Available online at www.ijournalse.org

Emerging Science Journal

(ISSN: 2610-9182)

Vol. 6, No. 4, August, 2022

Flipping the Undergraduate Classroom to Develop Student Analytical Thinking Skills

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Abstract

In Thailand, analytical thinking skills (ATS) have been identified as an essential element in the development of a 21st-century workforce. Moreover, due to the Covid-19 pandemic and the concern for student health and safety, the Thai Ministry of Education has stated that online education will become part of the New Normal in education. Therefore, it has become imperative that the most effective methods and mechanisms be found for online teaching in Thailand. Therefore, the authors investigated which factors increase Thai student ATS by flipping the classroom environment and using digital storytelling and inquiry-based learning (IBL). Therefore, this research aims to develop and evaluate the LIFD ATS instruction model to study the proposed effects of the ATS instruction model. A mixed research methodology was employed. The mean, standard deviation, and t-test were used to analyze the data. From the qualitative review, an initial learning model was developed and subsequently examined by a panel of eight education experts. After that, 40 students became the study's experimental group for the revised model. The results showed that the results of the expert assessment of the learning environment model using a flipped classroom combined with IBL and digital storytelling to promote ATS and academic achievement had appropriateness at the highest level. The evaluation of the student results using the ATS model identified four significant results. These were: 1) Post-test after the student's use of the ATS model determined their ATS abilities were higher than before the class. 2) Student learning achievement, innovation, and ICT skills increased as an outcome of the ATS model's use. 3) The comparison of academic achievement after study of the students who studied with the format was 83.33%, higher than the specified 80% criteria and previously established assumptions. 4) The evaluation results of the model's effectiveness determined that the learning effectiveness index (EI) of the learners was 0.6666 and the EI of the ATS was 0.6966, which was higher than 0.50, thus meeting the specified criteria. The study contributes to the knowledge concerning student ATS and these skills' importance to a 21st century knowledge worker.

Keywords:

Digital Storytelling;
Higher Education;
Inquiry-Based Learning;
Learning Environment;
Thailand.

Article History:

Received:	10	January	2022
Revised:	23	March	2022
Accepted:	02	May	2022
Available online:	29	May	2022

1- Introduction

Under the vision outlined in Thailand 4.0, *analytical thinking skills* (ATS) and *critical thinking skills* (CTS) have become key pillars in the goals outlined for a new knowledge-based economy [1]. Moreover, preparing Thailand's youth to form a skilled and competitive workforce is at the heart of building the country's digital economy and at the heart of Thailand 4.0's economic model [2]. Additionally, global studies have pointed out that 21st-century skills have to include ATS, which have been stated to include communication skills, creativity skills, and the ability to think critically [3, 4]. Also, the ability to think analytically is related to how an individual researches information and analyzes the data from the research [5]. Thus, ATS is the cornerstone of learning and living and the basis of all thinking. Therefore, the preparation of students to acquire these skills and use them effectively is a key goal for many professional educators in higher education, as well as qualities demanded by most employers of new university graduates seeking employment [5, 6].

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DOI: http://dx.doi.org/10.28991/ESJ-2022-06-04-06

Moreover, various scholars have reported that a critical pillar in analytical thinking is critical thinking and that learning activities are essential in ATS' promotion [7]. Also, teachers must develop learning innovations that facilitate their ability to teach and gradually insert ATS and the associated *higher-order thinking skills* (HOTS) into the learning management process [8, 9]. Therefore, cognition becomes the mental process used to gain knowledge and further one's comprehension, with *cognitive skills being* an essential element in analytical thinking and HOTS. Furthermore, in Thailand, like in other developing countries' educational systems, HOTS has become an essential element at all levels of education [3, 9], because it improves a student's learning performance by increasing their interpretation and problem-solving skills in day-to-day activities [10]. Therefore, analytical thinking as a HOTS also enhances the ability to classify elements of things, find rational relationships between them, and determine the real cause of what happened. As such, ATS are skills that lead to the development of thinking in various science disciplines. The importance of analytical thinking skills-oriented instruction has also been highlighted in Thailand's National Education Act of 1999 and the amendment versions for 2002 and 2010 [11]. In these documents, the necessity for educators to have the ability to incorporate analytical thinking processes and the ability to apply this knowledge in student learning problem prevention and solution is outlined. As a consequence, the capability of teachers to instill ATS in their teaching processes is essential in order to fulfill Thailand's present and future educational goals [5].

However, in a 2015 study from the Thailand Research Fund, it was determined that Thai student logical thinking and analytical skills were poorly constructed and very limited due to fact that of the 6,235 students tested, only 2.09% could pass the examinations across 10 Thai provinces [12]. These findings are also supported by the continual decline in the Thai *Programme for International Student Assessment* (PISA) scores which many academics blame on the educational system's failure to encourage logical thinking. In a World Bank [13] education country report from 2020, Thailand was stated as ranking 68th out of 79 PISA-participating countries from the triennial 2018 global PISA assessment. In Kenan Foundation Asia [2] reporting on 21st-century education, harsh words were given to Thailand concerning its PISA exam results which was stated to be "designed to evaluate how well education systems are preparing their students for success in modern society." As such, it was stated "Thailand never performs particularly well." It should be noted that student learning outcome inequality (in the PISA performance) in Thailand has widened across all dimensions over the 2015-2018 period [13]. Finally, other Thai studies have reported the significant weakness in Thai undergraduate student PISA and other testing scores, especially as they relate to student ATS and CTS [5, 9, 14]. Therefore, change is needed but what type of change can enhance the essential nature of a student's ability to think analytically?

First, newer teaching standards in Thailand have encouraged some educators and administrators to develop new methods to transfer knowledge [15], primarily since the Covid-19 pandemic has led to the creation of the critical need for the transition to online learning under what is now being referred to as the *New Normal* [16]. Additionally, the Thailand Qualifications Framework (TQF) has established expected learning outcomes for graduates, including communication, numerical analysis, and information communication technology (ICT) skills [17]. As such, a *convergence* is underway where a multitude of existing and new technologies, terminologies, acronyms, concepts, and learning models are coming together, which in Thailand is now being thrown together under an umbrella known as the *New Normal*. But what is the *New Normal*?

In the simplest of terms, the *New Normal* is the slow demise of the traditional classroom with rows of desks to an *online environment* [18, 19]. It is the end of *chalk and talk* teaching (hopefully) where the teacher-centered environment lets the teacher talk and the student listens [2]. It is movement of education onto digital devices which uses the Internet to transmit the lesson and the student's response. It is a process of using *blended learning* models and *flipped classrooms* to enhance collaboration within the digital and online experiences [20, 21]. It is the use of ICT to facilitate *inquiry-based learning* (IBL) [22, 23] and the use of *learning management systems* (LMSs) such as Moodle or Schoology to coordinate the learning process and gather the critical data necessary to develop a *personalized* learning experience [24- 27]. Finally, the *New Normal* uses online teaching and learning methods to break through the limitations of time and space, or stated another way, allows '*anytime-anywhere*' learning [28]. Therefore, the *New Normal* is many things to many people.

However, how much each element is used and accepted is dependent again on a wide range of factors including the teacher's ability to embrace newer technologies, the cost and robustness of the Internet bandwidth and connectivity [20], the cost and availability of digital devices such as smartphones and tablets, the sophistication of the LMS and the available support, and the student's willingness to spend eight or more hours a day watching Zoom sessions or video on their tiny smartphone screen [29]. There are other conditions as well, including the gender, grade, and major of the student [30]. Also, the student's long-term willingness to use the online medium depends on its perceived usefulness, the student's satisfaction, and the perceived switching cost.

Also, a key theme throughout these online methodologies has been placing students in the learning process center (*student-centered learning*) while paying greater attention to their abilities and weaknesses [2]. Other studies have also suggested that *student-centered learning* or *personalized learning* (PL) are also roads to better scores and *lifelong learning* abilities [20, 25, and 31], with online teaching a powerful tool in achieving these high ideals [16, 25]. Instructors now act as *facilitators* creating flexibility in the learning process [16]. Numerous studies have also reported on the

advantages of using a *flipped classroom* (FC) or *inverted classroom* as an efficient means in the process of learning and teaching [28, 32-36]. The flipped classroom turns the use of classroom lecture periods into various activities to practice problem-solving and practical applications [20, 37]. Flipped classrooms also help learners practice ATS while simultaneously enhancing the communications and exchange of knowledge.

In a flipped classroom study from Indonesia, it was reported that FCs are very useful in motivating students in developing self-study learning abilities, enthusiasm and knowledge, while also helping develop students' collaboration and creativity [38]. Moreover, student enthusiasm for knowledge and creativity is strongly encouraged, and they are more relaxed and get a challenging learning experience. This is important as the literature is often lacking in explicit definitions of different forms of feedback facilitated through the use of ICT in students' tasks [39, 40]. Finally, of equal importance to the methods used to develop ATS is also the means used to deliver the message. One highly successful method now being used in the digital age on digital devices is digital storytelling (DST) [41]. By combining digital technology in various formats such as still images, audio, and video clips which accompany the story creator's audio narration, DST can be a highly effective means in enhancing student critical and in-depth thinking skills [42-46]. In DST, the learners themselves create digital stories with instructors have the option to use these modules for future instruction and sharing [47, 48].

From the preceding, it was found that the learning environment, the use of IBL processes combined with digital storytelling can be used as foundations in ATS student achievement promotion. Thus, we set out to undertake a more in-depth literature review in Part 2, followed by an outline of our Methods in Part 3. In Part 4, we combine our results with discussing how they are essential and compare them to other contemporary studies. It is hoped that the processes and ATS model will help other educators' better support learners in developing ATS via online, flipped classrooms. Finally, we hope our model will help in increasing student academic achievement, which effectively leads to a learner's lifelong learning process.

2- Conceptual Review

This section gives an overview of the research related to the domain of analytical thinking skill (ATS) development.

2-1- Learning Environment (LE)

Multiple researchers have commented on what constitutes a *learning environment* (LE). Briefly stated, LEs are the conditions around teachers and students that affect a learners' learning internal and external to the traditional classroom, which are beneficial to a student's learning effectiveness [49-51]. LEs also involves the culture of the classroom, the class or the student's grounds in which they learn and maybe live [52], with the *classroom* being defined here as a traditional setting with rows of desks. Therefore, Les have become a more popular and accurate term, especially in classes now being conducted in online Les.

The Finnish National Board of Education (FNBE) has also detailed and defined how the *physical environment* (PE), *psychological factors* (PF), and *social relationships* (SR) are involved in the LE [53]. As we might expect, the FNBE discusses PE as the buildings, grounds, furniture, and equipment used for the work. Somewhat surprisingly, however, they also include the *technical or information learning environment*, including the *educational technology* used. However, this is in line with other research in which it was stated that information communication technology (ICT) is highly advantageous in allowing accessibility to distance learning and tracking a student's progress [54]. ICT also plays a critical role in a student's learning engagement and improvements by providing them with learning support through increased student-teacher and peer collaborations [40].

Other studies have also shown the benefits of alternative, non-traditional online LEs using flipped classrooms, blended learning, and inquiry-based learning (IBL), with LEs playing an essential role in determining student achievement and learning [23]. Also, classroom organization and the resulting student behavior are essential in schools by fostering the constructive interactions necessary to achieve better student outcomes [55, 56]. Furthermore, according to the FNBE, the *psychological learning environment* entails the *cognitive environment*, which includes the skills and information learned, while the *emotional environment* includes student motivation and related emotions. Concerning the *social learning environment*, this entails the social networks, structures, and systems, which are influenced by the individuals participating and interacting in the learning situation [57].

2-2- Flipped Classrooms (FC)

Over the past decade, numerous studies have probed into how FCs can be used to enhance a teacher's delivery method and a student's academic achievement across a broad range of disciplines and international settings [32, 36, 58, 59]. Conceptually simple, an FC uses multi-media segments to deliver content when and where a student has the time and resources to view them. On the other hand, teachers now use their classroom time to participate in learning activities that enforce the lessons and knowledge being viewed outside the classroom. Typically, lessons are viewed online

through a teacher's YouTube channel, but when the Internet is limited or unavailable, teachers have the option to produce lessons on other media such as thumb drives or DVDs.

Moreover, digitally-based flipped classrooms have been integrated with IBL and blended learning [20, 60, 61] and become a powerful tool in improving critical thinking, ATS and social and collaboration skills. Additionally, teachers using FCs become facilitators in directing and interpreting the knowledge gained from the class exercises and online activities. Involvement and practicing CTSs are also becoming more essential in preparing a 21st-century knowledge worker.

However, although there is debate concerning the existence of conclusive empirical evidence on whether virtual classrooms result in higher performance, there is no doubt that blended learning outperforms the traditional classroom in student performance and satisfaction [62], with the flipped classroom being one form of blended learning.

Another group of researchers have suggested a seven-step framework to design and evaluate flipped classes, starting with learning objectives/outcomes, pre-class activities, online delivery, face-to-face discussion and final evaluation [63]. Research has also pointed out the imperative nature of educating 21st-century learners in Thailand, with [64] adopting [65] four experiential learning cycle stages in conducting a flipped classroom. These four stages can be identified and discussed as follows:

- *Experiential engagement* is an immersive, hands-on activity in which the teacher guides the learner through various methods, including using custom activities, games, simulations, and interactive media experiments.
- *Concept exploration* is presented using online resources and video lectures to help students learn abstract concepts being taught. The concept exploration process can also be reinforced by using video lecture notes, podcasts, websites, or chats.
- *Meaning-making* is when students take time to reflect on what they have learned in the two previous phases and demonstrate their comprehension of the content being taught through verbal-based audio or video recordings and written blogs.
- *Demonstration & application* creates knowledge through either face-to-face interaction or group settings within the classroom. This phase in online classes is best served by independent or collaborative projects presented to their classmates and teachers during an interactive online forum.

2-3- Inquiry-Based Learning (IBL)

Another component identified as helping develop student ATS is *inquiry-based learning* (IBL), which is a process in which students explore, examine, and search for knowledge that focuses on developing problem-solving abilities. When using IBL, teachers encourage students to ask questions to collect the answers. Thus, this curiosity is the basis for developing HOTS that leads to learners asking meaningful questions, leading to relevant answers through experimentation [66-69].

Inquiry-based learning is also a 21st-century approach to learning management that facilitates real-world learning processes that focus on developing problem-solving abilities by emphasizing learning that begins with the pursuit of truth [70]. Therefore, it is a process in which learners must search, explore, examine, and research using various methods until learners comprehend the obtained knowledge in a useful way [68, 71-73]. Furthermore, IBL has been described as a five-step process, which includes *engagement, exploration, explanation, elaboration,* and *evaluation* [74, 75]. This 5-E model involves:

- *Engagement* (Phase 1) is where teachers engage students to determine their knowledge and misconceptions about what is to be taught. It is also the phase where teachers motivate their students to learn more about what is being taught.
- *Exploration* (Phase 2) is where teachers act as facilitators in providing students with real-world learning experiences. Moreover, this phase is student-centered and uses active exploration, observation, investigation, prediction testing, hypothesizing, and communicating with classmates. Phase 2 also incorporates the main IBL activities, encouraging students to develop concepts and skills.
- *Explanation* (Phase 3) is more teacher-guided and involves determining what the students have discovered from the exploration phase 2. Here, further questions will be generated, with learners required to use common conclusions to link what they have learned.
- *Elaboration* (Phase 4) is a step that allows learners to confirm and expand their understanding of concepts to a broader and more profound level. It also allows students to practice their skills and act according to their needs.
- *Evaluation* (Phase 5) is involved with learners receiving feedback on their explanations of their understanding. Teachers encourage learners to assess their knowledge, understanding, and abilities in this phase.

2-4- Digital Story Telling (DST)

Digital story telling is a process using techniques and educational digital media, usually 2 to 10 minutes in length [44]. The DST process can include text, images, music, and voiceovers to make the story more exciting and attractive utilizing digital media and technology. It presents content in a way that attracts listeners or viewers because of its sense of intimacy and individual participation possibilities.

Digital story telling is also useful for teaching and learning activities, enabling learners to gain knowledge and information and creating a good relationship and atmosphere between teachers and learners. Digital story telling also stimulates the attention of learners and improves thinking skills and content-based synthesis skills [41-46, 76-78].

Therefore, we determined six critical elements involved from this rich mix of input concerning academic DST. These were:

- *Point of view* – Creating a useable lesson with DST requires clarity in the story's message and what point the author is trying to make.
- *Dramatic question* - Find the story's main points to make the story interesting. After that, ask the viewers questions at the end of the presentation.
- *Emotional content* – Connecting the story with the audience emotionally.
- *Spoken narrative and soundtrack* – This is the personalization of the soundtrack while also using sound/music to embellish your story.
- *Seeing your story and performance* - Consider all the elements, including the structure and presentation method.
- *Sharing your story* - Review all the segments and facts that were the origins of this presentation before publishing.

2-5- Analytical Thinking Skills (ATS)

Analytical thinking involves the ability to classify, distribute, and differentiate information, subsets of events, or stories for better understanding leading to the right decision [77-80]. Moreover, according to Bloom, the three highest levels (evaluation, analysis, and synthesis) are often quoted as representing ATS [78]. However, in an analysis of Thai teacher ATS, it was determined that there were three types of ATS. These included the *analysis of elements*, *analysis of relationships*, and the *analysis of organizational principles* [81].

These ideas are consistent from an Indonesian study concerning AT teaching models. From the analysis of the various models it was determined that ATS improvement starts with *problem identification*, *searching relevant information*, then *observation and experimentation*, concluding with the *communication of the results* [82]. These study results are also consistent with yet another Indonesian study in which it was determined that AT skills are developed best through discussion (89%) followed by lectures (67%) [83]. It was also pointed out in the study that technology can provide good support and learning sources in developing thinking skills. The ability to process information and use the Internet allows students to find and collect relevant information, sort, classify, compare, and analyze parts/relationships as a complete part [84].

2-6- Combining LE, FC, IBL, and DST into our ATS Learning Model

Figure 1 shows the initial ATS model using LE, FC, IBL, and DST developed from the literature. In it, we see that Step 1 is concerned with the *Engagement stage*, which prepares learners' interest by identifying topics or things they want to learn. Also, in this stage, teachers are tasked with learner motivation while also defining tactics to increase experience and guiding students on how to learn the content.

In the *Exploration stage* or Step 2, DST is used to enhance students' CTS and ATS [41- 46, 76, and 78]. Also, in Stage 2, the teacher ensures that each student fully understands the subject or question and determines the survey guidelines. Moreover, a determination is made to ensure that each student has collected enough information to be used in Step 3's *Summary stage* [82].

In the *Summary stage* or Step 3, students develop the ability to explain concepts gained from surveys, while teachers provide opportunities for learners to discuss and exchange ideas about learning skills or behaviors [83]. Explanations require learners to use common conclusions to link what they have learned. At this appropriate time, the teacher should guide the learner on summarizing and elaborating.

In the *Elaboration stage* or Step 4, students have confirmed, expanded on, or deepened their understanding of the concept. It also allows students to practice their skills and act according to their needs. Teachers should also guide students in applying the skills learned in daily life. This will give students more concepts, processes, and skills.

Finally, in the *Evaluation stage* or Step 5, learners will receive feedback on their understanding. Teachers encourage learners to assess their knowledge, understanding, and abilities [84].

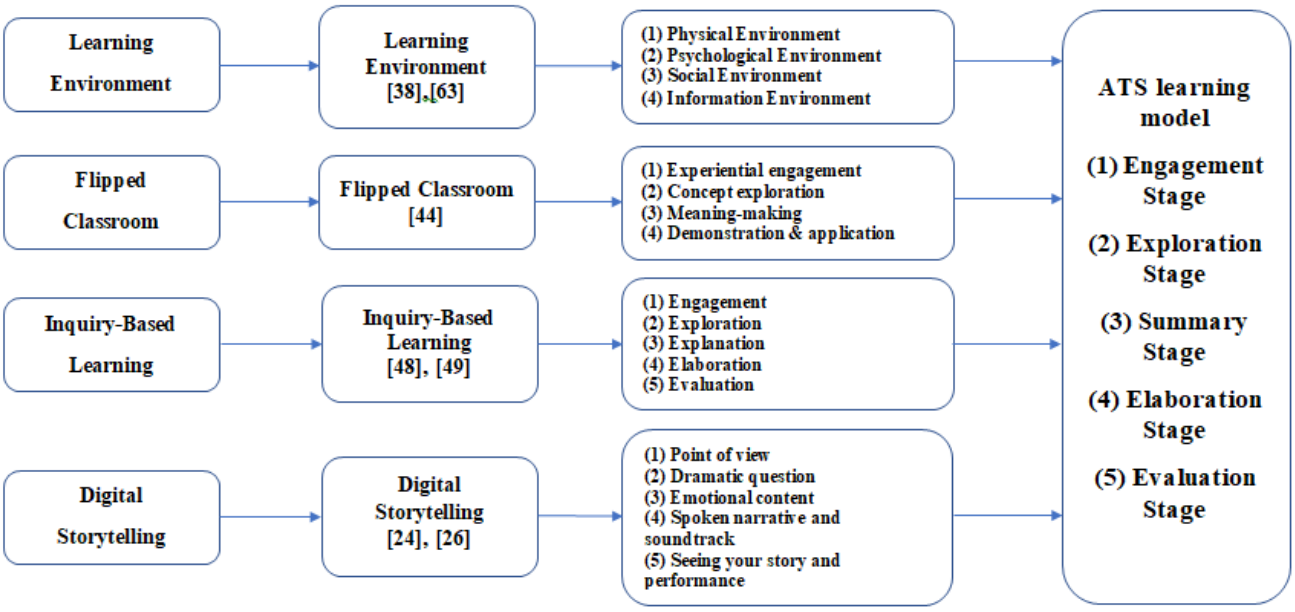

Figure 1. Proposed ATS learning model

2-7- Research Objectives

- Develop a learning environment model of a *flipped classroom* in combination with *inquiry-based learning* by means of *digital storytelling*. To promote analytical thinking skills and academic achievement of undergraduate students.
- To study the effect of using a flipped classroom learning environment model in combination with a digital storytelling approach to promote analytical thinking skills and academic achievement of undergraduate students.

3- Material and Methods

The conceptualization of the ATS learning model was drawn from the literature and theory related to the LE, FC, IBL, and DST. After that, the model was evaluated by eight educational experts. Using four standards, the model was further evaluated before testing on an experimental group of 40 Thai undergraduate students in 2020.

3-1- Population and Sample

The research population was 560 undergraduate students in the 2021 academic year's second semester. Cluster random sampling selected the study's experimental group consisting of 40 undergraduate students. For six weeks from 13 March 2021 to 27 April 2021, the primary researcher from the study tested the LIFD ATS Instruction Model on eight groups of five students, each using a flipped classroom learning environment. The panel of eight education experts was selected by use of purposive sampling.

3-2- Ethics Clearance

Before the beginning of the study, a research proposal was submitted to our institution's Human Ethics Committee from which permission was obtained to conduct the study. After which, each of the eight-member educational panel was informed about the confidential nature of their participation. Then, agreements and confirmations were noted via email. Furthermore, each of the 40 students selected for the experimental class was also informed of their privacy rights and was also told they could opt out at any time if they chose to do so. As with the panel's experts, each student was sent and confirmed the confidentiality statements before participation.

3-3- Panel of Experts

The study's panel of eight Thai experts was selected from purposive sampling. They included three experts in curriculum development and teaching, two experts in measurement and assessment, three experts in computer studies, and finally, one in educational technology. Furthermore, each had obtained a doctoral degree and had a minimum of five years of teaching expertise. A further look at their level of each scholar's expertise can be found from the following titles held:

- Lecturer in the Department of Computer Studies.
- Lecturer of the Curriculum and Instruction Department.

- Lecturer in Curriculum and Teaching.
- Lecturer in Department of Computer Studies (Measurement Expert).
- Lecturer in Computer Studies.
- Lecturer in Computer Studies.
- Chairman of the Computer Education Department.
- Lecturer in the Teacher Development Unit and Educational Personnel at a major Thai publishing house.

The experts used a panel discussion to provide information and opinions concerning the composition and process of developing an analytical thinking skills learning model using a flipped classroom. Each expert was then asked to use a five-level Likert agreement scale to assess the proposed ATS learning model using an interpret value of 5 = *highest agreement*, 4 = *high agreement*, 3 = *moderate agreement*, 2 = *low agreement*, and 1 = *lowest agreement.*

3-4- The Proposed ATS Model's Suitability Assessment

The standards questionnaire used to assess the model included propriety (PS), utility (US), feasibility (FS), and accuracy (AS) [57-59] (Table 1) [85–87].

Table 1. The mean suitability level of the LIFD ATS Instruction Model

Standards	Experts (*n*=8)		Interpretation
	$\bar{x}$	S.D.	
Propriety standards (PS)	4.67	0.49	Highest
Utility standards (US)	4.65	0.48	Highest
Feasibility standards (FS)	4.50	0.51	High
Accuracy standards (AS)	4.50	0.57	High
Average	4.63	0.51	Highest

The experts' questionnaire consisted of four main elements including the model's principle, model's purpose, the theoretical model's elements and procedures (LE, FC, IBL, and DST), and model's measurement and evaluation.

The experts discussed the model in the focus group and gave opinions and recommendations. After the focus group, data were collected and analyzed by the mean and standard deviation (SD). Qualitative data was analyzed using content analysis.

Expert responses used a Likert scale whose values had a range of calculated means as follows: [4.51 – 5.00] → 5, [3.51 – 4.50] → 4, [2.51 – 3.50] → 3, [1.51 – 2.50] → 2, or [1.00 – 1.50] → 1.

3-5- Student Achievement and Analytical Thinking Ability Evaluations

Concerning the students' achievement test, it used a four-choice, 30-item test in which the researchers created a series of questions aimed at measuring learners' knowledge, skills, and brain performance in various fields. The Index of Item-Objective Congruence (IOC) for the achievement test was 0.60 - 1.00, with a difficulty range of 0.20 - 0.70. The Kuder-Richardson Formula 20 (KR-20) was then used to assess the test for reliability from which a score of 0.92 was obtained. The KR20 is a unique case of Cronbach's Alpha in which the items are binary variables (typically scored as 0 or 1) [88].

The analytical thinking ability test was a four-choice, 30-item test. The researchers created a series of questions to measure the ability to think analytically, using three primary characteristics of analytical thinking: significance analysis, relationship analysis, and principles analysis. The analytical thinking ability test IOC ranged from 0.60 - 1.00, with a difficulty range of 0.20 - 0.70. The KR-20 was then used to assess the test for reliability from which a score of 0.89 was obtained.

4- Results

4-1- The Model's Appropriateness Results

Table 1 shows the results from the experts' input on the learning model's appropriateness, in which the assessment used four recognized standards, including propriety standards (PS), utility standards (US), feasibility standards (FS), and accuracy standards (AS) [85-87], According to *The Joint Committee on Standards for Educational Evaluation* [89], *utility standards* are used in educational evaluations to ensure that an evaluation serves the information needs of intended users. The *feasibility standards* are used to ensure that an evaluation will be realistic, prudent, diplomatic, and frugal,

while the *propriety standards* are used to ensure that an evaluation will be conducted legally, ethically, and with due regard for the welfare of those involved in the evaluation and those affected by its results. Finally, *accuracy standards* are used to ensure that an evaluation reveals and conveys technically adequate information about the features that determine worth or merit of the program being evaluated.

The results indicate that the panel of eight experts felt that the model achieved the information needs of its intended student and teacher users (PS) which was additionally deemed to be at the highest level of importance (mean = 4.67, SD = 0.49). This was followed closely the experts belief that the model was realistic (US) also at the highest level (mean = 4.65, SD = 0.48). Next the experts judged the model was appropriately developed with the needs and welfare of the students (FS) highly looked after (mean = 4.50, SD = 0.51) and that the model technically conveyed the correct information and value (AS) of the model and its use in a flipped classroom in teaching undergraduate analytical thinking skills (mean = 4.50, SD = 0.57).

4-2- The Final LIFD ATS Instruction Model

The initial ATS learning model was redesigned (Figure 2). In the more robust and complete model, we note that the teacher-initiated ATS activities and DST have direct input in achieving the IBL process. From the IBL process, both the analytical process and learning achievement outcomes can be achieved.

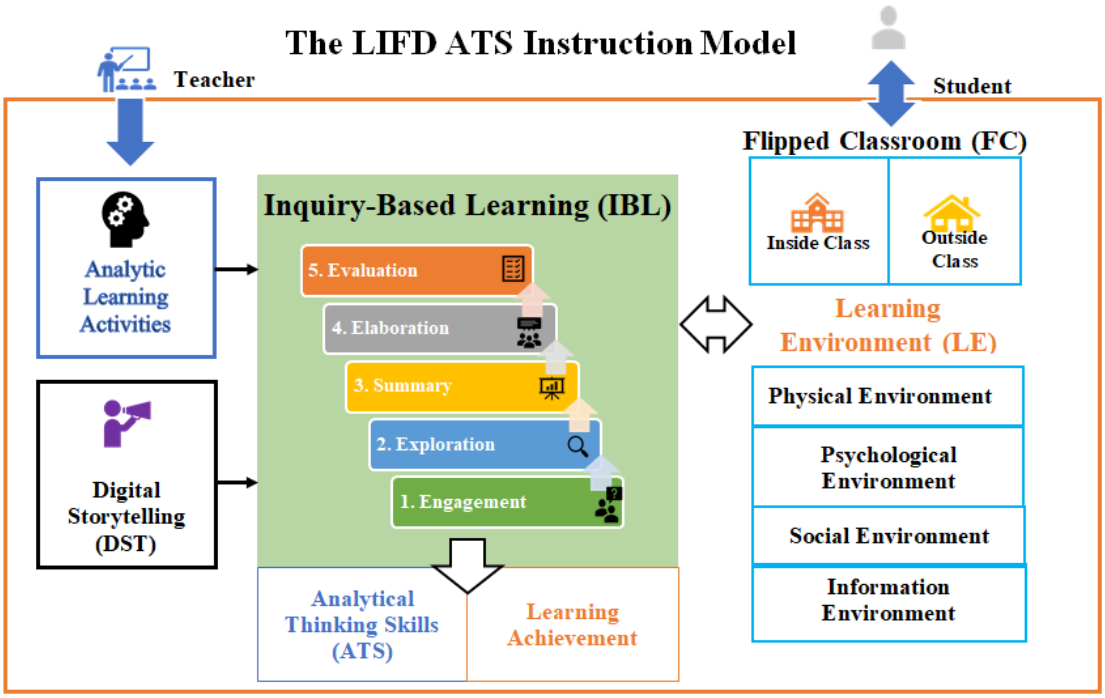

Figure 2. The final LIFD ATS Instruction Model

4-3- The Experimental Group Effectiveness Index (EI) Results

Table 2 reveals the results from both the experimental group of 40 students' achievement testing and analytical thinking testing. Readers should note that prior to the class beginning on 13 March 2021, a pre-test (P_1) was given for each test. After the class completion on 27 April 2021, a post-test was also given (P_2). As each assessment had 30 items, and there were 40 students, the best possible score was 1,200 (30×40=1,200). The 'effectiveness index' (EI) formulas (1-4) were adopted from previous research [90-92]:

E.I. achievement test = 1000-600/ (40*30)-600 = 400/600 = 0.6666 (1)

or;

E.I. achievement test =83.33-50/100-50 = 33.33/50= 0.6666 (2)

or;

E.I. analytical thinking test = 1018-600/ (40*30)-600 = 418/600 = 0.6966 (3)

or;

E.I. analytical thinking test = 84.83-50 / 100-50 = 34.83/50 = 0.6966 (4)

Table 2. Student achievement testing and analytical thinking testing results

Sample	N	Full score	Total Score		mean	E.I.	%
			P_1	P_2			
Achievement test	40	30	600	1,000	25	0.6666	66.66
Analytical thinking test	40	30	600	1,018	25.45	0.6966	69.66

The results interpretation indicated that after using the LIFD ATS Instruction Model, the students' knowledge increased 66.66%, and their analytical thinking ability increased by 67.32%. These scores were both significantly higher than the previously set threshold of 0.50 or 50%.

Results interpretation suggests that the experimental group students received teaching activities under the FC environment, which encouraged learners to learn both inside and outside the classroom. Moreover, encouraging independent research and study outside the classroom was also a contributing factor to the model's success. Once the students returned to the classroom, each participated in group activities practicing and reinforcing what was learned independently. These review sessions further enhanced student understanding. Also, teacher use of learning materials to stimulate students' interest in a variety of ways was a significant contributing factor to their success. Multi-media resources included video clips, YouTube videos, pictures, and news stories combined with the DST samples. In the search for answers to the proposed questions, student thinking and ATS were stimulated, which included thinking processes being practiced using questions connected to different situations.

Table 3 shows the course content achievement for innovation and educational information technology courses of the students who studied with the posttest model were significantly higher than the pretest at the .05 level, indicating that the model helped the students to achieve better academic success. The t-test was used as the dependent variable in comparing the pretest and posttest scores. The posttest scores are higher than pretest scores at a statistically significant level of .05.

Table 3. Student pre-test and post-test testing results

Sample	N	$\bar{x}$	S.D.	df	t	*p*
Pretest	40	15	2.828	39	20.00*	.000
Posttest	40	25	1.485			

* $p < 0.05$

Table 4 shows that student ATS were higher after attending the ATS training courses than before the ATS classes began at a statistically significant level of 0.05. This showed that the model helps to promote undergraduate student ATS. The t-test was used as the dependent variable in comparing the pretest and posttest scores. The posttest scores are higher than pretest scores at a statistically significant level of .05.

Table 4. Student ATS pre-test and post-test testing results

Sample	N	$\bar{x}$	S.D.	df	t	*p*
Pretest	40	15	2.172	39	21.94*	.000
Posttest	40	25.45	1.709			

* $p < 0.05$

Table 5 shows that the academic achievement of educational innovation and information technology courses of students who studied with the posttest format was 83.33 percent, which was higher than the 80 percent threshold set with a statistical significance at the .05 level.

Full score = 30, N = 40

Total score = 30*40 = 1,200

Total score achievement test = 1,000

Posttest = 1000/1200 = 0.8333 or 83.33

Percentages of posttest results compared with an 80% criterion, and one sample t-test

Table 5. Student ATS post-test testing results

Sample	N	Criteria	$\bar{x}$	SD	df	t-test	*p*
Posttest	40	80%	25	1.48	39	4.259*	.000

* $p < 0.05$, df = degrees of freedom.

5- Process Discussion

5-1- Analytical Thinking Skills (ATS) Development Process

The ATS development process that takes place in the learning process consists of the following 5 ‘expected goals’ [78]:

Goal 1: Learners can correctly determine what needs to be analyzed in their thinking.

Goal 2: Learners can clearly define problems or objectives in their thinking.

Goal 3: Learners can clearly define principles or rules for thinking.

Goal 4: Learners can consider distinguishing information and choose which data to use.

Goal 5: Learners can correctly summarize the answers to what they want to analyze in their thinking.

This instructional step is linked to using a flipped classroom, which consists of the following two parts:

Part 1 – The outside classroom consists of two steps. These include:

Step 1: Engagement stage

Role: The teacher presents problems, issues, and case studies related to the lesson and asks interest-inducing questions. Together, learners and teachers determine the problems or issues they want to explore in each lesson.

Cognitive Tools: Google Classroom, Sticky notes, Kahoot.

Expected goals: (1), (2), (3).

Step 2: Exploration stage

At this stage, DTS is used to help teach the lesson. This approach is applied to enhance students' critical and ATS.

Role: Instructor organize groups of 3-5 students determined by their cumulative grade point average (GPA). An example of this might include one learner as a high achiever, three moderate achievers, and one low achiever.

- Within the group, learners divide their roles and responsibilities with emphasis being placed on fundamental roles such as who is the supervisor, data collector, and presenter.
- The teacher recommends resources that will come as a guideline for answering problems or issues of interest. Information from sources is discussed within each group and between the groups.
- Learners study using DST sessions prepared by the teacher.
- Learners discuss each of the issues to understand each one better. Moreover, each topic is thoroughly investigated, from which each group makes possible assumptions.
- Learners prove the hypothesis through various methods such as searching for information, practicing, experimenting, doing field activities, simulations, etc.
- Learners record their findings in an orderly way by clearly referring to the sources.
- Learners discuss the results to verify the hypothesis.

Cognitive Tools: Google search, Digital Storytelling, Google Drive.

Expected goals: (2), (3), (4).

Part 2 – The inside classroom consists of three steps. These include:

Step 3: Summary stage

Role: Learners analyze recorded data and organize data in appropriate formats using tables, graphs, diagrams, etc.

- Learners create their own new body of knowledge, citing the source of information with supporting evidence and explaining its importance while showing the performance results consistent with the assumptions set.
- Learners present their results to teachers and other group members.
- Teachers use questions to encourage learners to show trends and relationships of information.
- The teacher asks questions to guide the learners to draw conclusions and discuss the results rationally. Teachers also encourage learners to verify the consistency of the results based on their assumptions.

- Learners and teachers exchange ideas and give feedback reflecting on the descriptions from each group to make things more transparent.
- Learners connect new knowledge with previous knowledge, using explanations based on prior knowledge.

Cognitive Tools: Mind mapping, Google Docs.

Expected goals: (3), (4).

Step 4: Elaboration stage

Role: Instructors create new situations and events for students to apply new knowledge.

- Learners broaden their new knowledge by discussing and expressing their new opinions about their new knowledge more clearly.
- Learners show a link between new knowledge and previous knowledge using models or diagrams.
- Teachers encourage learners to research more on issues that students are interested in.
- Learners present information on how to obtain information.

Cognitive Tools: Padlet, Facebook, Google Docs.

Expected goals: (2), (3), (4).

Step 5: Evaluation stage

Role: Learners assess their learning development.

- Each group member's performance is assessed by the group's members.
- Learners take quizzes and evaluate the learning objectives.
- Learning development assessment is done by the teacher by evaluating the results.

Cognitive Tools: Google Form, Google Doc, Google site.

Expected goals: (1), (2), (3), (4), (5).

As for analytic learning activities, teaching activities were planned and taught using the joint learning worksheet, which is a process that encourages learners to remember what they have learned from outside the classroom and how well they understand it. This is then used to support the activities inside the classroom later. These are steps that require students to think analytically. Visual representation of these inside and outside classroom activities was best served by using a Mind map.

From analyzing all five skills, the teacher asked the learners to measure and evaluate the learning outcomes measured at the end of the teaching activities according to the model using (1) an achievement test, (2) and an ATS test. The ATS test consisted of *elements analysis*, *relationships analysis*, and *organizational principles analysis* [56].

6- Discussion

From the research results from the evaluation and analysis of a flipped classroom learning environment combined with DST and inquiry-based learning to improve undergraduate student ATS and academic achievement, several outcomes were noted. First, from the input from eight educational experts it was determined that the study's proposed model was appropriate and applicable. From the draft model, five ATS learning model stages were determined to be appropriate. These included the 1) *engagement stage*, 2) *exploration stage*, 3) *summary stage*, 4) *elaboration stage*, and 5) *evaluation stage*.

6-1- The LIFD ATS Learning Model

These five stages find significant support from other studies. One such supporting model is referred to as the *5E Instructional Model for Science*. In a similar manner, this *constructivist science learning* model also uses five stages which are *engagement, exploration, explanation, elaboration* and *evaluation* [71, 74, 75], Research has shown that when educators use the 5E approach, students are better able to redefine, reorganize, elaborate, and change their initial concepts through self-reflection and interaction with their peers and their environment [71], The model can also be used to organize work as a daily lesson, in individual units, or as a yearly plan [74].

Furthermore, this study's ATS training course instructors used learning materials to stimulate the interest of the learners in a variety of ways. These included searching for information using a wide variety of multi-media content such as audio and video clips, photos, news stories, digital stories, and asking questions used to stimulate the students' thinking

processes and answer search [44]. From the vast array of input, the students are then tasked to use their ATS to practice using questions or linking different situations given by the teacher throughout the teaching activities to create new knowledge and understanding for each learner [93].

This is consistent with another study in which the authors investigated the development of a 5E-STEAM model on 10 Indonesian teachers' use of CTS in science learning [94]. The needs assessment results determined that only 10% of the teachers were using STEAM in their classes, while others used problem-based learning, discovery learning, and inquiry learning. Also, as many as 70% of the teachers have never heard of the 5E Learning Cycle and the study's 5E model used elaboration in the 4th stage. This was stated as an excellent tool in stressing collaborative teamwork.

In another Indonesian 5E model implementation for developing student CTS, the pre-test-post-test results showed that student CTS improved significantly and that student *elaboration* was the weakest of the five indicators [95], Also, there were significant male/female CTS improvement differences, as male students had a quicker response and higher self-confidence than female students in solving the problems.

6-2- Flipped Classroom Learning Environments

The researcher developed the LIFD ATS model based on the principles, concepts and theories of a flipped classroom learning environments. This resulted in an ATS learning model and learning environment which responded to individual differences and learners' learning potential. It encouraged learners to create a learning process that created CTS and ATS when combined with teaching activities organized under a flipped classroom environment encouraging learners to learn both inside and outside the classroom. When students can study new knowledge by themselves from many different sources outside the classroom, back in the classroom, students have group activities combining IBL which helps in the review and enhancement of each student understanding.

Comparison of learning achievement after school (posttest) through a learning environment model of a flipped classroom model combined with IBL using DST was 83.33% for the students, which is higher than the threshold of 80%. The 80% predetermined statistical significance at the .01 level is in line with the research of [96], which showed that the flipped classroom teaching style improves learning achievement at the .01 level.

Learners can achieve the objectives of the content through the use of personalized learning. In addition, students can learn anywhere, anytime [28], without restrictions on the location of access to learning. This helps encourage all learners to develop more ICT skills, including the introduction of modern ICT to help stimulate and create an interesting learning atmosphere. As a result, learners have more fun learning and understanding each module's content.

In a similar study from Thailand concerning learning models that promote CTS using a virtual learning environment flipped classroom for undergraduate students [9], the results showed that the model consisted of four components. These included 1) *theory and principles,* 2) *objectives,* 3) *teaching and learning process arrangement*, and 4) *evaluation*. This was also consistent with another study in which the author researched a learning environment model using a flipped classroom model based on problem-based learning principles to promote CTS for high school students. The author's four main components of the model were identified as 1) model principles, 2) model objectives, 3) flipped classroom learning environments based on problem-based principles to promote analytical thinking skills and, 4) measurement and evaluation and the process of organizing a flipped classroom learning environment based on problem-based principles [96-98].

6-3- Inquiry-Based Learning (IBL) Environments and Learning Cycles

Numerous studies and reports have discussed the advantages of an IBL approach. It is a method which allows students to individually discover and construct information [74]. Also, many studies have suggested that IBL should be at the core of all science curriculums and used in the process of new knowledge acquisition [22, 23, 97]. IBL is also a multifaceted activity which entails making observations, question development, and information search and examination to see what is already known. IBL also involves the planning of investigations, knowledge review, and experimental evidence. Finally, in today's 21st century classroom ICT and digital tools and platforms play a critical role in the gathering, analysis, and interpretation of data, which then leads to answer proposal, explanations, predictions and results communications.

Therefore, the movement to IBL pedagogical classroom practices which use flipped classrooms requires a more hands-on approach, where students are at the center of the learning process [2, 33]. Additionally, studies more and more discuss the usefulness of IBL lessons which use the learning cycle method (LCM) like this study [99].

However, LCM is not new and can be traced back to a 1950's elementary school science curriculum project [74]. A LCM divides learning into multiple phases based upon an established planning method, which can also find its roots in Jean Piaget's cognitive development theory [100]. When compared to traditional pedagogies, LCM use creates better retention, higher scores, superior processing skills, and better science learning attitudes.

Finally, these ideas are consistent with another study in Indonesia, in which researchers developed a *New Inquiry-Based Learning* (NIBL) for university chemistry students which was found to be effective in improving their multiple higher-order thinking skills (MHOTS) which included ***C****TS*, ***A****TS*, ***C****reatively, and* ***P****ractically* (CACP) [97]. The results of this study revealed that the experimental group's CACP thinking skills increased significantly.

6-4- Digital Storytelling

When IBL was combined with digital storytelling (DTS) in a flipped classroom environment for use in developing student ATS, multiple DTS attributes and steps were determined as useful during the process. These included establishing an initial step in which the view point of the story-teller's presentation was articulated with clarity, accuracy, and conciseness. In the second step, the story teller finds the best moment and key theme that makes the story interesting. This can be done by posing a question for the target audience prior to the commencement of the story, hoping that this elicits enough interest in the story through its completion to find the answer. Like all good stories, emotional content is essential. Therefore in the 3rd step of the story, the DTS creator needs to find empathy from the audience with the characters so they become further immersed to the story. Similarly, in the 4th step, the story teller wants the ability to convey the tone and mood of the story. Is it a dark and rainy night? Is it a day at the shore with the seagulls? Is it on a train to a new country? All these themes have sound and music readily available which can be integrated softly into the background of the author's voice overs. Likewise, since a photo can say 1,000 words, the choice of still images and video in the 5th step can be critical to the story's success. Finally, how is the story shared with the audience?

6-5- Learning Style

The learning effectiveness index (EI) of learners was 0.67 with the EI being higher than the established criteria. This is consistent with the process of identifying the issues of curriculum content in the learning management plan according to the students' learning needs and their self-development and apply the knowledge gained to learning [93],

6-6- Learning Achievement

When evaluation was undertaken between the pre-test and post-test of the experimental student group, it was determined that the post-test learning achievement scores were significantly higher than the pre-test scores with statistical significance. This is in line with [101] in Thailand who also found that ICT and cloud based technology had a significant effect on the flipped classroom model's effectiveness, the students' achievement and satisfaction.

The study's results are consistent with other studies which argue that educators play a crucial role in the development and enhancement of a learner's CTS [102], with the preparation and development of student CTS a critical educational goal for university educators [103, 104]. Other studies have also pointed out criticism can be heavy when educational institutions do no prepare students with CTS and problem solving skills [105, 106]. Therefore, research in the development of student HOTS, CTS, and ATS are critically needed [107].

6-7- Post-test Results Analysis

When evaluation was undertaken between the pre-test and post-test of the student ATS experimental group, it was determined that the post-test learning achievement scores were significantly higher than the pre-test scores with statistical significance. This is consistent with [108] who found that IBL learning activities should not focus on lectures alone but instead use activities to practice student analytical thinking in which opinions can be shared. Online learning resources allow learners to study without limitation of time and place, as well as the ability to communicate and collaborate via social media between learners and teachers.

7- Conclusions

The LIFD ATS Instruction Model was reviewed by eight education experts who found the model's suitability to be at the 'highest' level (mean = 4.63, S.D. = 0.51) for students at the bachelor's degree level. Moreover, the combination of using a flipped classroom learning environment model, digital-storytelling and IBL led to student post-class achievement testing and Analytical Thinking Ability (ATA) testing indicating the students' learning achievement effectiveness index (EI) was 0.6666%, and their ATA result was 0.6966, which is greater than 0.50, therefore it meets the specified criteria. Moreover, the comparative results of the pre-test and post-test achievement tests indicated that student educational innovation and ICT modules had a posttest score higher than the pretest score with a statistical significance at the 0.05 level, indicating that the model helped students to have better academic achievement. The results of the comparison of the student ATS from both the pre-test and post-test testing indicated that the model was effective as it was statistically significant at the 0.05 level, showing that the model helps to promote the ATS of undergraduate students. The comparative results showed that the pre-test and post-test study achievement of students studying with a flipped classroom learning environment model combined with IBL and DST was 83.33%, which is higher than the 80% threshold set and statistically significant at the 0.05 level. Therefore, it was concluded that the developed ATS instruction model was an excellent initial prototype for online ATS teaching.

7-1- Suggestions for the Application of the Research Results and Limitations

- The most effective way to use the proposed learning environment model, which uses flipped classroom learning and digital storytelling to improve analytical thinking and learning, is as a student-centered learning approach. As a student-centered approach, learners have more roles in determining their own learning. However, teachers still play an important role in helping students to learn according to their own learning goals, acting as facilitators in obtaining the information they need. The instructor guides, supports, helps and encourages students to learn in each step of the learning activities. This is especially important if a learner lacks the motivation to learn or have the ability to understand the objectives of the specified learning plan.
- Teachers should analyze the curriculum, context and readiness of learners in all dimensions in order to enable the use of learning styles for maximum efficiency.
- The most effective way to use the proposed learning environment model, which uses flipped classroom learning and digital storytelling to improve analytical thinking and learning, is as a student-centered learning approach. As a student-centered approach, learners have more roles in determining their own learning. However, teachers still play an important role in helping students to learn according to their own learning goals, acting as facilitators in obtaining the information they need. The instructor guides, supports, helps and encourages students to learn in each step of the learning activities. This is especially important if a learner lacks the motivation to learn or have the ability to understand the objectives of the specified learning plan.

7-2- Suggestions for Further Research

Researchers should use the proposed ATS learning management model on students in different contexts, such as learners at other levels, including secondary school and elementary school. This learning management model should be studied in order to develop learners' abilities in other areas as well.

8- Declarations

8-1- Author Contributions

Conceptualization, N.P. and T.K.; methodology, T.K.; software, T.K.; validation, T.K.; formal analysis, N.P. and T.K.; investigation, NP; resources, NP; data curation, NP; writing—original draft preparation, NP; writing—review and editing, N.P. and T.K.; visualization, N.P.; supervision, T.K.; project administration, T.K.; All authors have read and agreed to the published version of the manuscript.

8-2- Data Availability Statement

The data presented in this study are available in article.

8-3- Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

8-4- Acknowledgements

The authors wish to give their sincere thanks to our visiting American Professor Ajarn Charlie who assisted with the paper’s English language editing and proofing.

8-5- Ethical Approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the King Mongkut's Institute of Technology Ladkrabang (protocol code EC-KMITL_64_057 and an approval date of May 14, 2021) for studies involving humans.

8-6- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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