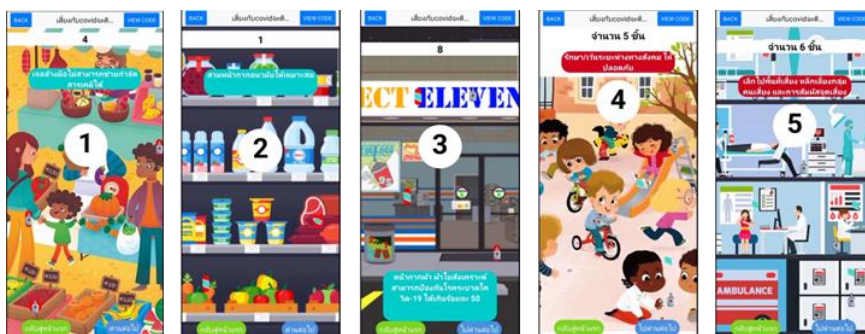




Fig. 2. Thinkable applications examples (continued)

3.3 Measuring tool

In this study, the CT Test was designed to assess the students' CT abilities. The CT test is consistent with other CT tests under validation, such as the Talent Search Computational Challenge of Bebras Organization and the Test for Measuring Basic Programming Abilities [49]. The CT test was built on the following principles:

1. Aim: CT test aims to measure the students' CT abilities.
2. Target population: CT test is specifically designed for students in higher education.
3. Instrument type: multiple-choice test with 4 answer options.
4. Length and estimated completion time: 20 items; 30 mins.
5. Computational concept addressed: each item addresses one or more of the following four CT components (decomposition, pattern recognition, abstraction, and algorithm design).

The example of CT test items translated into English is shown in Fig. 3 and 4. The Reliability as internal consistency of the CT test, measured by Cronbach’s Alpha is 0.79 that can be considered as high reliability [50, 51]. The average along the 20 items is $p = 0.59$ (medium difficulty); ranging from $p = 0.26$ (quite difficult) to $p = 0.76$ (quite easy).

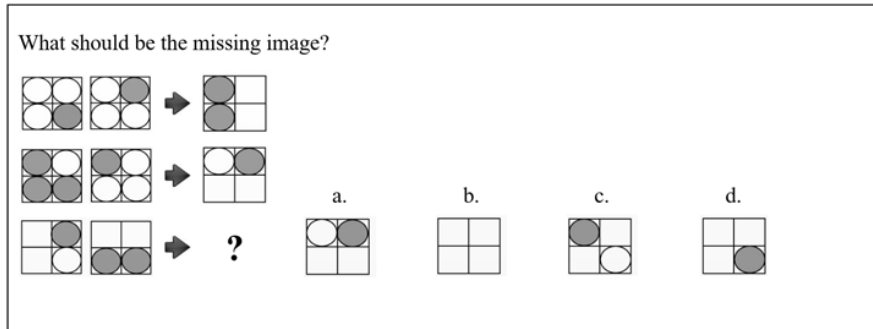


Fig. 3. Item 4; pattern recognition

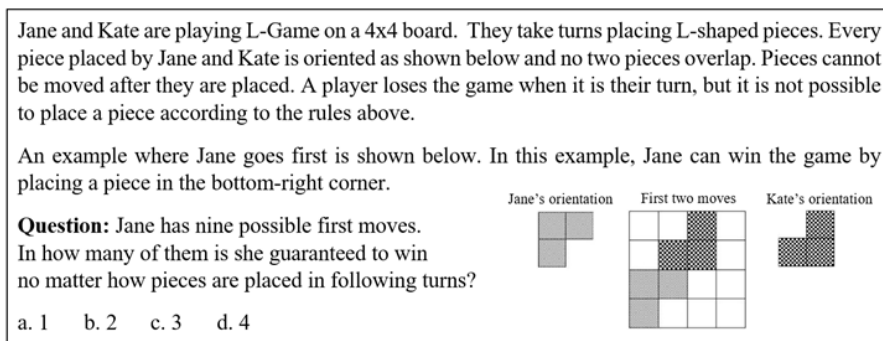


Fig. 4. Item 16; decomposition and abstraction

4 Results

4.1 Overall results

The students have created three types of COVID-19 apps: quizzes (multiple choice and yes/no questions), games, and quarantine related lifestyle software (for relaxation, home cooking, and money management). To assess the Thinkable application projects, the rubric is presented in Table 3. A project in which the obtained total score is lower than 12 points is considered basic level. A project that obtains from 12 to 15 points is evaluated as developing level, and those that obtain more than 15 points are evaluated as proficiency level. The scores obtained in the sessions are presented in Table 4. The criteria for the assessment project are divided into six categories: CT

concepts, design, creativity, content, usability, and presentation. The student who gets scores in each category of more than 2.5 points is considered at the proficiency level, from 2.01 to 2.5 points the developing level, and less than 2 points the basic level. The analysis of the projects produced by the students reveals that most students have average scores in design and presentation at the proficiency level, and average scores of other categories are at the developing level. The average of total scores is at the developing level.

Table 5 shows the medians (more representative than the mean in asymmetric distribution), means, and standard deviation for the pre-test and post-test of all students' CT abilities, without the difference in gender and learning performance. Table 5 reveals greater improvement in the post-test result. Standard deviation slightly decreases in the post-test.

Fig. 5 shows box plots for CT scores in pre- and post-tests. Fifty percent of the central data are represented in the box. The interquartile range (Q3–Q1) in the post-test is wider than in the pre-test. It can be assumed that the post-test score has more variability than the pre-test score. The medians of the pre- and post-tests are close to the average. However, the box plots show different distributions of scores, and the outliers are marked in the pre-test.

The median, mean, and standard deviation for the pre- and post-tests of all students' CT abilities classified by CT components are shown in Table 6. All CT components have an increase in the post-test, especially in decomposition and algorithm design. The medians of pattern recognition and abstraction are not different in the pre- and post-tests. Standard deviation slightly increases in decomposition but decreases in abstraction.

Table 3. Rubric for Thinkable project assessment

| | Basic (1 point) | Developing (2 points) | Proficiency (3 points) |
|--------------|---|--|--|
| CT Concept | Consists of one or two of the following: sequences, loops, parallelism, events, conditionals, and operators. | Consists of three or four of the following: sequences, loops, parallelism, events, conditionals, and operators. | Consists of five or six of the following: sequences, loops, parallelism, events, conditionals, and operators. |
| Design | A few graphics are of poor quality and are not related to the content. Colors have been used randomly and do not enhance the app. | Most graphics are of good quality and are related to the content. Color is used to enhance the app inconsistently. | All graphics are of good quality and are related to the content. The color scheme is appropriate to the content and app. |
| Creativity | The app comes from an existing idea that many others have built. | The app is interesting and helpful, but it is not new. | The app is new, interesting, and helpful. |
| Content | Some content does not align with the objective, and content has more than two misspellings. | Most content aligns with the objective, but content has one or two misspellings. | All content aligns with the objective and no misspellings. |
| Usability | Complex to use and no instruction available. Some minor technical issues. | Quite easy to use and loads quickly. Instruction available, but it is not clear. | Easy to use and loads quickly. Instruction is clear and simple to follow. |
| Presentation | The speech includes several distracting pauses and no video demonstrating how to use the app. | The speech includes some distracting pauses, but there is a video demonstrating how to use the app. | The speech flows nicely with no pauses, and there is a video demonstrating how to use the app. |

Table 4. Results of Thinkable project assessment

| | M | SD | Interpretation |
|--------------|----------|-----------|-----------------------|
| CT Concept | 2.11 | 0.32 | Developing |
| Design | 2.66 | 0.48 | Proficiency |
| Creativity | 2.18 | 0.39 | Developing |
| Content | 2.27 | 0.45 | Developing |
| Usability | 2.41 | 0.50 | Developing |
| Presentation | 2.82 | 0.39 | Proficiency |
| Total | 14.45 | 1.35 | Developing |

Table 5. Median, mean, and standard deviation for pre- and post-tests of all students' CT abilities

| CT abilities | N | Mdn | M | SD | t | Sig |
|---------------------|----------|------------|----------|-----------|----------|------------|
| Pre-test | 90 | 10 | 10.39 | 3.01 | 11.58 | 0.00 |
| Post-test | 90 | 15 | 14.37 | 2.94 | | |

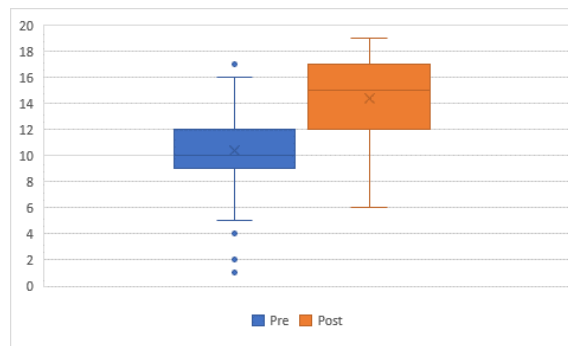


Fig. 5. Box plots for CT test score in pre- and post-tests

Table 6. Median, mean, and standard deviation for pre- and post-tests of all students' CT abilities classified by CT components

| | Decomposition | | | Pattern Recognition | | | Abstraction | | | Algorithm Design | | |
|-----------|----------------------|----------|-----------|----------------------------|----------|-----------|--------------------|----------|-----------|-------------------------|----------|-----------|
| | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> |
| Pre-test | 2 | 2.21 | 1.42 | 2 | 2 | 1.05 | 5 | 4.32 | 1.21 | 2 | 1.86 | 1.35 |
| Post-test | 4 | 3.58 | 1.48 | 2 | 2.42 | 1.05 | 5 | 4.86 | 0.46 | 4 | 3.51 | 1.35 |

4.2 CT abilities results per gender

Table 7 shows the median, mean, and standard deviation between genders. Both males and females have significant improvement in the test ($p = 0.00$). However, females have slightly more average post-test scores than males. Standard deviation slightly decreases for both males and females. In Table 8, both males and females have an increase in the post-test results in all the components, a great improvement in decomposition and algorithm design, and a small improvement in pattern recognition and abstraction.

Box plots for CT score split by genders are shown in Fig. 6. The outlier belongs to the pre-test. The interquartile range of the pre-test in males has the shortest range. Hence, it can be stated that the pre-test of males has the least different distributions. The mean and median for males are closer than for females. Both minimum scores for the pre-test and post-test for males are higher than for females. However, both interquartile ranges for the pre-test and post-test for females are wider than for males. It can be assumed that the scores of females have more variability than the scores of males.

Table 7. CT abilities results per gender

| | Male (n =31) | | | | | Female (n = 59) | | | | |
|-----------|--------------|----------|-----------|----------|----------|-----------------|----------|-----------|----------|----------|
| | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>t</i> | <i>p</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>t</i> | <i>p</i> |
| Pre-test | 10 | 10.03 | 2.94 | 8.22 | 0.00 | 11 | 10.58 | 3.06 | 8.61 | 0.00 |
| Post-test | 14 | 14.03 | 2.89 | | | 15 | 14.54 | 2.98 | | |

Table 8. CT abilities results classified by CT components per gender

| CT abilities classified by CT components | Male (n = 31) | | | Female (n = 59) | | |
|--|---------------|----------|-----------|-----------------|----------|-----------|
| | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> |
| Decomposition (pre) | 2 | 2.03 | 1.14 | 2 | 2.31 | 1.55 |
| Decomposition (post) | 4 | 3.45 | 1.55 | 4 | 3.64 | 1.45 |
| Pattern Recognition (pre) | 2 | 1.87 | 0.96 | 2 | 2.07 | 1.10 |
| Pattern Recognition (post) | 3 | 2.55 | 1.12 | 2 | 2.36 | 1.01 |
| Abstraction (pre) | 5 | 4.19 | 1.33 | 5 | 4.39 | 1.14 |
| Abstraction (post) | 5 | 4.90 | 0.30 | 5 | 4.83 | 0.53 |
| Algorithm Design (pre) | 2 | 1.94 | 1.39 | 2 | 1.81 | 1.35 |
| Algorithm Design (post) | 3 | 3.13 | 1.43 | 4 | 3.71 | 1.27 |

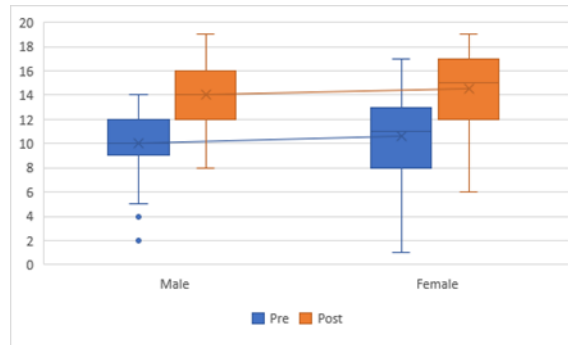


Fig. 6. Box plots for CT score in pre- and post-tests split by genders

4.3 CT abilities results per learning performances

Table 9 shows the median, mean, and standard deviation among different learning performances (high, medium, and low). All types of students have an increase in the

post-test results. Standard deviation slightly decreases in high-performing students but increases in medium-performing students. There is no standard deviation in the post-test of low-performing students. In Table 10, all types of students have an increase in the post-test results in all the components; both high- and medium-performing students have a great improvement in decomposition and algorithm design, and a small improvement in pattern recognition and abstraction. However, both high- and medium-performing students have a high score of abstraction in the pre-test, so the average score increased only slightly compared to the other components. The standard deviation of all CT components decreases in high-performing students, while the standard deviation of decomposition, pattern recognition, and algorithm design increases in medium-performing students. Low-performing students have a great improvement in abstraction. There is no standard deviation in pattern recognition (pre-test) and abstraction (post-test) in low-performing students.

Box plots for CT score split by learning performances are shown in Fig. 7. The outlier belongs to the pre-test of medium-performing students. The median and mean in the pre-test are closer than the median and mean in the post-test of high- and medium-performing students. In the post-test of low-performing students, the median and mean are the same, upper and lower whiskers are not found, and there is no interquartile.

Table 9. CT abilities results per learning performances

| | High (n = 45) | | | Medium (n = 43) | | | Low (n = 2) | | |
|-----------|---------------|----------|-----------|-----------------|----------|-----------|-------------|----------|-----------|
| | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> |
| Pre-test | 11 | 10.89 | 2.74 | 10 | 10.09 | 3.05 | 5.5 | 5.5 | 4.95 |
| Post-test | 16 | 14.84 | 2.37 | 15 | 14.02 | 3.40 | 11 | 11 | 0 |

Table 10. CT abilities results per learning performances

| CT abilities classified by CT components | High (n = 45) | | | Medium (n = 43) | | | Low (n = 2) | | |
|--|---------------|----------|-----------|-----------------|----------|-----------|-------------|----------|-----------|
| | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> | <i>Mdn</i> | <i>M</i> | <i>SD</i> |
| Decomposition _(pre) | 2 | 2.40 | 1.56 | 2 | 2.09 | 1.23 | 0.5 | 0.5 | 0.71 |
| Decomposition _(post) | 4 | 3.82 | 1.34 | 4 | 3.40 | 1.58 | 2 | 2 | 1.41 |
| Pattern Recognition _(pre) | 2 | 2.13 | 0.94 | 2 | 1.91 | 1.15 | 1 | 1 | 0 |
| Pattern Recognition _(post) | 2 | 2.31 | 0.85 | 3 | 2.58 | 1.22 | 1.5 | 1.5 | 0.71 |
| Abstraction _(pre) | 5 | 4.49 | 1.08 | 5 | 4.23 | 1.17 | 2.5 | 2.5 | 3.54 |
| Abstraction _(post) | 5 | 4.93 | 0.25 | 5 | 4.77 | 0.61 | 5 | 5 | 0 |
| Algorithm Design _(pre) | 2 | 1.87 | 1.42 | 2 | 1.86 | 1.32 | 1.5 | 1.5 | 0.71 |
| Algorithm Design _(post) | 4 | 3.78 | 1.15 | 4 | 3.28 | 1.52 | 2.5 | 2.5 | 0.71 |

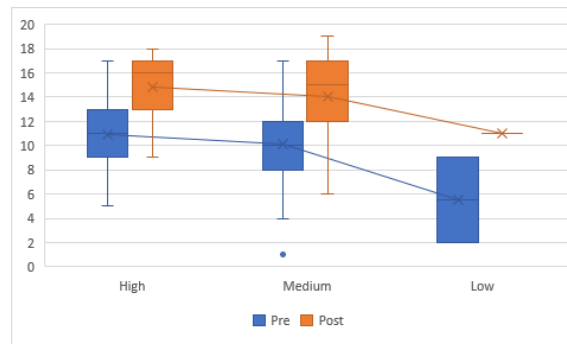


Fig. 7. Box plots for CT score in pre- and post-tests split by learning performance

5 Discussion

The COVID-19 pandemic has become a crucial challenge across all sectors, including higher education institutions. Universities have switched from face-to-face classrooms to distance learning to support the continuity of teaching and learning. Nevertheless, the impact of COVID-19 is an opportunity for universities to learn from the unplanned and rapid changes.

We designed online learning activities by a combination of block-based programming and working in pairs as an intervention, so this paper explored whether students' CT can be enhanced. One of the results shows that there is a statistically significant increase in students' post-test results for both genders and different learning performances. This suggests that it is necessary to teach students block-based programming if instructors want to cultivate CT for students who have no prior experience with programming.

Supportively, enhancing the course through real-life problem and block-based programming can improve the students' CT concepts and motivation [25]. Block-based programming is a drag-and-drop interactive environment that helps them eliminate syntax errors and introduce CT concepts attractively. Even though it is claimed that block-based programming appeals more to younger children [16], some educators [25, 52, 53] used block-based programming as a visual programming environment to foster teachers' and university students' CT. However, some educators have suggested that the development of CT is not only used in programming teaching [31], but also is applied in various subjects, such as mathematics [54], biology [55], and language [56].

The lack of interaction between classmates is a significant barrier. Online learning enables student–instructor communication at the expense of student–student communication [5]. To fill this gap, we encouraged students to interact through discussion and pair work to complete projects related to the COVID-19 situation. This is linked to the idea put forward by Nelson [57] that an effective way of learning is to engage students in the collaborative problem-solving of real - world problems. This is also

why we wanted to connect the COVID-19 situation with student projects so that they might become better researchers and problem solvers. Additionally, working in pairs gives students more discussion time. This gives them more confidence and motivation to complete the project. This partly supports Kopinska and Azkarai's [58] conclusion that most students prefer to work with partners and the class in which the instructor included a greater amount of pair work improved the students' motivation more. Furthermore, motivation is sustained through real-world problems and projects. The students achieve greater success in the classroom when they are highly motivated and interested in their topic.

According to this study, block-based programming and pair work could be incorporated into the Innovation in Educational Technology and Mass Communication course for improving the students' CT abilities. Such interventions can help students perform better on the course and in their projects. Finally, this study is conducted in the higher education context, it may be tested if similar strategies also work for K-12 education levels as well.

6 Conclusion

This research provided online learning activities to overcome the difficulties of learning during the COVID-19 pandemic. Block-based programming and working in pairs were used to develop CT abilities of freshmen enrolled in the Innovation in Educational Technology and Mass Communication course. We classified the students into three groups: high-, medium-, and low-performing students. In this study, we classified CT abilities into four components: decomposition, pattern recognition, abstraction, and algorithm design. The results show that the students have an increase in the post-test results in all the components, a great improvement in decomposition and algorithm design, and a small improvement in pattern recognition and abstraction. Both males and females have a significant improvement in the test ($p = 0.00$). However, females have slightly more average post-test scores than males. All types of students have an increase in the post-test results in all the CT components. The average scores of high- and medium-performing students are similar, while the average scores of low-performing students are the least. However, it was found that the largest increase in performance was reported for the low-performing students. The students could also make creative projects that meet the criteria set. They could work together to achieve their goals, although they did not meet each other as they did in the classroom. It can be concluded that online learning activities can raise the CT abilities of all types of students.

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