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Promoting Undergraduate Pre-Service Teacher Computational Thinking

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***Abstract* –The study aimed to evaluate the results of a computational thinking (CompThink) and learning management model using a flipped classroom (FC), combined with critical thinking problem-solving (CTPS) activities. The sample consisted of 57 third-year Thai computer studies (CS) pre-service teachers (PST) (29 = control group, 28 = experimental group). The mean scores of CompThink and Academic Achievement were analysed using a One-way MANOVA. Post-course testing revealed that learning achievement and CompThink were higher than students studying using traditional methods.**

***Keywords* –computational thinking, critical thinking, flipped classroom, student-teacher, Thailand.**

1. Introduction

Multiple studies have pointed out that the nature of work is changing with new 21st-century work environments requiring communications skills, the ability to solve unstructured problems, and the ability to adjust to non-routine manual work [1].

As labor moves from the assembly line, new skills are required as well as how students are prepared to meet the challenges and acquire the skills needed in a new generation of digital knowledge workers.

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Additionally, the need for students to learn how to integrate a multiplicity of information to solve unstructured problems is now paramount in importance [2]. At the same time, these students must be taught the skills necessary in acquiring, thinking critically, and communicating information to others.

In these new environments, computational thinking (CompThink) has risen in importance as an essential skill in solving unstructured problems, interpreting and understanding data, and communicating information to others using information communications technologies (ICT).

Therefore, higher education institutions must make it their priority to promote CompThink among students. CompThink is not only basic computer science and programming concepts [3], but also the thought processes used to formulate problems and their solutions which then can be solved effectively through the use of ICT processing [4].

CompThink also complements critical thinking as a method of solving problems, making decisions, and interacting with the 'real' world [5]. CompThink uses ICT to develop student ideas about abstraction, decomposition, algorithmic design, generalization, evaluation, and iteration. CompThink also has broad applications in the arts, sciences, humanities, engineering, medicine, and social sciences [6].

Therefore, ICT and digital devices have become ubiquitous. This is especially true in education where learning the efficient use of human-computer interaction (HCI) has become known as '*computer-like thinking*' or '*computational thinking* [6]. Additionally, CompThink is now seen as a tool in the development of society and a nation's competitive advantage. However, CompThink is an evolving concept with many differing viewpoints on what it is and how it should be taught and implemented.

One scholar who has tackled the many issues of CompThink is Wing [4] who sees CompThink as an effective computer science tool for problem-solving, system design, and HCI understanding. As such, CompThink should be in all educators' toolkits to help with solving scientific questions, creating innovation, and solving issues of societal demands.

In Thailand, CompThink is promoted at the higher education level due to specific qualifications within Bachelor's degree programs [7]. Moreover, students' learning abilities and skills in solving complex problems combined with critical thinking are also required.

Furthermore, with the onslaught of the global Covid-19 pandemic, Thailand became a quick adapter of online teaching and coaching [8], with many educators using FCs to deliver their newly developed content.

These learning concepts are consistent with teaching and learning management requirements outlined in the Thai Qualifications Framework for Higher Education (TQF: HEd). Therefore, this research also aims to help in the development of guidelines for preparing pre-service computer studies (CS) teachers to teach CompThink, programming, and advanced thinking processes which can then be applied in teaching students from primary school through higher education. Furthermore, numerous studies have pointed out the advantages of using flipped classrooms (FCs) and online teaching even before the global COVID-19 pandemic [9], [10]. Moreover, when CT and CTPS activities are combined with teaching CompThink, the formula for increasing academic achievement (AA) success increases.

2. Literature Review

The following review of the literature provides an overview of the main factors that the authors believe are important in student-teacher computational thinking and critical-thinking skills development.

2.1. Flipped Classroom (FC) Principles

Flipped classrooms have become recognized as a highly effective tool in delivering instruction using online media platforms. FCs are also consistent with the technological pedagogical content knowledge (TPACK) framework, which outlines what forms of knowledge are required by PSTs and in-service teachers to effectively integrate technology [11].

When FCs are combined with the TPACK framework, teachers transform how they spend their time delivering and reviewing specific content [12]. FCs are also a collaborative learning process that uses online learning and practical learning activities. Class learners can learn independently outside the classroom through the use of digital devices such as smartphones and tablets. Learning effectiveness and classroom management can be increased even further when content is delivered and managed through learning management systems (LMS) such as Moodle Cloud, Schoology, or Google Classroom.

Thus, the main focus of the FC is to prepare learners before they enter the classroom, after which classroom time is spent practicing learning activities that promote collaborative learning. This is consistent with scholars such as Binheem et al. [9] who reported that FCs when combined with innovative technology use, lead to student creativity creation, improvement in critical thinking skills (CTS), and overall learning motivation. As a result, academic educators around the world are focusing on using FCs and applying it to their learning management.

2.2. Critical Thinking Problem Solving (CTPS) Activities

Many studies have pointed out the essential nature of *critical thinking skills* (CTS) and *problem-solving* development in contemporary education models and approaches [13]. In higher education, other scholars have reported that CTPS student preparation is a critical goal as it is a prerequisite for lifelong learning and a knowledge-worker skill sought by most employers today [14]. Moreover, CTPS has been stated as a pillar in the guidelines for Thailand's new 4.0 knowledge-based, digitally enabled economy.

2.3 Computational Thinking (CompThink)

CompThink skills and programming skills have been referred to as necessary skills for digitally enabled knowledge workers in a 21st economy [15], [16]. CompThink has also been stated to be basic in analyzing, solving problems, designing workflows, and understanding human behavior [17]. CompThink has also expanded beyond being a way computer scientists think logically and has been stated as a method used in critical thinking in a diverse number of subjects. CompThink has also been referred to as the ‘5th C’ of 21st century skills whose engaging methodology inspires student learning [18].

However, CompThink is not a new concept as it can find its roots as far back as 1980, when Seymour Papert first used the term in discussing the author’s *constructionist* approach to education [19]. Papert’s CompThink also noted the computer's importance as a powerful meta-tool for making abstract concepts concrete. Papert also felt that CompThink could be transferred to other disciplines.

Later, Wing’s [20] essay on CompThink and programming skills became a spark in bringing computer science education to K-12 learners [19]. This is consistent with other studies which have highlighted the connections and AA successes between CTPS, CompThink, and *science, technology, engineering, and mathematics* (STEM) skills [17], [21], [22].

Cansu and Cansu [6] expanded these CompThink benefits even further by reporting that CompThink also has a wide range of applications in the humanities, arts, social sciences, and sciences, which can be used to increase human potential and social development. CompThink can also be applied globally as it is a critical component in CTPS, making decisions, and interacting with others [20], [21].

2.4. Research Objectives

RO1. Compare PST learning effectiveness and achievement of a CompThink class (RE) using an FC model and CTPS versus a PST control group class (RC) using traditional learning methods.

RO2. To assess each PST's satisfaction (RE and RC) with the FC classroom style combined with CTPS.

3. Research Methodology

Figure 1 details the results of previous conceptual research concerning the development of the CompThink skills learning model using both FC techniques and CTPS activities [17].

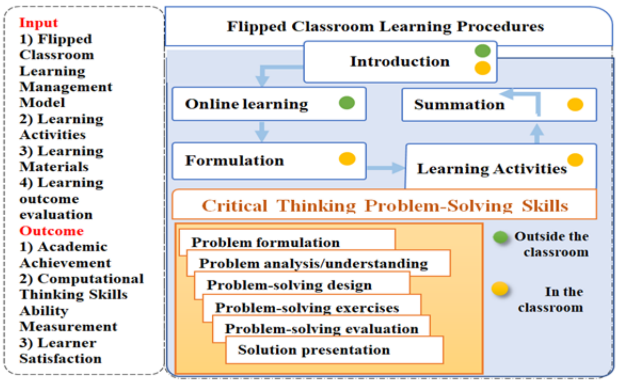

Figure 1 CompThink learning model
Source: [17]

Included in the CompThink learning model are four plans of 14 total hours duration (including two hours allocated for a pre-course test and an after-course test).

The CompThink learning management plan consists of the following contents:

Plan 1 content: CTPS activities that can be applied to solve problems in daily life.

Plan 2 content: Designing steps for CTPS.

Plan 3 content: Simple programming.

Plan 4 content: Programming Interface with digital circuits.

3.1. Teaching Methods/Techniques

The CompThink FC combined with CTPS activities uses the following teaching methods:

1. Introduction to learning

Introduce the FC learning concepts while clarifying the objectives. The learning process is divided into two parts including 1) self-study outside the classroom and 2) classroom learning activities.

Additional detail is provided concerning what students will need to prepare for learning, the evaluation methods, and their learning achievement assessment before the course commencement.

2. Studying online

This segment uses video content hosted on Moodle Cloud LMS and provided by the instructor. Each online course video segment is 30 minutes long.

3. Assessment stage during class - 30 minutes

Before starting each activity, a pre-test was administered to assess students who had studied the assigned material. There were also warm-up activities before class, when possible, which entailed the review of the assigned online material from the Moodle LMS.

4. 90-minute learning activities

For each activity, the PSTs were grouped into five-member groups when possible. After that, the instructor presented problems with computational thinking in each group by giving an example of 'cooking' using the following components: 1) problem-solving part by splitting the problem into parts (decomposition), 2) abstract thinking (abstraction), 3) pattern recognition, and 4) computational thinking (Table 1).

During the physical class, each instructor walked around the classroom and guided each of the five-member groups. The group which solved the problem faster and more accurately obtained extra points.

3.2. Population and Sample

The population for the study consisted of 153 PSTs enrolled in a CS program for their Bachelor of Education degree in the 2021 academic year at Thailand's Nakhon Ratchasima Rajabhat University. Cluster random sampling involved dividing the population into groups (clusters) and selecting a random sample from each cluster.

The sample consisted of third-year student-teachers divided into an experimental group (RE) with 28 student-teachers and a control group (RC) of 29 student- teachers.

3.3. Ethics Clearance

The study was approved by KMITL's Human Ethics Committee after a review of ethics guidelines. The team also ensured the confidentiality of participants by obtaining clarification on the correct wording of the informed consent form.

3.4. Research Tools

The following research tools were used:

1.A FC learning management model combined with CTPS activities that enhanced CT. The model consisted of four main components including 1) the learning management model, 2) learning activities, 3) learning media, and 4) the final evaluation of the learning outcomes.

2. An educational achievement measurement form the researchers then created an achievement measurement scale using four of the six cognitive learning levels of Benjamin Bloom as revised by Anderson and Krathwohl [23].

The four levels of the assessment included *remembering*, *understanding*, *applying*, and *analyzing*. Evaluation and creating were not included. Additionally, each 25-item quiz was designed with four potential answers.

However, before the use of the quiz in the study, five experts in learning management, computational teaching, technology, CS, and computer science teaching and curriculum development assisted with each quiz's evaluation. Each expert had a Ph.D. and a minimum of five years of educational teaching experience in higher education. Content validity and correctness of the language used were evaluated. The results of the analysis revealed that the 25 achievement tests had a difficulty (p) between 0.53-0.80, a discriminating power (r) between 0.47-0.93, and a test confidence value of 0.89.

1. Computational Thinking Measurement Tool

The researchers created a CompThink measurement tool in accordance with the learning management plan for each content. It was a subjective model using five items and a rubrics scoring method using a 5-level scale, whose criteria were suggested by Thailand's *Promotion of Teaching Science and Technology Institute* (Table 1).

Table 1 Scoring criteria by the level of computational thinking

CompThink Elements	Quality Level	CompThink
Splitting the problem into parts. (Decomposition)	Very Good (4)	Able to break a big problem into its components correctly and completely.
	Good (3)	Able to split a big problem into smaller problems correctly.
	Medium (2)	A large problem can be broken down into smaller problems, but some may not be correct.
	Little (1)	Breaking a big problem into a minor problem. However, most of it is incorrect.
	Update (0)	Can't break a big problem into smaller problems.
Abstract Thinking (Abstraction)	Very Good (4)	Ability to accurately and completely select minor problems from complex problems.
	Good (3)	Ability to correctly select minor problems from complex problems.
	Medium (2)	Ability to select minor problems from complex problems, but some may not be correct.
	Little (1)	Inability to correctly select minor sub-problems out of more complex problems.
	Update (0)	The inability to select minor problems from complex problems.
Finding a pattern. (Recognition)	Very Good (4)	Able to explain problem-solving patterns accurately and completely.
	Good (3)	Able to describe the problem-solving model correctly.
	Medium (2)	The solution model can be described, but some parts are not correct.
	Little (1)	Most of the troubleshooting schemes are not described correctly.
	Update (0)	Couldn't explain the solution model.
Algorithmic thinking	Very Good (4)	Able to write clear, correct, and complete steps for problem-solving.
	Good (3)	Able to write clear and correct algorithms for problem-solving.
	Medium (2)	A solution algorithm can be written, but some of them are not correct.
	Little (1)	Able to write solution algorithms, but most of them are incorrect.
	Update (0)	Could not write a solution algorithm.

CompThink Elements	Quality Level	CompThink
Summary of answers.	Very Good (4)	Able to write answers correctly and completely.
	Good (3)	Able to write the correct answer.
	Medium (2)	Able to write the answers, but some of them are not correct.
	Little (1)	Able to write an answer, but most answers are incorrect.
	Update (0)	Can't write an answer.
Process invention. Solve the problems.	Very Good (4)	Able to write correct, complete, and constructive answers.
	Good (3)	Able to write answers correctly and completely.
	Medium (2)	Able to write the correct answer.
	Little (1)	Able to write an answer, but some of them are not correct.
	Update (0)	Can't write an answer.

2. Assessment of the computational thinking measurement form

Assessment of the CompThink measurement form was undertaken by five educators teaching in the fields of technology and education, CS, computer science, teaching, and curriculum development at the university level. All experts had a minimum of five years of teaching experience and a master's degree or higher.

Content validity and the correctness of the language used the index of item-objective congruency (IOC) as a measurement scale. Results showed that the IOC values were 0.60-1.00 which had a difficulty (*p*) of 0.45-0.73. The discriminating power (r) was 0.53-0.90 and the inter-rater reliability (IRR) with the Pearson Correlation Coefficient, it was found that the computational thinking test results among the five assessors had a Cronbach alpha confidence value of 0.96.

5. PST satisfaction measurement of the learning anagement style

The researchers created a satisfaction measurement form that consisted of four components. These were 1) the learning management model, 2) the learning media, 3) the learning activities, and (4) the measurement and evaluation process.

After the form's creation, five educational experts with a minimum of five years of teaching experience were asked to assist with the form's evaluation. The experts were lecturers in technology and education, CS, computer science, and teaching and curriculum development. Content validity and correctness of language use had an IOC between 0.80–1.00.

3.5. Data Collection

The researchers conducted a computational thinking teaching and learning management experiment using an FC teaching model combined with CTPS activities. The study was composed of 57 PSTs who participated in control (RC=29) and experimental (RE=28) groups. Each individual was a third-year PST candidate enrolled in a Bachelor of Education program in CS for 2021 the academic year 2021 at Thailand’s Nakhon Ratchasima Rajabhat University.

3.6. Data Analysis

1. The one-way multivariate analysis of variance (one-way MANOVA) was used to compare the means of both the RC and RE for each PST’s CompThink and learning achievement pre-course and post-course scores.

2. PST course satisfaction was measured using descriptive statistics including the mean ($\bar{x}$) and standard deviation (SD). The criteria for interpreting the mean level of satisfaction are shown in Table 2.

Table 2 PST course satisfaction means and levels

Average Range	Satisfaction level
4.50 - 5.00	Highest
3.50 - 4.49	High
2.50 - 3.49	Moderate
1.50 - 2.49	Small
1.00 - 1.49	Minimal

4. Results

Table 3 shows that the AA and CompThink of the RE were significantly higher than the RC at the 0.05 level.

Table 3 Mean and SD academic achievement and computational thinking

Study groups	Achievement measurement results			Competency measurement results for CompThink		
	Full	**$\bar{x}$**	**SD**	**Full**	**$\bar{x}$**	**SD**
RE (n=28)	25	21.18	3.64	25	21.39	3.57
RC (n=27)	25	18.85	3.58	25	17.70	2.32

Full=full score, $\bar{x}$ = mean, SD=standard deviation

However, the researchers could not conclude whether there was a statistically significant increase or not.

Therefore, it was determined that further testing was required. As such, a one-way MANOVA evaluation was needed. However, before testing, the researchers conducted additional preliminary test detailed in Table 4.

Table 4 Statistics for preliminary examination of the agreement

Test	Statistic	PA	Result	Test results
variable relationship	Bartlett's Test	Sig. < ∝	0.00*	The dependent variable has no relationship. together until a polyline coherence occurs. (Multicollinearity)
The variance-covariance metric	Box's M Test	Sig. > ∝	0.06	Variance Metrics – Covariance equal
data distribution	Shapiro-Wilk	Sig. > ∝	>0.05	The data has a normal distribution. (Normality)

PA= preliminary agreement

Table 5 details the one-way MANOVA testing results for both the RE and RC groups, from which it was determined that the variance of academic achievement and CompThink ability of the RE and the RC after school had a substantially significant difference at the 0.05 level indicating that at least one teaching method resulted in at least one dependent variable of the RE and RC groups.

Table 5 Results of the one-way MANOVA testing between the experimental and control groups

Source of Variance	Test Statistics	F	Sig.
Intercept	Pillai's Trace	1149.83	0.00*
	Wilks' Lambda	1149.83	0.00*
	Hotelling's Trace	1149.83	0.00*
	Roy's Largest Root	1149.83	0.00*
Method	Pillai's Trace	7.433	0.00*
	Wilks' Lambda	7.433	0.00*
	Hotelling's Trace Coefficient	7.433	0.00*
	Roy's Largest Root	7.433	0.00*

*$p < 0.05$

Table 6 presents the statistical values for post-course testing for academic achievement and CompThink ability of the RE and RC groups.

Table 6 Post-course statistical values for PST CompThink and AA

Source	Dependent Variable	SS	df	MS	F	Sig.
Corrected Model	Academic Achievement	84.19	1	84.19	6.55	0.00*
	CompThink	187.07	1	187.07	20.47	0.00*
Intercept	Academic Achievement	21863.46	1	21863.46	1699.72	0.00*
	CompThink	21010.49	1	21010.49	2299.27	0.00*
method	Academic Achievement	84.19	1	84.19	6.55	0.00*
	CompThink	187.07	1	187.07	20.47	0.00*
Error	Academic achievement	681.74	53	12.86		
	CompThink	484.31	53	9.138		
Total	Academic Achievement	22686.00	55			
	CompThink	21761.00	55			
Corrected Total	Academic Achievement	765.93	54			
	CompThink	671.38	54			

*$p < 0.05$

In Table 7 the satisfaction evaluation results of the PSTs participation in an FC combined with CTPS activities to increase their CompThink learning skills are detailed. Overall, all aspects were deemed very appropriate at the highest level. Moreover, when each aspect was considered, it was found that the aspect with the highest mean was the learning activities (mean =4.78, SD=0.42), followed by the learning materials (mean = 4.64, SD=0.50), and learning management (mean = 4.62, SD = 0.49). The aspect with the lowest average was measurement and evaluation (mean =4.55, SD=0.49).

Table 7 Mean and SD of PST satisfaction using a FC with CTPS activities in a CompThink learning model

Aspects	PSTs RE (n=28)		Satisfaction Level
	$\bar{x}$	SD	
Learning activities	4.78	0.42	Highest
Learning materials	4.64	0.50	Highest
Learning management	4.62	0.49	Highest
Measurement and evaluation	4.55	0.55	Highest
Summation	4.65	0.49	Highest

Figure 2 details the final PST CompThink model using an FC learning process combined with CTPS activities.

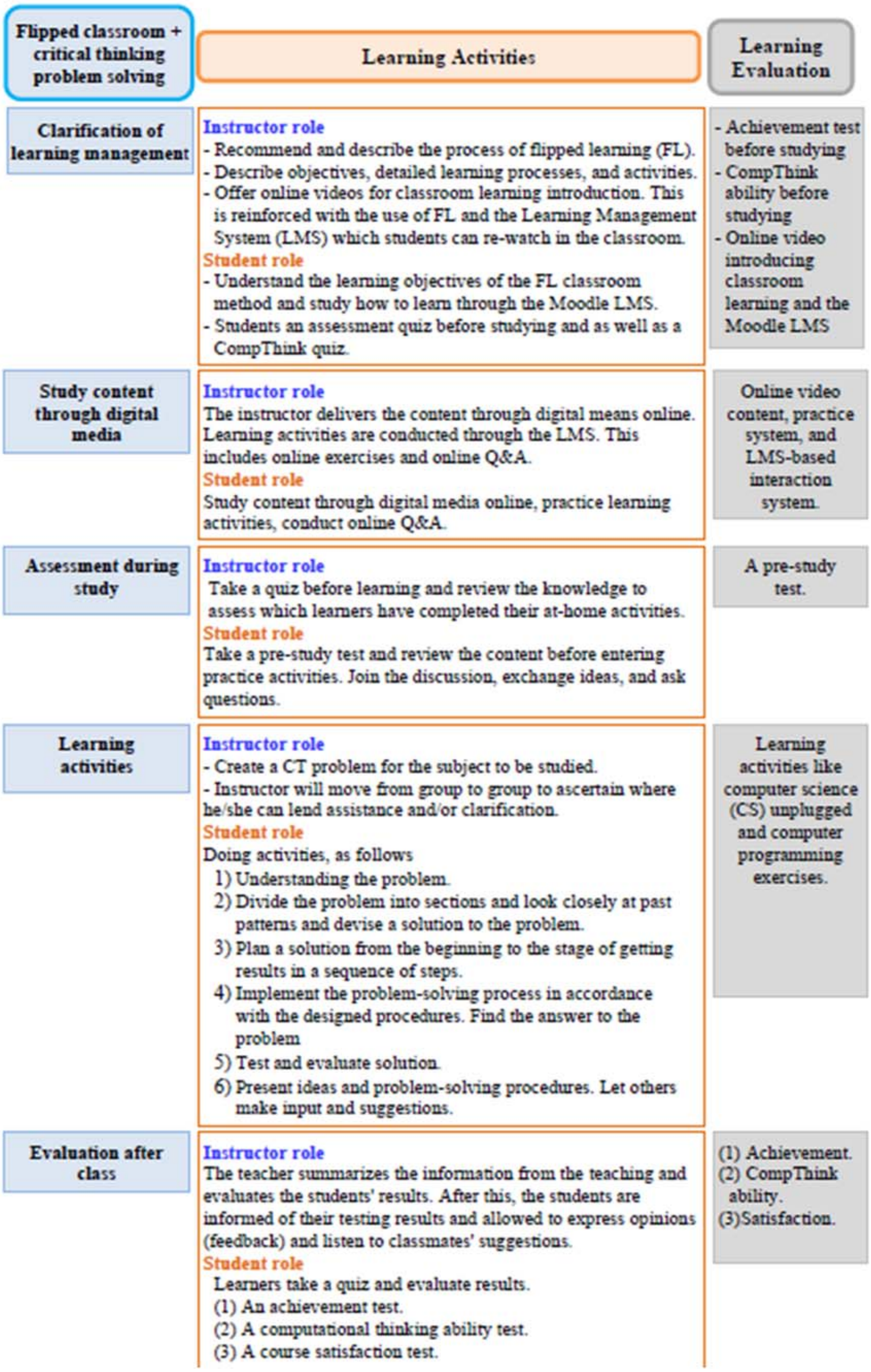

Figure 2 Final CompThink learning model

5. Discussion

The study's testing showed that the post-course AA and CompThink scores of the RE group were substantially higher than the RC group at the 0.05 level (Table 3). This is consistent with Hsieh et al. [24] (2022) who also determined that when project-based learning was combined with CompThink in a Taiwanese robotics education class, first-year university scores improved when compared to traditional, paper-based methods.

In another study from Turkey, Talan and Gulsecen [25] (2019) also determined that an FC was an effective teaching method and statistically significant in raising student achievement, academic engagement, and satisfaction levels. Similarly, this study also determined that using an FC teaching method combined with CRPS activities had a statistical significance outcome in PST course satisfaction (Table 6), as well as a mean score at the highest level (mean = 4.65, SD = 0.49).

Other studies have suggested that the reasons for FC effectiveness and high student satisfaction scores are due to a multiplicity of factors. These include the ability of instructors to create flexible teaching strategies customized for undergraduate student knowledge levels. FCs also allow flexibility in when, where, and how students access their lecture material [17], [25]. FCs also allow greater student collaboration and teacher management, especially when combined with an LMS [26].

Moreover, FCs are an effective tool in student-centered learning (SCL) where self-discovery and online interaction are stated as common advantages. These are as diverse as increasing student retention and AA, while helping improve education quality and access [27]. Thus, FCs are now seen as a critical tool for achieving a broad range of goals across a wide spectrum.

Further importance to this study can be attributed to the importance of CompThink skills development and its integration with a self-discovery learning style using practical, hands-on, CTPS, and higher-order thinking skills (HOTS) [4], [20].

Moreover, effective computer science (CS) studies involve solving complex problems by using advanced thinking abilities to promote active learning [28], [29] as opposed to traditional methods (chalk and talk) classroom lectures that focus on knowledge content only. The outcome of this is that CS skills enable learners to comprehend how technology functions, and determine what is the most effective means of using ICT in improving each person's life [30].

Jackson et al. [31] explored how abstraction skills were enhanced by the use of computer programming activities and noted that the activities were an effective means of helping students form mental images. The authors and others have also noted the critical importance of abstraction and generalization skills in computer science education [6].

In support of this study's findings, Shanmugam et al. [32] also determined that CompThink can be enhanced through the combination mobile digital devices and online learning. This then will lead to a significant increase in student motivation to learn.

6. Conclusion

The study's aim was to evaluate the findings of a CompThink learning management model using a FC combined with CTPS activities. The sample consisted of 57 third-year Thai CS PSTs divided into two groups consisting of an RC (n=29) and an RE group (n=26). Analysis was performed on each student's pre-course and post-course CompThink skills and their academic achievement results.

Post-course testing revealed that learning achievement and CompThink scores for the RE group were higher than the PSTs who studied using traditional methods (RC group). Moreover, PST satisfaction for the CompThink course was determined to be at the highest level.

Additionally, the author developed a CompThink management model using a FC method combined with CTPS activities was determined to consist of four major components. These were 1) learning activities, 2) learning materials, 3) learning management, and 4) measurement and evaluation.

The FC process was also determined to consist of 1) clarification of learning management guidelines 2) studying content through electronic media 3) assessments during class, and 4) critical thinking problem-solving activities.

The activities were carried out both individually and in five-member groups. Course activities included 1) problem identification, 2) problem analysis, 3) problem-solving design, 4) problem-solving activities, 5) checking problem solving, 6) leading, and 5) post-study evaluation.

The AA and CompThink scores of the RE group were significantly higher than the RC group at the 0.05 level. The mean score of RE was also 21.18 points out of a possible 25 points. This is in comparison to the RC group which had a mean score of only 18.85 out of a possible 25 points.

Furthermore, the CompThink performance of the RE group had a mean of 21.39, while the RC group had a very low mean score of 17.70. Finally, the PSTs involved in the FC model's CompThink effectiveness were highly satisfied having a mean = 4.65, and SD = 0.49.

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