The Development of a Teacher's Guide for English Proficiency Games

Monica MORENO[a,b*], Dominique Marie Antoinette MANAHAN[b], Marika Gianina FERNANDEZ[b], Jose Isidro BERAQUIT[b], Nicole BUGAYONG[b] & Ma. Mercedes T. RODRIGO[b]
[a]*Department of Education, Ateneo de Manila University, Philippines*
[b]*Ateneo Laboratory for the Learning Sciences, Ateneo de Manila University, Philippines*
*mmoreno@ateneo.edu

Abstract: English proficiency is vital in today's global employment market. Digital games have been shown to help improve learners' language competencies. However, it is sometimes difficult for teachers to maximize digital games as educational resources. In this paper, we discuss the development of a teacher's guide as a companion to the digital games *Ibigkas!* and *Learning Likha.* Both games are intended to help improve the English proficiency of Filipino learners from 9 to 12 years old.

Keywords: teacher's guide, digital games, English proficiency, second language learning, reading comprehension, Filipino learners

1. Introduction

English is the world's second largest native language, the official language in 70 countries, and spoken in countries responsible for 40% of the world's total GNP (Torres, 2019). Thus, mastery of English is critical for international communication, business and science. However, acquiring English as a second language can be daunting for learners. Such is the case in the Philippines where, despite the wide use of spoken and written English, many young Filipinos have inadequate command of English. When tested in 2015 and 2016, Filipino university graduates averaged a Common European Framework of Reference of Language (CEFR) score of B1, achieving English proficiency marks lower than the CEFR B2 proficiency target set for high school graduates in Thailand and Vietnam (Romero, 2018). Furthermore, many public elementary school students have average to poor mastery of English (Ocumpaugh et al., 2018). To help improve English proficiency, teachers can make use of digital games, which have been shown to improve language skills such as listening, vocabulary, and grammatical accuracy (Sykes, 2013). Teachers are positive about the idea of using digital games for teaching, and are aware of their benefits. However, many encounter obstacles in integrating games into the teaching process (Felicia, 2009; Wastiau, Kearney & Van Den Berghe, 2009). This study describes the development of a teacher's guide as a companion to two games, *Ibigkas!* (translated as "Speak Up!" in English), and *Learning Likha,* which are intended to help improve the English proficiency of 9- to 12-year old Filipino learners.

2. The English Proficiency Games

Two digital games were developed to help improve specific English literacy skills. The first game, *Ibigkas!,* focuses on the recognition of English words, specifically students' knowledge of rhymes, synonyms, and antonyms. It is a drill-type mobile game that can be played in single player or multiplayer mode. When in multiplayer mode, the game makes heavy use of collaboration and teamwork. All players must have mobile devices connected to a network. To start the game, one must act as the game host and select the content to be used -- whether rhymes, synonyms or antonyms. See Figure 1 for the Ibigkas! Mobile game settings interface.

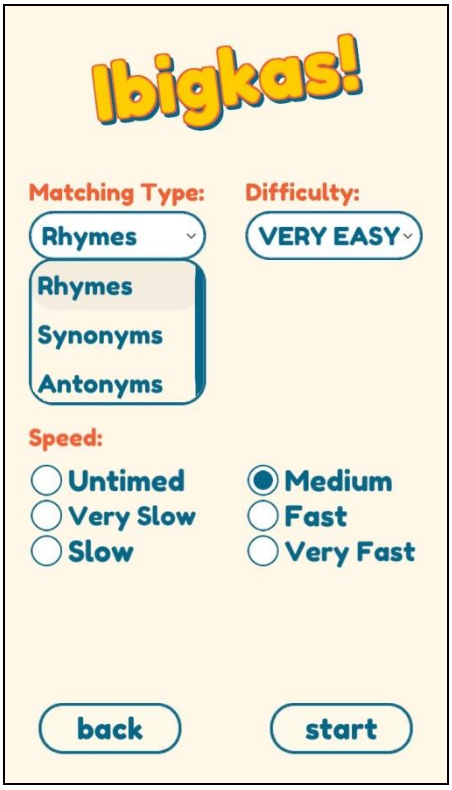

Figure 1. Ibigkas! Mobile: Game Settings

Each player then receives three different word choices on their device. Only one receives a target word which randomly appears on a screen. The player that gets it has to say the word aloud (hence the game's name) for the other players to hear. All players then have to check their word choices to see which one is either a rhyme, synonym or antonym of the target word. See Figure 2 for an illustration. There can only be one correct answer. The player with the correct match shouts out the answer and taps it on his screen. Once the correct answer is tapped, the screen flashes green, and a new round begins.

Figure 2. Ibigkas! Mobile: Mechanics

Ibigkas! also has a card game version with the same educational goals and collaborative style, albeit slightly different game mechanics. This was developed to answer the need for a technologically-independent version for school teachers who had limited access to mobile devices. Figure 3 shows a portion of the set up of the target word cards and answer word cards.

Figure 3. Ibigkas! Card game

The second game, Learning Likha, is a narrative-centered mobile game that targets the comprehension skill of noting explicit details through written, oral and visual language. Here, the gameplay is based on the story of the main character Likha, and her friend Taro the tarsier. Likha and Taro need to help their bandmates prepare for town festivities by fetching their indigenous Filipino musical instruments from different shops in the town. A player immerses himself in the narrative by first typing in his name as a friend of Likha's. Thereafter, as the game progresses, the player is periodically asked to help Likha and Taro by selecting from a town map the correct shop where a specific instrument may be found. Players are aided by written descriptive details about the shop, as well as spoken dialogue. See Figure 4 for the town map's screen.

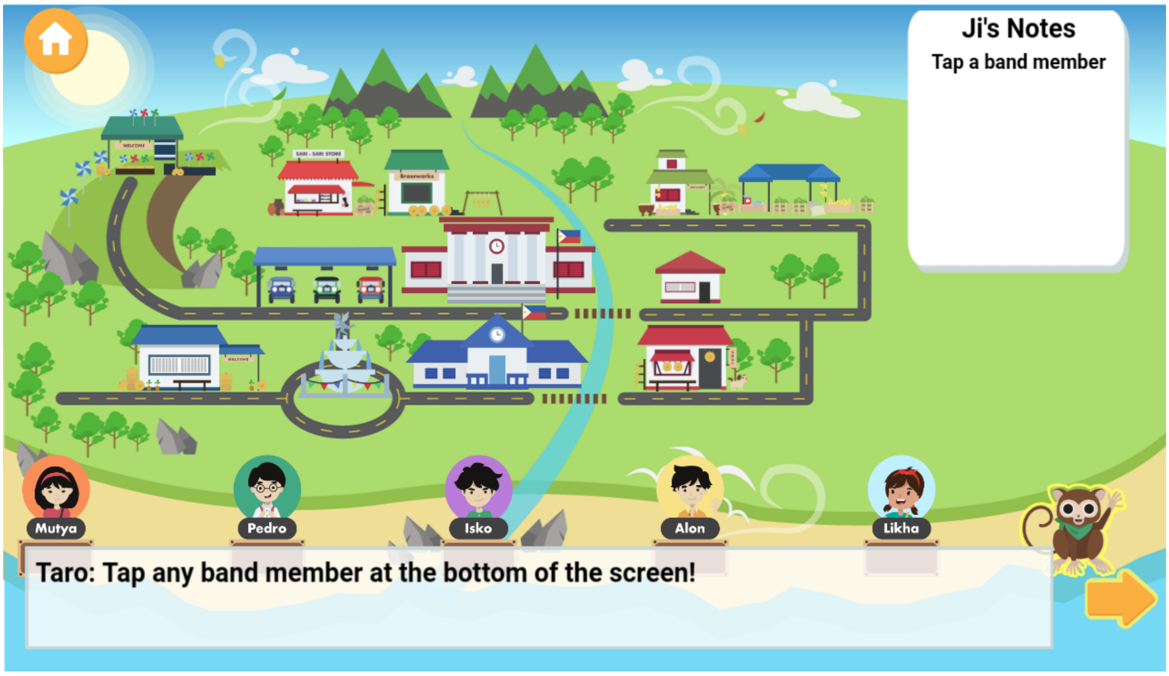

Figure 4. Learning Likha – Town Map

Once the right shop is selected, the player listens to a dialogue between Likha and the shopkeeper in which the musical instrument is described. See Figure 5 for an example.

The player then selects the correct instrument from among three choices, aided by written descriptions on the game screen. The story moves on in this manner until all instruments have been collected for each bandmate and they can all play together in the town festivities.

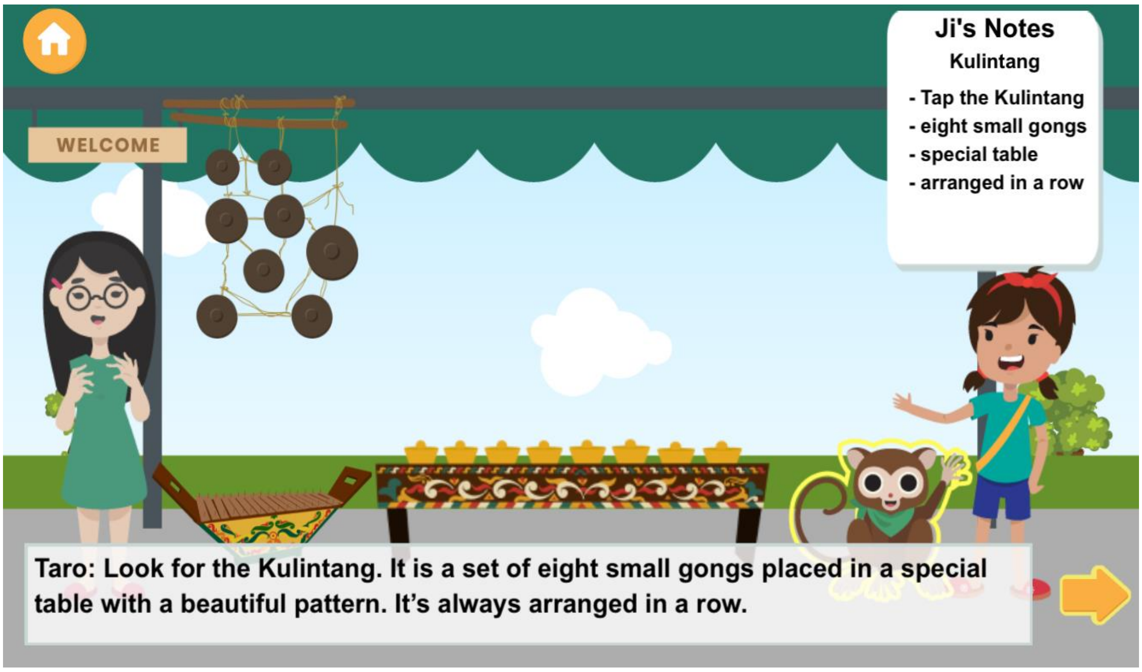

Figure 5. Learning Likha – Inside the shopkeeper's shop

3. User Test Feedback

The games were tested on learners in Grades 4, 5 and 6 from two public elementary schools and a tutorial center that catered to underprivileged students. A total of 85 learners and 39 public school teachers played the *Ibigkas!* mobile game (Rodrigo, Ocumpaugh, Diy et al, 2018; Banawan, Lumapas, Ocumpaugh et al, 2019), while 91 learners tried out *Learning Likha (*Moreno, Manahan, Fernandez et al, 2019; Rodrigo, Agapito & Manahan, 2019).

Teacher and student reactions towards both games were generally positive. The students enjoyed the collaborative nature of *Ibigkas!*, and they said they acquired new words through social learning. In addition, the students enjoyed the narrative content and challenges of *Learning Likha* and were motivated to complete the game. Teachers also enjoyed the games and appreciated their educational goals. These findings suggest that the games can be applied as relevant and engaging educational resources in the context of English language learning.

In this light, a guide to help amplify the games' educational impact was deemed to be useful for teachers. Detailed teaching guides are effective in developing classrooms by presenting strategies that work with specific materials to best deliver a learning objective (Bridge, 2018). Thus, this would enlighten teachers on how to best use the games to maximize English proficiency in 9-12 year old Filipino learners.

4. The Design Process

To conceptualize the teacher's guide, we conducted a group interview with 7 teachers from AHA Learning Center, a center that gives free after-school programs to disadvantaged learners. We combined a focused group discussion with a co-design workshop to gather feedback and ideas on using the *Ibigkas!* Mobile, *Ibigkas!* card game and *Learning Likha* as learning tools inside the classroom so that a teacher's guide could be developed for these three games. A lead facilitator first welcomed the participants and stated the objectives of the session. Then, an instructional video introducing *Ibigkas!* Mobile game and demonstrating the mechanics for the single player mode was shown to the participants. After this segment, the research team distributed mobile phones and tablets to each participant for them to try playing *Ibigkas!* Mobile in single player mode. Then, the participants were asked to group into triads so they could try playing *Ibigkas!* mobile in multiplayer mode.

4.1 Focused Group Discussion

After the participants played *Ibigkas!* in single player and multiplayer mode, they were asked what they thought about the game, which part of the lesson would the game/s be useful for, and how they would use the games as part of the lesson or class activity. The participants shared their answers with the group while the research team took notes. The questions were posed again after the participants played the *Ibigkas!* card game and *Learning Likha*. After the gameplay, the lead facilitator led the discussion of the group on their thoughts and ideas on how to maximize the games inside the classroom.

4.2 Co-design Workshop

After the focused group discussion, the participants were grouped into pairs or triads. Provided with paper and pens, each small group brainstormed with their teammates on possible classroom tasks using all the games. The following guide questions were used:

1) What do you think is the purpose of the material?
2) For what specific topics or subjects would the material be appropriate?
3) How would you use this material in a lesson?
4) Can you devise a lesson plan where this could be used as the:
    a) Motivation or introduction
    b) The main lesson (used to teach the concept)
    c) Follow-up activity
    d) Evaluation

Thirty minutes was allocated for this segment. When the time expired, each pair/group presented their draft lesson plans. Their outputs were then collected and acted as a reference for the creation of the Teacher's Guide. We saw that their workshop outputs largely focused on creating activities for the *Ibigkas!* card game, perhaps to lower barriers to participation. The teachers felt that this material was very flexible and could be appreciated by learners from Grades 3 until 5 (8 till 10 years old) for various purposes -- learning about synonyms and antonyms, and using words from the card game to expand their spoken and written vocabulary. One group focused on *Learning Likha* as a material to teach the following of directions. The workshop outputs were in the form of lesson plans that outlined the sequence of activities for each learning objective. All lesson plans had a motivation phase and a group activity which made use of either the game itself or some aspect of it (e.g., some *Ibigkas!* game cards). Some lesson plans contained follow-up or assessment activities. Table 1 is a sample lesson plan from the workshop:

Table 1

Sample Workshop Output

Grade, Topic	Grade 3, Synonyms and Antonyms
Objective/s	At the end of the lesson, the students should be able to: 1. Differentiate synonyms from antonyms 2. Cooperate with their group mates while playing with the Ibigkas! Card game 3. Play a modified "Trip to Jerusalem" (A game wherein a group of 4or more players dance around chairs, which are fewer than the number of players. The goal is to be able to sit on one of the chairs when the music stops. For each round, a person who was not able to sit will be eliminated, and a chair will be removed.) using the Ibigkas! cards
Motivation	• Show things and let the students give adjectives that would describe these. Have them add words and encourage them to give other adjectives. • Ask them to point words with the same meaning

	• As them to give a pair of words that are opposite
Lesson Proper	1. List the antonyms in a column, and then synonyms in another one. 2. Write “Antonyms” and “Synonyms” above each column 3. Ask them the definition of the two words
Game/Activity	1. Divide the class into two groups. Give them the set of cards - antonyms and synonyms 2. Give instructions.Play the game. Ask for help for additional facilitators> Instead of using chairs, students will have to find the words that are the antonyms or synonym of the word they have after the music stops
Generalization	• Ask the kids to say what the lesson was about and give examples for each
Quiz/Assessment	• Paste cards on the board and ask them to write their antonyms or synonyms

5. The Teacher’s Guide

To fill in the gaps in the lesson plans and ensure the use of all games in the classroom, the research team first broke down the workshop outputs into separate lessons. For instance, the workshop output above described lessons to teach synonyms and antonyms. At the end of this lesson, students were expected to be able to use adjectives and differentiate synonyms from antonyms. For the teaching guide, these learning objectives were broken down into three separate lessons -- “I Can Describe Things”, “Words Can Have Similar Meanings”, and “Words Can Have Opposites”. In the same workshop output, *Ibigkas!* cards were used as a word bank for a modified “Trip to Jerusalem” game. The lesson ended with self-generation of antonyms and synonyms using the cards as target words. In the guide version, these activities were re-classified into another lesson called “Building A Wide Vocabulary”, which builds upon previous lessons that present synonyms and antonyms separately. Other tasks were shaped around these activities to lengthen exposure to the topic. Finally, activities using *Learning Likha* and *Ibigkas!* Mobile were also added to complete the teacher’s guide. The full guide is available at http://penoy.admu.edu.ph/~alls/ibigkas-downloads for free. Table 2 presents an excerpt from the teaching guide’s version of the workshop output above.

Table 2

Excerpt from Teacher’s Guide version

GRADES, TOPIC	Building a Wide Vocabulary, Gr 1 - 6
OBJECTIVES	Distinguish a synonym from an antonym
STRATEGIES	***Presentation*** 1. Place one card from each stack, as organized according to the same symbols, in different places around the classroom. Keep the rest of the stack. 2. From the stack on-hand, randomly give students one word card each. Play music and have students dance in a circle. Stop the music arbitrarily, and

	wait for students to go to the card that is an antonym or synonym of their word. Students who stand in the wrong place (e.g. have the wrong synonym or antonym) will be asked to step out of the circle. 3. Rearrange the posted cards around the classroom. Have students return their word cards to the stack. Shuffle the cards, then hand them out randomly again to the students. 4. Play the music again, and repeat steps (2) until (5). Remove one or two of the cards posted around the classroom, and repeat steps (2) until (5). Stop the game when there are few students left. ***Extension Activity 1*** 1. Shuffle the antonym cards. Distribute these among the students and teacher face-up (i.e. showing the word). The cards are arranged face-up in front of each player. The teacher displays two cards. If they are antonyms of each other, they are placed side by side as two columns. If they are synonyms, they are placed one underneath each other in a column. If they are not related, they are spaced apart. 2. The next player turns up two cards. If any are related to the previous cards as a synonym or antonym, this new card is placed in the appropriate column. If the new cards are related to each other, they are placed side by side, or underneath each other, in new columns. If they are not related to any card at all, they are spaced apart. 3. Step (3) is repeated for each player, until all cards have been laid out. The class now checks each card, looking at the back of each to see if the symbol is the same. Students choose two antonyms and two synonyms, and use each in a sentence. Usage in a paragraph is optional.

The entire guide is structured to scaffold the interaction between the teacher, students and materials, and promote the following benefits (Bridge, 2018):

Support of student mastery and teachers' pedagogical knowledge. The teacher's guide contains the important elements of a detailed lesson plan (Murray, 2002). It provides information about the topic or lesson objectives, recommended grade levels and the materials needed to carry out the lesson. Instructional procedures are grouped by function -- a set of presentation instructions (which also includes motivation tasks), followed by a set of extension activities. The latter are arranged from simple to complex and can be used either as follow-up activities to increase student exposure to the topic or as assessment tasks. These activities include both group and individual work. This way, teachers can focus on student mastery without having to brainstorm about other activities to give.

Increased opportunities for students to improve a core set of skills in a more dynamic classroom environment. *Ibigkas!* and *Learning Likha* were originally developed to improve the English proficiency of Filipino learners. The games focus on specific language skills -- word recognition in the form of rhymes, synonyms and antonyms, following directions, and comprehension in the form of noting details. The topics and activities in the guide center on the awareness and use of these skills as group and individual tasks to suit various teaching-learning situations and provide opportunities for interaction.

6. Conclusions and Recommendations

Apart from the playing of games themselves to deliver educational content, some teachers need support on how particular games can best be used. In this light, a teacher's guide on the *Ibigkas!* mobile, *Ibigkas!* card game and *Learning Likha* game was developed to give teachers ideas on how to use the games in presenting a lesson, as a motivational activity, or as a group activity. The guide is meant to serve as a companion to the three games, but by no means is it definitive. As teachers become more organized and confident about using the games, they can eventually create their own procedures, tasks, and be more innovative as to how they would support their students' learning of English.

It is recommended that the use of the teacher's guide be monitored through systematic observations of the teachers' implementation of the activities inside the classroom. Its effects on teaching strategies, student engagement, and English language proficiency skills would be an interesting topic for future study. Since the study respondents were limited to teachers from only one learning center, it is recommended for the testing and development of the teacher's guide to be done with more teachers from different regions of the Philippines.

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WORKSHOP 4 - The 7th Workshop on Technology-enhanced STEM Education (TESTEM Workshop)

Effects of the Interdisciplinary Robotic Game to Elementary School Students' Abilities of Computational Thinking and STEM

Hsin-yin HUANG [a*], Ju-ling SHIH[b], Shu-hsien HUANG[c], Jyh-Chong LIANG[d]
[a] *Department of Information and Learning Technology, National University of Tainan, Taiwan*
[b] *Graduate Institute of Network Learning Technology, National Central University, Taiwan*
[c] *Department of Information Management, National Chin-Yi University of Technology, Taiwan*
[d] *Program of Learning Sciences, National Taiwan Normal University, Taiwan*
d10655004@gm2.nutn.edu.tw, juling@cl.ncu.edu.tw, shushein@gm.ncut.edu.tw, aljc@ntnu.edu.tw

Abstract: In 21st century, problem solving, computational thinking (CT) and collaborative skills are essential skills to achieve. In this study, problem-solving aptitude including five CT dimensions and STEM attitudes were examined through questionnaires. Total of ninety-nine 5th-graders were involved in the interdisciplinary robotic game <STEM Port>, which is designed to enhance the effectiveness of the new learning structure in the context of Great Voyage. It is found that CT dimensions has intersected correlations to the STEM aspects. Interdisciplinary education has positive effects to the students, and the curriculum would lead them to have better performance in the complex problem-solving situations.

Keywords: Interdisciplinary robotic game, game-based learning, computational thinking, stem education.

1. Introduction

The application of robotics game in learning is one of the various learning technological advancements that have been highlighted in recent years. The robotic is a unique learning tool which could offer hands-making and fun activities. Therefore, the interdisciplinary education of CT and STEM has become the world trend. CT is regarded as one of the basic key skills of fundamental problem solving skills beyond the computing. Many countries aim to develop students' CT skills for improving problem-solving skills through interdisciplinary curriculum (Bocconi, Chioccariello, Dettori, Ferrari, & Engelhardt, 2016; Shih, Huang, Lin, & Tseng, 2017). We designed interdisciplinary Robotic Game to stimulate students' skills of CT and STEM due to most robotic game that was designed for just one disciplinary or single activities. This isn't the same as the complex surroundings in real life. CT includes five basic dimensions, such as algorithm, evaluation, decomposition, abstraction and generalization; and STEM refers to science, technology, engineering, and mathematics. Both usually integrate problem-based learning concept (PBL) to cultivate learners' problem-solving skill in real life.

In order to enhance students' learning motivation and to observe their CT skills and STEM performances, we used an interdisciplinary robotic game <STEM Port> to allow the students to apply their existing knowledge, CT and problem-solving skills to win the game. The game is designed for the students to use block coding to control the robots to navigate on the big map to the predicted locations. Students discuss how to control the robot to the right location and whether to trade or fight. Teachers often use competitive psychology to stimulate students' learning motivation and enhance learning effectiveness (Lin, Huang, Shih, Covaci, & Ghinea, 2017). Therefore, the strategic mechanism, which allows the learners to cooperate and compete with other players in order to achieve the goals. The use of interdisciplinary robotics game improve the students' problem solving and CT skills in this study. Results of this research suggested that the pedagogical value of robots lies in making learners to get interdisciplinary knowledge to identify and solve problems. But it's could not apply to all fields.

2. Related Work

2.1 Game-based Learning

Game-based learning (GBL) refers to an educational system that implements game or game-elements as a motivational driver for students (Park, Kim, Kim, & Mun, 2019). It is perceived as a potentially engaging form of supplementary learning that could enhance the educational process and has been used at all levels of education including primary education (Hainey, Connolly, Boyle, Wilson, & Razak, 2016). Passive learning becomes more active (Liu & Chen, 2013; Papastergiou, 2009), and children learn to construct knowledge in the process. Students explore the issues assigned by teachers from various perspectives, work with peers to find answers, and then develop the skill to communicate, coordinate, and do creative thinking and problem solving. Game activities involve problem solving spaces and challenges that provide learners with a sense of achievement (Qian & Clark, 2016).

Traditional games like Scrabble and chess are examples of appropriate vehicles for evoking the higher-order skills that are necessary for effective problem-solving. It also promote learning in an engaging and entertaining manner and to underpin the skills and attitudes of CT (Apostolellis, Stewart, Frisina, & Kafura, 2014). Games provide learning opportunities and learners learn infinitely more such as to take in information from many sources and make decisions quickly; to create strategies for overcoming obstacles; to understand complex systems through experimentation.

While implement game mechanisms and elements in activities, such as scoring, ranking, getting badges, doing competition and interaction, can turn the entire teaching activity into a gamified activity (Curzon, Dorling, Ng, Selby, & Woollard, 2014; Perrotta, Featherstone, Aston, & Houghton, 2013). Motivation is the most important factor that drives learning. The definition of motivation is a learners' willingness to make an extended commitment to engage in a new area of learning (Gee, 2003).

2.2 Computational Thinking

CT represents a cognitive ability to apply fundamental concepts and reasoning that derive from computer science in general and computer programming/coding in particular, including real life activities and to solve daily life problems. As a cognitive ability, CT was argued to be one of the most important skills in the 21st Century (Mohaghegh & McCauley, 2016), and should be fostered in childhood (Tsarava, Moeller, & Ninaus, 2018; Wing, 2006).

The skill of abstraction is a way to accelerate the efficacy of thinking, analyzing, and taking actions. Problem solutions can be produced through analyzing problems, making judgments and decisions, and integrating tools and resources to carry out. The purpose is to help students to solve problems by assessing the appropriate tools and strategies to be used in specific situations. CT has been studied by many scholars since Wing put forward it, and Selby, Dorling, and Woollard (2014) defined the five core concepts: *A) Algorithm* is to develop rules that can solve similar problems step by step and be implemented repeatedly. *B) Evaluation* is the process of ensuring an algorithmic solution is a good one. *C) Decomposition* is a way of thinking about problems, algorithms, artefacts, processes, and systems in terms of their parts. The separate parts can then be understood, solved, developed, and evaluated separately. This makes complex problems easier to solve and large systems easier to design. *D) Abstraction* is another way to make problems or systems easier to think about. It simply involves hiding details and removing unnecessary complexities. *E) Generalization* is a way of quickly solving new problems based on previous problems solved. It is to take an algorithm that solves specific problems and adapts the algorithm to solve a whole class of similar problems. Generally speaking, CT is a type of analytical thinking that employs mathematical and engineering thinking to understand and solve complex problems within the constraints of the real world (Voskoglou & Buckley, 2012). To help produce future generations with these competencies, we should teach these concepts at a young age, and continue using a spiral curriculum to reintroduce elements of CT in interdisciplinary and different years (Apostolellis et al., 2014).

2.3 STEM and Robotic Game

Existing research mentioned the importance of foundational coding skills for STEM learning by suggesting young children to learn various skills and concepts through playing apps and computer games (Pila, Aladé, Sheehan, Lauricella, & Wartella, 2019). STEM is a cohesive learning paradigm based on real-world application (Afari & Khine, 2017). It is not limited to those subjects which often includes other domains such as social studies, English language arts, art, and more (Breiner, Harkness, Johnson, & Koehler, 2012). It uses an interdisciplinary approach (Barak & Assal, 2018) by breaking down the "silos" of discipline-independent teaching that students often encounter throughout the day, and making connections to the context of the real world (Breiner et al., 2012; Honey, Pearson, & Schweingruber, 2014).

Robotics provides a very rich and attractive learning environment for STEM education (Barak & Assal, 2018). Robot is a learning tool that enhances student experiences through hands-on, mind-on learning. It also provides a fun and exciting learning environment because of its hands-on nature and the integration of technology (Afari & Khine, 2017). The hands-on, project-based and goal-oriented learning experience that an educational robotics competition provides has long-lasting impacts on students' learning and motivation for further exploring in STEM or STEM related fields (Eguchi, 2016). Educational Robotics creates an environment where children can interact with the context and work with real-world problems.

3. Research Design

3.1 Game design of <STEM Port>

<STEM Port> is an interdisciplinary game designed by the research team which is based on the historical context of Great Voyage. In the game, a big map in the size of 600 x 400 cm showed the geographic area covered in the Age of Discovery in the 17th century (Figure 1). Students were divided into five groups and role-play one of the five countries such as England, Netherland, Portugal, Spain, and France. Robots represent the ships of respectively countries by colored lights. The players took turns to move their ships by block coding to go to designated colonies to trade for spices. Whichever country completed its spice tasks first won.

Learners should apply their interdisciplinary knowledge and CT skills to complete the tasks of the game. They "decompose" the task requirements and rules of the game; try to obtain the goals in limited rounds. Then, apply "algorithm" skills to calculate the distance, angle, of the robots, and do "abstraction" to turn the measurement into coding blocks. They "evaluate" the differences between the predict and the actual paths, and make decisions to their actions in the next round. As the students solicit the main strategies for the game, they can "generalize" the patterns to different rounds and quickly use the resources around them to solve the problems.

This robotic game mechanism required the students to use block coding (Figure 2), in this case was mBlock, to control robot ships to move forward or turn. They had to estimate the distance to go to their destinations, and used the limited game points to move the robots. In the navigation process, they had to decide whether they would do trading or going into battles. By using simple and basic commands, the students would focus on using the coding skills to solve the game problems and to complete their tasks. Thus, a coding-based and problem-solving-oriented CT were functioned at the same time in the game. This programming environment can cultivate students' CT abilities during programming activities by enabling them to concentrate on the problem solving process as they learn (Kong, Chiu, & Lai, 2018). Robotics offer a broad range of challenges and opportunities for learners to develop disruptive thinking, innovative ideas, and other learning skills needed in the classroom and outside the school (Constantinou & Ioannou, 2018).

Figure 1. Game design of <STEM Port>.

Figure 2. mBlock coding program.

3.2 Computational Thinking & STEM Questionnaire

In this study, four classes of 5th graders in an elementary school in southern Taiwan participated the activity. There were 65 boys and 34 girls with a total of 99 students. Each class played an individual game in four different days. This study used mBot robots and navigation route prediction records as well as computational thinking and stem questionnaires as research tools to assess learners' CT performances and STEM attitudes in the robotic game.

Before the start of the game, the CT questionnaire was distributed to the students as the pre-test. Then, the students played the game <STEM Port> for about 60 minutes. After the game was finished, post-test CT and STEM questionnaires was conducted. The results of the questionnaires were cross-analyzed with the students' gaming outcomes with regressions in CT and Pearson Correlation Coefficient in STEM.

The CT questionnaire used in this study was newly designed based on the relevant literature (Atmatzidou, Demetriadis, & Systems, 2016; Curzon et al., 2014; Dagienė, Sentance, & Stupurienė, 2017; Selby, Dorling, & Woollard, 2014) and taking the principles of International Challenge on Informatics and Computational Thinking as the main reference. To construct a valid and reliable questionnaire for computational thinking, two faculty members specializing in education validated the items twice (Chu, Liang, & Tsai, 2019).

The questionnaire includes five dimensions, each with 5 questions. For example, "I will try to dissect the big problems into small parts" is to test out the students' perception to the Decomposition skills; "I will try to think of the most efficient way to solve the problems" is to test out their Evaluation skills; "I will figure out the detailed steps for problem-solving" is for the Algorithm skills; "I will try to find out the key factor of the problem" and "I will try to use previous experience to solve new problems" is to test their Abstraction and Generalization skills respectively. The analysis showed that the correlation coefficients of the overall divergence ranged from 0.42 to 0.61, and both reached significant ($p<.01$), which was a medium-high correlation, indicating that each dimension has a certain degree of correlation. The reliability Cronbach' α of this scale is 0.91. The reliabilities for the five dimensions ranged from 0.74 to 0.83. The pattern coefficient of all dimensions is above 0.4. It shows that the reliability and validity of questionnaire is good.

The STEM questionnaire used in this study is designed based on the relevant literature (Lou, Diez, Hsiao, Wu, & Chang, 2009; Unfried, Faber, Stanhope, & Wiebe, 2015).The questionnaire includes three dimensions: Mathematic, Science, and ET (Engineering and Technology). There are 9 questions in Mathematics, 9 questions in Science and 12 questions in ET with total of 30 questions. For example, "In the future, I could do harder math problems." is to test out the students' perception to the Mathematics attitude; "Science will be important to me in my life's work." is to test out the students' perception to the Science attitude. "I am good at building and fixing things" and "I would like to use creativity and innovation in my future work" is to test out the students' perception to the ET attitude. The reliability Cronbach's α of these three dimensions scale is ranged from .568 to .897. The values is above .5。

Two invalid copies of the questionnaire were excluded which ended up with 97 copies for analysis. The analysis is to answer the research questions: "Could this game improve the elementary school students’ computational thinking skills?” and “What is the relationship between <STEM Port> game and students’ computational thinking skills and STEM attitude?”

4. Result and Discussion

4.1 Computational Thinking Skills

In order to explore how the students’ CT skills influence their gaming outcomes, regression analysis was conducted using the five dimensions of the CT skills as predictors (Huang, Huang, Shih, Tsai, & Liang, 2019). Overall speaking, the CT skills of LA (low algorithm) group were not related to the outcome, therefore, only the CT skills of HA (high algorithm) group were briefly discussed in the following explanations.

In the beginning Round, the analysis result showed that HA group's Decomposition skill was positive (t=2.96, p=.004), indicating that if the students know how to dissect the problem into small parts, they can have better performance in this interdisciplinary robotic game. As such good performance, the HA group also could dissect the next path into some parts well and get the right location. Thus the decomposition is typically discussed in terms of breaking apart problems into manageable parts, so the complex problems can be broken into smaller parts by HA group in the <STEM Port>(Rich, Binkowski, Strickland, & Franklin, 2018).The analysis result of the Generalization skill was negative (t=-1.94, p=.057<.1), indicating that making reference of their current strategies to the new round was not what the students should do at this stage. In Round 2, the analysis result of the HA group's Generalization skill was negative (t=-1.64, p=0.106), indicating that the students were still familiarizing with the game and programming skills.

In the end Round, the analysis result of the HA group's Decomposition skill was negative (t=-3.46, p<0.001), which is different from Round 1, indicating that the Decomposition skill was not as important at the end stage since they were supposed to be very familiar with the game mechanism and programming. However, the result of Evaluation skill was positive (t=2.25, p=0.029), indicating that being able to know what strategies were good or bad for their victory, and to apply correct strategies became the most important at the end of the game.

The results showed that this activity was helpful to explore the functions of the CT skill dimensions of the students. For the HA group, and the students’ skill of Decomposition and Evaluation were closely correlated to their gaming outcomes. Generally speaking, students with high algorithm skill performed better than those with lower algorithm skill. Algorithmic thinking is the core element of CT, and is difficult for the LA group. It is our aim to plan curriculum that would increase students’ algorithmic thinking thus better fill up the gap between the LA and HA students. Based on this result, we aim to further investigate what might influence students’ CT skills in terms of their STEM attitude.

4.2 STEM Attitude

In order to assess how the interdisciplinary robotic game influence students’ STEM attitude with their gaming outcomes, analysis was conducted using the three dimensions of the questionnaire (Table 1). The results of STEM t-test between HA/LA groups (Table 2) indicated that the STEM attitude of HA group was better than LA group.

Table 1. *STEM attitude Cronbach's Alpha value*

STEM	N	Item	Mean	Std.	Cronbach's α
Math	94	9	3.212	.527	.568
Science	94	9	3.063	.784	.865
Engineering/Technology	94	12	3.791	.698	.897

Table 2. *The STEM attitude t-test of HA group and LA group*

STEM	Std. Error	t
Math	.199	2.252*
Science	.191	2.378*
Engineering/Technology	.178	2.339*

*p<.05, **p<.01

4.3 Relationship between CT skills and STEM Attitude

After the game, as shown in table 3, all STEM aspects of the students are correlated with Decomposition and Generalization skills. Engineering and technology are correlated with Algorithm skill. In <STEM Port> students decomposed the entire path into some sections of codes which compose the ship routes, they need to apply all CT skills to solve problems.

Table 3. Correlations between CT and STEM

Fact	N	STEM	Pearson Correlation	Sig. (2-tailed)
Abstraction	94	Math	.147	.157
		Science	.165	.111
		ET	.142	.171
Algorithm	94	Math	.148	.154
		Science	.189	.067
		ET	.261*	.011
Evaluation	94	Math	.113	.279
		Science	.082	.431
		ET	.081	.436
Decomposition	94	Math	.356**	.000
		Science	.213*	.039
		ET	.356**	.000
Generalization	94	Math	.319**	.000
		Science	.223*	.031
		ET	.272**	.008

*p<.05, **p<.01

As shown in table 4, the HA students' math are correlated with Decomposition and Generalization. Engineering and Technology are associated with Abstraction and Decomposition. It indicates that the interdisciplinary robotic game is significant for high algorithm skill students' CT skills in Decomposition, Abstraction, and Generalization. Although the LA students' STEM attitudes are not related to CT, the gaming results show that the robotic game could raise their learning motivation. In particular, the LA students were highly motivated in their problem-solving tasks even without extrinsic rewards and scores.

Table 4. *The Correlations between CT and STEM among High & Low Algorithm skills students*

Group		High Algorithm skill		Low Algorithm skill	
N		64		30	
Fact	STEM	Pearson Correlation	Sig. (2-tailed)	Pearson Correlation	Sig. (2-tailed)
Abstraction	Math	.142	.264	-.152	.421

	Science	.101	.425	-.010	.960
	ET	.264*	.035	-.329	.076
Algorithm	Math	.071	.580	-.107	575
	Science	.012	.928	.188	.320
	ET	.205	.104	.083	.662
Evaluation	Math	.104	.415	-.236	.210
	Science	.057	.654	-.253	.177
	ET	.125	.326	-.330	.075
Decomposition	Math	.265*	.034	.268	.152
	Science	.123	.334	.038	.844
	ET	.318*	.011	.201	.286
Generalization	Math	.271*	.030	.188	.319
	Science	.118	.353	.214	.256
	ET	.152	.230	.313	.093

$^{*}p<.05$, $^{**}p<.01$, ET: Engineering/Technology

5. Conclusion

In this study, the students can obtain the CT skills in the <STEM Port> game. From other research (DomíNguez et al., 2013), students completed the gamified experience and got better scores in practical assignments and in overall performances. Students were excited and immersed in the game. The students learn how to win the game with discussion. The game had received many positive feedbacks from the students. It is likely to reduce distractions, thereby improving the quality of learning beyond what is provided in this activity.

The students need to establish spatial concept, and use their CT skills to complete the tasks. HA group used the Decomposition skill the most in the first round, since they had to try out to dissect the tasks and transformed the route into codes. In Round 2 and 3, they were familiarizing the game mechanism and the coding skills, so their performances tend to be more stable. Until the last round, Evaluation skill started to take effects since they started to use their experiences, resources, and strategies to apply their successful experience to the end. That also indicated that the game was appropriately designed to require the students to apply different CT skills in the game. Reversely, from students' CT skills, it could even predict how the students might perform in the game since the predictors were elicited from the statistics.

In this study, games helped students to integrate and apply the interdisciplinary knowledge and skills (Plass, Homer, & Kinzer, 2015). The robotic learning environment and the pedagogical approach of involving the students in rich assignments of growing complexity were among the major factors that contributed to students' motivation and success in learning the course (Barak & Assal, 2018).

The students with low Algorithm skills cannot achieve as much as those with high Algorithm skills. It is necessary for us to help the students to have better Algorithm skills so that they can accomplish more in the strategic game and problem-solving tasks, and can have better performance in general. More dimensions of CT skills should be reinforced in our pre-activity training. CT courses should be diagnosed with the five dimensions, and make sure students were educated in a more well-rounded CT skills and STEM attitude so that they can have better performance in the complex problem-solving situations(Chen et al., 2017). Concerning the attitude of STEM, we need to foster the LA students' CT skills with informal teaching and learning approaches. The critical purpose of applying CT and sharing its elements with other disciplines is to teach students how to better solve problems and discover new questions in future. While most CT and STEM studies have focused on assessing students' learning achievement in some kinds of activities, one of the major contributions in this study is the proposal of interdisciplinary robotic game learning approach that guides students to complete problem-solving tasks in an effective and enjoyable manner.

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