Enhancing Student Computational Thinking Skills by use of a Flipped-Classroom Learning Model and Critical Thinking Problem-Solving Activities: A Conceptual Framework

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Article History: *Do not touch during review process(xxxx)*

Abstract: This study set out to investigate the potential for increasing Thai undergraduate student computational thinking skills (CTS) by use of flipped-classroom teaching techniques integrated with critical thinking problem-solving activities. The proposed study will use mixed research methods to combine elements of both qualitative and quantitative research approaches. Additionally, the IPO Model was adopted for the study in which there were *input, process,* and *outcome* components. Using this methodology, the input in the process of learning management is the implementation of the learning management model. The outcome is the result of learning with the model. The proposed study's quantitative approach will make use of a questionnaire using a five-level Likert type agreement scale. A panel of seven experts has already been convened to assess the flipped classroom learning management model. LISREL 9.1 is proposed to conduct the descriptive statistical analysis which will include the mean ($\bar{x}$) and standard deviation (S.D.). The contribution to the literature and society from the study is the critical nature of critical thinking problem-solving skills and CT in education and industry. These are thus the initiators of innovation and creativity.

Keywords: Computational thinking skills, creativity, inverted classroom, IPO Model, problem-solving activities, Thailand

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1. Introduction

Today, flipped classrooms have become a popular teaching method for all levels of education and disciplines around the world. In the simplest of terms, a flipped classroom student watches an instructor created or curated video before coming to class and thereafter returns to the teacher-led classroom to explore the new materials in-depth, with classroom exercises used to apply what is used from the knowledge gained from the 'flipped lesson' outside the classroom(DeLozier et al., 2017).Additionally, by the use of gatekeeper quizzes and problem-solving activities, opportunities for solving real-world problems can be achieved (Lo & Hew, 2017; Techanamurthy et al., 2020). Flipped classroom environments have also been proven to increase student participation, while simultaneously shown to create more positive attitudes towards learning (Almodaires et al., 2018; Shih & Tsai, 2017; Smallhorn, 2017).

Furthermore, flipped classrooms have found a comfortable home with digitally empowered, 21st-Century tech-savvy students whose use of smartphones, the Internet, and social media feed their need for active participation (Moto et al., 2018), as compared to passive, teacher-centered, 'chalk and talk' learning lessons from years past. Flipped classrooms also fuel the need for information, communications, and technology (ICT) development mandated under ICT goals set by Thailand's 12th National Economic and Social Development Plan (Baxter, 2017) and precepts outlined under Thailand's 4.0.

Additionally, undergraduate education is being transformed due to the integration of digital technologies into the classroom (Kadambaevna et al., 2021), where the importance of each teacher's learning activities is of crucial importance in assisting students in building their comprehension and learning stimulation. Also, student cooperative classroom activities are the driving force for self-knowledge creation, which has its roots in constructivist-inspired thinking (Almodaires et al., 2018), where knowledge is acquired through content involvement instead of repetition or imitation (Kroll &LaBoskey, 1996). Therefore, flipped classrooms have become a 21st – Century technological digital innovation for educators in which student-centered assigned lectures outside of class and devoting class time to various learning activities is now possible (Glowa& Goodell, 2016; DeLozier& Rhodes, 2017; McGrath et al., 2017).

Moreover, student computational thinking skills (CTS) are gaining greater importance as well, with educators noting CTS's potential in enhancing students' problem-solving skills, which are a prerequisite for the type of skills required in today's technology-driven economies (Saad, 2020). Also, Voogt et al. (2015) have stated that CTS is an element of one's universal competence, which should be added to every student's analytical ability as a crucial element in their education curriculum. The important nature of student CTS was also elaborated on by the Danish scholars Caeli and Bundsgaard (2020) which noted its increasing importance but at the same time detailed the difficulties for educators to teach it and their lack of training in teaching it. This is consistent with CTS research from Taiwan in which Hsu (2019) also noted the "hotly discussed" issue of student CTS education. Likewise, the study also noted the crucial need for CTS educator technological and pedagogical content knowledge training.

From the aforementioned observations and supporting studies, we determined that the use of a flipped classroom has great potential in promoting Thai undergraduate CTS. As ICT and computer science studies play an important role in carrying out daily activities in work and life, their efficient use requires educators to develop student knowledge and skills in computer technology. Furthermore, according to Wing (2006, 2011), computational thinking (CT) should be in every educator's toolkit, as CT involves problem-solving, system design, and human behavior understanding by drawing on the concepts fundamental to computer science. The field of computing is also driven by scientific questions, technology innovation, and society's demands (Wing, 2008).

Although Wing's (2006) seminal essay on CTS was taken as an initiator for multiple programs in bringing computer science to all levels of K-12 education (Lodi & Martini, 2021), it was Seymour Papert in 1980 who used the term '*computational thinking*' for the first time with a different nuance of the meaning. For Papert, CT was the result of his *constructionist* approach to education, where social and affective dimensions are as important as the technical content (Lodi & Martini, 2021).Papert's CT also stressed the computer's importance as a powerful meta-tool for "making the abstract concrete" as well as the assertion that CTS was transferable to other disciplines.

Therefore, CT promotion is potentially possible through the use of flipped classroom methods, including the integration of online learning and digital technology devices such as smartphones and learning management systems (LMSs)(Eppard&Rochdi, ;2017Wang, 2010;Zainuddin et al., 2019). When combined with student preparation outside the classroom, in-classroom analytical problem-solving activities, and complex problem-solving processes based on computer science techniques, we believe that CTS can be increased. However, educators must be willing to encourage learners to engage during learning sessions and assist in the process of solving teacher-led problem-solving exercises. This can then lead to the development of advanced thinking processes, the enjoyment of learning, and the higher critical-thinking processes. Kruger (2013) also added that that *higher-order thinking skills* (HOTS) use concept formation, critical thinking, creativity and brainstorming, problem-solving, mental representation, rule use, reasoning, and thinking logically. This then can lead to a student's ability to understand complex problems by logically connecting different sets of information, which can then provide various perspectives on problem-solving. Therefore, 21st Century educators need to integrate literacy skills, knowledge, skills, attitudes, and mastery of ICT (Handajani et al., 2018; Moto et al., 2018).

2. Literature Review

2.1. The Flipped Classroom

Starting in 2007 two high school teachers in Colorado started using software to prerecord their lectures which could later be used by students to review outside the classroom (Bergmann &Sams, 2009). Initially, they referred to this process as '*pre-broadcasting*' which today has evolved into what is commonly referred to as a '*flipped classroom*' (Noonoo, 2012). However, these flipped classroom pioneers freely admit that the actual idea was articulated in a 2000 article when two Miami University (Ohio) professors who wrote an article on what they called the '*inverted classroom*' for use by their economic studies students (This was before the creation of YouTube in 2005) (Lage et al., 2000). Two decades later the *inverted,pre-broadcasting, or flipped* classroom has become a mainstay for educators willing to embrace technological innovation, educational change, and the desire to overcome technological obstacles when they are confronted with them.

The contention from the flipped classroom pioneers Bergmann and Sams(Noonoo, 2012) is that the best use of an educator's face-to-face time is not doing a lecture in front of their students but instead to be involved with hands-on activities and inquiry- and project-based learning student activities. Moreover, instructor-created video or some other form of modality is best used for the direct instruction segment by students from home which then frees up class time to do important, instructor-supervised classroom exercises. Also, pre-service teachers are exceptionally good flipped classroom teaching candidates as they represent the '*YouTube generation*' and most are excited about the concepts that flipped classrooms can afford. Also, mobile technologies such as smartphones give students 24/7 access to their lessons, which is an important element in the flipped classroom concept. This allows students to choose when and how they're learning content, and when they do come to class, they're going to interact and get more context for the content they're learning (Eppard&Rochdi, 2017; Shih & Tsai, 2017). Flipped classrooms also allow students to participate in meaningful learning activities together with lecturers and classmates utilizing an active learning model, problem-based solving, and collaborative and cooperative activities. Flipped classrooms also emphasize that teachers and learners have a different role than traditional (passive) classrooms (Shih & Tsai, 2017), with teachers taking on a variety of roles inside the classroom using a student-centered learning method (Almodaires et al., 2018; Bishop &Verleger, 2013; Lo & Hew, 2017; Ozdamli&Asiksoy, 2016; Zainuddin et al., 2019). Flipped classrooms also transfer the learning responsibility from the instructor to the student, where there is a blending of direct instruction with constructivist teaching(Bergmann et al., 2014).

Furthermore, according to Eppard and Rochdi (2017), while Bloom's Taxonomy is useful at explaining learning stages and learning types at each stage, the taxonomy does not detail how to utilize each level in a given context. However, flipped learning advantages as it relates to Bloom's taxonomy, is that students are motivated to use *higher-order thinking skills* (HOTS) through flipped classroom activities. Moreover, the preponderance of flipped learning research uses group-based, classroom learning activities, based on *student-centered learning* theories whose foundation can be found in the works of Piaget and Vygotsky(Blake & Pope, 2008; Eppard&Rochdi, 2017). In addition, flipped learning as a pedagogical approach lends itself to *Bloom's Mastery Model*(Bergmann & Sparks, 2019), from which Johnson and Bergman (2018) have written that what is different now from the 1930s and 1940s is technology allows educators to use flipped classrooms in which students have the videos, the resources, and supplemental resources they need to learn the curriculum at their own pace, and it is because of the flipped classroom that mastery is possible. Finally, according to Eppard and Rochdi (2017)*cognitive constructivism* and *social constructivism* are also supported by the flipped classroom and Bloom's Taxonomy. Vygotsky viewed *constructivism* learning as a process that occurs when a student is assisted by others who are more competent in the skills being learned. Thus, learning is optimized by collaboration within the learner's *zone of proximal development* (ZDP). Moreover, Piaget's *theory of cognitive development* is based on a belief that learners are like scientists in which learners "construct" their knowledge which is reinforced as they build their knowledge through their observations and experience(Eppard&Rochdi, 2017).Finally, these theories when applied to the design and development of flipped classroom learning management emphasize the concept of learner-centered learning (Eppard&Rochdi, 2017).

2.2. AnalyticalProblem Solving (APS) Activities through Active Learning

For the study, we propose to develop *analytical problem solving* (APS) activities for Thai undergraduates as a method to develop student problem solving and critical thinking skills, with an emphasis on *active learning* activities. *Active learning* (the opposite of passive learning), has been discussed in higher education at length with some research suggesting that this approach supports critical thinking and problem solving (Zayapragassarazan& Kumar, 2012). Active learning is believed to stimulate students' curiosity, help them cope with learning challenges, build self-confidence and advanced thinking skills, and confidently express their opinions and conclusions. Active learning also enhances student-centered activities and collaboration with other students. Additionally, in a report on active learning by the European University Association (2019), it was suggested that active learning entails a wide range of pedagogical processes that emphasizes the importance of student ownership and activation. Active learning also harnesses the benefits of curiosity-driven methods, research-based/problem-based learning, and diverse assessment practices, from which the student's critical thinking skills are stimulated. Brame (2016) also noted the difficulties in defining active learning but wrote that one feature was a student's effort at actively constructing their knowledge, with HOTS and self-learning key elements linked between activity and learning.

In 2003 for the first time, *analytical problem solving* (APS) appeared in the global educational assessment of 15-year-olds undertaken by the *Programme for International Student Assessment* (PISA) (Greiff et al., 2013), with the definition of APS by PISA describedas the assessment of problem-solving. However, in real-world terms, APS is the implementation of problem-solving by finding problem-solving processes, changing a situation to its intended purpose, finding suitable solutions to problems, and using critical thinking to solve problems. Moreover, APS involves analytical and logical thinking, as well as logical reasoning which leads to the desired outcome. Scholar discussion of these ideas can be summarized from some of the following:

John Dewey has been credited as the first individual to use the term '*critical thinking*' as the name of an educational goal, which he identified with a scientific attitude of mind. He went on to describe critical thinking's importance in problem-solving by stating that "only by wrestling with the conditions of the problem at first hand, seeking and finding his way out, does a student think" (Gibson, 2006, p. 12.). Dewey also stated that the consideration of ICT was a 'primary problematic' in using information effectively in an educational process. This is consistent with Handajani et al. (2018) who also suggested that critical thinking is the ability to understand complex problems by interconnecting information and to achieve multiple perspectives on problem-solving.

Chareonwongsak (2003) has added that critical thinking is the ability to classify elements of a particular thing or subject and find rational relationships between them, while also being able to find the real cause of what happened. Piaget defined '*logical thinking*' as mental procedures that an individual uses when an unknown situation (problem) arises (Karplus, 1977). In everyday life problem solving requires the ability to think using rules and logic to assure that the correct thinking process. Finally, in Indonesia Sa'dijah et al. (2021) explored how both male and female math teachers enacted decision-making processes in teaching HOTS, as HOTS development is crucial to mastery of the four keys associated with 21^{st} Century competencies, namely *critical thinking, creativity, communication*, and *collaboration*(Stauffer, 2020).

2.3. Computational Thinking (CT)

Computational thinking is a fundamental skill related to the ability to analyze, solve problems, design workflow, and understand human behavior. Wing (2011) has also stated that CT is the through processes used in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent. Shute et al. (2017) have also added that CT in education can be defined as the conceptual foundation needed to solve problems efficiently and effectively, with or without computer assistance, with solutions that are reusable in different contexts. Moreover, CT is a way of thinking and acting, which can be exhibited through the use of particular skills. Also, when CT is combined with *science, technology, engineering, and mathematics* (STEM) skills, the analytical thinking capacity of young students can be increased. CT is also a skill that everyone can apply internationally, not just computer scientists who only learn a single science discipline and apply it (Wing, 2006). Kules (2016) also voiced the critical nature of CT and noted CT's complement to critical thinking as a way of reasoning to solve problems, make decisions and interact with our world. CT also has wide applications in the arts, humanities, sciences, and social sciences with great potential in human and society development (Cansu&Cansu, 2019).

2.4. Research Objectives

(1) To develop a flipped classroom learning management model with critical thinking problem-solving ability to promote Thai undergraduate computational thinking.

(2) To examine the quality of the flipped classroom learning model in conjunction with critical thinking problem solving to promote computational thinking.

3. Methodology

This study used mixed research methods (Creswell & Clark, 2017) to combine elements of qualitative and quantitative research approaches (Schoonenboom& Johnson, 2017) and to develop a pattern, which was subsequently divided into two main areas. Additionally, Eseryel's (2002) IPO Model was adopted in which there are *input, process, output*, and *outcome* components. Using this methodology, the input in the process of learning management is the implementation of the learning management model. The output is the result of learning with the model.

Initially, qualitative research was employed to review the literature from the documents and the relevant research; afterward, the information was analyzed and synthesized. This was then followed by the development of the study's model to establish its elements and details related to flipped classroom learning patterns, analytical problem-solving activities, and the promotion of CTS. Further details can be found in Table 1.

Table 1. Analysis of the model development guidelines

Input Factors	Procedures	Results
The development of a flipped classroom learning management model together with critical thinking Problem-solving	The implementation of a learning process consists of two processes that are integrated. These include flipped classroom learning management and critical thinking problem-solving activities as follows: (1) Clarification of learning management guidelines. (2) Study content through digital media. (3) Ongoing learning assessment. (4) Organize learning activities and make sure the process is followed. Thus far, critical thinking problem-solving activities have been identified to include: a. problem identification, b. problem analysis, c. design solutions, d. carry on problem-solving activities, e. check the solution and f. presentations.	The evaluation of the outcome of the learning management model will be based on (1) academic achievement (2) computational thinking ability and, (3) learner satisfaction.

Input Factors	Procedures	Results
activities	(5) Post-study assessment.	

3.1. Input

The input components for a flipped classroom learning management model are as follows:

3.1.1. Flipped classroom learning management model

This phase includes the development of a flipped classroom learning management plan that covers teaching and learning implementation. Moreover, planning, learning design, and strategy are developed. Instructor-led teaching methods and techniques are evaluated as well as objective explanations. The flipped classroom approaches and measurement and evaluation methods are detailed.

3.1.2. Learning activities

Computational thinking learning activities are divided into 2 sessions:

(1) In the self-study session, learning is conducted outside the classroom by study through the use of both instructor-created and online video materials. Each student's LMS also can interact with other classmates for clarification and discussion.

(2) In the classroom learning session, learners apply their self-taught knowledge using hands-on activities involving critical thinking problem-solving.

3.1.3. Learning materials

In this phase, teachers choose appropriate computer tools to use for teaching and learning from an LMS such as Moodle. These can include streaming media, practice/intervention systems, communication systems, and measurement and evaluation systems.

3.1.4. Learning outcome evaluation

Finally, the instructor summarizes the information from the teaching sessions, the observation data, work evaluation, computational thinking ability, and academic achievement.

3.2. Process

The flipped classroom learning management process is as follows:

3.2.1. Clarification

In this phase, 15-20 minutes is allocated to clarify the learning management guidelines, while introducing and explaining the flipped classroom teaching model and the associated learning approaches, assessments, and expected learning outcomes.

3.2.2. Digital content viewing

During this phase, students are assigned digital content consisting of sessions 10-15 minutes in length. From this, learners can self-study outside the classroom before class in preparation for the related classroom activities and assessment quizzes.

3.2.3. Instructor summation

The instructor summarizes the information from the teaching sessions, as well as evaluation of the data from the exercises involved with computational thinking ability. Pre-and-post sessions assessment quizzes should entail 15-20 minutes.

3.2.4. Critical thinking problem-solving activities

Critical problem-solving activities should entail approximately 60-75 minutes of classroom time in which a review of the earners' knowledge is undertaken. By doing this, the instructor can ensure that each student has reviewed the assigned lesson's content.

Furthermore, research suggests that critical thinking problem-solving activities should include some if not all of the following:

(3) Formulation of the problem with the subject to be studied.

(4) Analyze and understand the problem. Gather information and ideas related to the problem.

(5) Design solutions and define the structure, characteristics, and work processes from the use of design tools such as flowcharts, algorithm design, etc.

(6) Programming exercises according to the designed algorithms.

(7) Check the solutions and test and evaluate the solutions until the correct results are obtained.

(8) Present the results of evaluation and algorithms. Summarize, present, and evaluate by sharing opinions.

3.2.5. Post-study assessment

Allocate 15-20 minutes after each classroom session for a post-session assessment quiz from which the results are summarized.

3.3. Outcome

The outcome components consist of the following three elements:

3.3.1. Academic achievement

In this outcome phase, academic achievement, behavior change, and learning experience using the flipped-classroom learning model in conjunction with researcher-created critical thinking problem-solving exercises are assessed.

3.3.2. Computational Thinking Skills Ability Measurement

In this outcome phase, student CTS ability from the flipped classroom and critical thinking problem-solving exercises is assessed by the researchers.

3.3.3. Learner satisfaction

Finally, each learner is allowed to evaluate the flipped classroom learning management model content, the learning activities, and the measurement and evaluation processes.

3.4. Expert Model Assessment

Seven individuals who were teachers at the university level and have expertise in technology and education, computer studies, and teaching and curriculum development were invited to serve on a panel of experts to assess the quality of the flipped classroom learning management model (Figure 1) and proposed student questionnaire (Table 2) (Haqiyah et al., 2021). Through in-depth interviews, the researchers determined that the proposed five-level questionnaire suitability for the model had an IOC value between 0.60 - 1.00, with the results analyzed by the average mean. The questionnaire scale interpretation made use of '5' as a *very positive* response, ‘4’ indicated a *positive* response, ‘3’ was *somewhat positive*, ‘2’ was a *negative* response, and finally, ‘1’ was determined to be a *very negative* response (Rajaram, 2021).

Figure 1. Flipped classroom learning management model with critical thinking problem-solving skills procedures

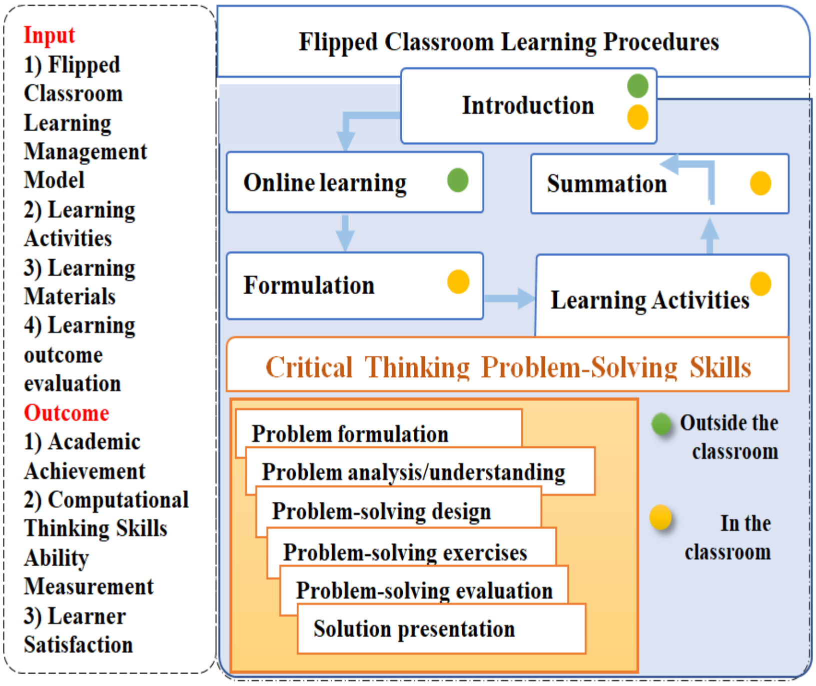

Table 2. Level of the suitability of the flipped classroom learning model according to the expert's opinions

IPO list items	Experts (n=7)		Opinion Level Agreement
	$\bar{x}$	S.D.	
Input, four elements of learning management are appropriate.	4.61	0.40	Greatest
Average of Process	4.61	0.39	Greatest
Process, five flipped classroom processes activities are appropriate.	4.54	0.34	Greatest
Process, six critical thinking problem-solving activities are appropriate.	4.67	0.44	Greatest
The results obtained from all three learning outcomes	4.62	0.45	Greatest
Total Average	4.61	0.41	Greatest

Table 3 presents the teaching process details of the proposed flipped classroom learning management model.

Table 3. The teaching process of the flipped classroom learning management model in conjunction with critical thinking problem-solving activities to promote CT

Procedures		Outside Classroom	Inside Classroom	Operating activities	
Flipped classroom learning	Critical thinking problem solving			Instructor role	Student role
Clarification of learning management guidelines	-			- Recommend and describe the process of flipped learning in and out of the classroom. - Have clear objectives. - Describe clear and detailed learning processes and activities. - Learning preparation where details are presented in the classroom for the first time. - Offer online videos for classroom learning introduction. This is reinforced with the use of flipped learning and the Learning Management System (LMS) by which students can re-watch the classroom videos. - Have students take an assessment test before and after the flipped learning sessions to measure each student's achievement from the use of flipped learning sessions.	- Understand the learning objectives of the flipped classroom learning method and study how to learn through the Moodle LMS. - Give each student an assessment quiz before studying and as well as a CT quiz.
Evaluation: (1) Achievement test scores before studying (2) Competency test scores before studying.					
Tools used: (1) An achievement test before studying (2) A test to measure the CT ability before studying (3) Online video introducing classroom learning and the Moodle LMS system.					
Study content through digital media.				The instructor delivers the content through digital means online. Learning activities are conducted through the LMS. This includes online exercises	Students study content through digital media online, practice learning activities, conduct online Q&A.

Procedures				Operating activities	
Flipped classroom learning	Critical thinking problem solving	Outside Classroom	Inside Classroom	Instructor role	Student role
				and online Q&A.	
Evaluation: (1). Do exercises. (2) Assess participation, use, and interaction on the LMS.					
Tools to use Online video content, practice system, and LMS-based interaction system.					
Assessment during study			√	Take a quiz before learning and review the knowledge to assess which learners have completed their at-home activities.	Take a pre-study test and review the content before entering practice activities. Join the discussion, exchange ideas, and ask questions.
Assessment: Test scores before studying.					
Tool used: A pre-study test.					
Learning activities	1) Problem formulation.			- Create a critical-thinking problem for the subject to be studied. - Each classroom instructor will move from group to group to ascertain where he/she can lend assistance and/or clarification.	Understanding the problem.
	2) Analyze the problem.				Divide the problem into sections and look closely at past patterns and devise a solution to the problem.
	3) Design solutions.				Plan a solution from the beginning to the stage of getting results in a sequence of steps.
	4) Carry out problem-solving activities.				Implement the problem-solving process in accordance with the designed procedures. Find the answer to the problem
	5) Check the solution.				Test and evaluate solutions until correct results are obtained.
	6) Results presentation.				Present ideas and problem-solving procedures. Let others make input and suggestions.
Evaluation: Performance evaluation and classroom observation.					
Tools to use: Learning activities like CS Unplugged and computer programming exercises.					
Evaluation after class				The teacher summarizes the information from the teaching and evaluates the students' results. After which, the students are informed of their testing results and allowed to express opinions (feedback) and listen to suggestions of various classmates to improve future sessions.	Learners take a quiz and evaluate results after each learning session. When all lessons have been completed, the students take: (1) An achievement test. (2) A computational thinking ability test. (3) A course satisfaction test.
Evaluation: (1) Academic achievement score after study. (2) Computational thinking ability score after class					

Procedures		Outside Classroom	Inside Classroom	Operating activities	
Flipped classroom learning	Critical thinking problem solving			Instructor role	Student role
(3) The student's results of measuring and evaluating satisfaction.					
Tools used: (1) A post-study achievement test. (2) Computational thinking ability after study assessment. (3) Student satisfaction questionnaire.					

3.5. Ethical consideration

Ethics approval for the study was obtained from King Mongkut's Institute of Technology Ladkrabang Human Ethics Committee before consultation with experts relating to the questionnaire's design (Pimdee, 2020).Before distributing the questionnaires, we will also give a simple and clear explanation about the purposes of the research and inform each individual that the information we obtain will be confidential and no identities will be disclosed. Furthermore, all data obtained from the survey respondents will be kept in a secure location.

4. Discussion

In the analysis of using a flipped-classroom learning management model in conjunction with critical thinking problem-solving activities to promote computational thinking, it was determined that there were four elements involved. These consisted of the *learning management model* (LMM), the *learning activities*, the *learning materials*, and finally, the *learning results evaluation*. This is consistent with similar findings from Techanamurthy et al. (2020), which indicated the importance of workplace problem-solving skills in initiating innovative and creative solutions.

Furthermore, the flipped classroom management model made use of the following processes/procedures: (1) clarification of learning management guidelines, (2) the study of digital media outside the classroom, (3) continual assessment during the study, and (4) the organization of learning activities.

Combined with the above processes, the critical thinking problem-solving activities identified six steps. These included: (1) Identifying problems, (2) problem analysis, (3) problem-solving design, (4) problem-solving activities, (5) problem-solving review, and (6) presentation of conclusions.

In the post-class evaluation phase, emphasis will be placed on self-learning that is consistent with education theory consistent with flipped classroom education. In the review of the educational theory which demonstrated similarities to flipped classroom model, we felt that the *student-centered pedagogy* in *constructivist developmental theory*articulated by Piaget and Vygotsky to be particularly useful (Mascolo, 2009; Piaget, 1973 Vygotsky, 1978). In *constructivism* thinking, learners '*construct*' their comprehension of the world as a product of their *actions* within it. This is consistent with Vygotsky (1978) who looked at learner development in the context of *social constructivism* and the collaborative nature of learning, based on cognitive functions being the products of social interactions. Finally, even the founders of the flipped classroom made connections between their method and those outlined by *Bloom's Mastery Model*(Bergmann & Sparks, 2019).

Therefore, we identified that the *learning results evaluation* part of the model should include (1) academic achievement assessment, (2) computational thinking ability assessment, and (3) the level of student satisfaction with the model and the flipped classes used to promote CT. CT along with the promotion of critical thinking problem solving is a skill that must be instilled in every youth.

We also contend that computer science education promotes CT, which in turn allows students to apply their knowledge, skills, and experience to life along with the advancement of computer science and technology used in various fields of work, with one expert from this study emphasizing that "Each learning activity and tool must affect the computational thinking ability involved in solving complex problems based on computer science." CT has also been linked to creativity and innovation (Mishra et al., 2013; Repenning et al., 2015).Moreover, flipped classroom teaching should link learning activities and use tools in line with the promotion of CT. It is interesting to note that CT became a 'mainstream' concept in almost the same year that the flipped classroom became 'mainstream' (2006 and 2007). These two highly complementary processes were also introduced shortly after YouTube was founded in 2005. As we can, there has been a technological convergence making each possible, which supports Dewey's much earlier consideration of ICT as a '*primary problematic*' in using information effectively in the educational process (Williams, 2017).

Furthermore, evidence abounds that computers as a problem-solving tool enhance the students' abilities in solving real-world problems involving mathematical modeling (Frejd, 2014; Newell & Simon, 1972). This is also crossed by earlier findings of other researchers for the problem-solving process in general (not only for mathematical problems). Therefore, the study must implement a wide variety of tools for both classroom and non-classroom activities. A good example of this type of 'tool' is the use of an LMS such as Moodle. Measurement and evaluation must have a comprehensive method as well. Another expert from the study presented that activity measurement and evaluation should be behavioral measurements, both individually and in groups, using the Rubric Score mechanism. In the first study period, classroom activities should be also conducted as the learners are probably not aware of the flipped classroom approach to learning management.

In Thailand, Laowreandee et al. (2017) suggested guidelines for organizing activities to promote and develop thinking skills. These included (1) organize cooperative activities in which group members can interact freely and openly, (2) organize problem-solving activities, (3) arrange activities in which there are multiple answers possible but only one correct choice, (4) organize activities that promote problem-solving and critical thinking, (5) organize activities that are not specific to one gender, (6) use questions that promote HOTS, and finally, (7) use a variety of measurement and evaluation methods that are consistent with the techniques and theory.

5. Conclusion

Thus far from the quantitative analysis, it can be concluded that the proposed flipped classroom learning model is an excellent design for critical thinking problem-solving, and the promotion of CTS. Moreover, using digital online content to free class time for instructor-led hands-on learning activities is a well-proven concept successfully implemented globally for over 15 years. Also, flipped classrooms support learning activities involving 'active learning', a recognized method for developing *analytical problem solving* (APS) and CT skills. Finally, flipping a classroom can be a 24/7 operation with students setting the time and place for lesson viewing. When combined with an LMS such as Moodle, session assessment through quizzes is easy. There is also the ability for collaboration and learning by doing. This then leads to a deeper understanding of what is being learned.

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