Effective Collaborative Learning through Online Flipped Laboratory amid the COVID-19 Pandemic

Lawan Sriphong, Sathit Niratisai, and Chanokporn Sukonpan

***Abstract*—The novel coronavirus (COVID-19) pandemic has a great impact on pharmacy education. Laboratories needed to shift from traditional learning to full online-learning mode. As a result, the flipped online model has been developed as an online tool to accommodate with this online laboratory requirement. Laboratory experiences in an online collaborative format were conducted in pharmaceutical analysis laboratory course in 2020, and 2021. The students learned in online flipped laboratory can use digital technology quite well. They have been able to perform online laboratory effectively. The perspective of student engagement to collaborative learning was developing among group working. Besides, students showed strong positive-attitude to collaborative learning and teamwork. Nonetheless, in comparison with experiment-practice learning, students reflected negative perception of online learning. Thus, virtual facilitation in pre-class learning material is a key of improvement to strengthen students' engagement and improve psychomotor skills.**

***Index Terms*—Collaborative learning, flipped learning, online, laboratory, COVID-19.**

I. Introduction

Since the novel coronavirus (COVID-19) pandemic spreads across the globe, it has caused boundless disruption to every element of life. At the same time, the pandemic has challenged the profession and the Academy to adjust, modify and adapt to the paradigm of pharmacy education [1]. This pandemic has accelerated opportunities for new models of pharmacy education across the world [2]. Changes across all aspects of teaching and instruction have occurred. Traditional face-to-face (F2F) courses and, in some cases, entire degree programs are being taught using distance technology. Faculty members and students alike are adjusting to working and learning from home. Tremendous resources and energy have been invested to actuate the changes that have occurred [1]. Both pharmacy faculty member and students were forced to quickly adopt to a new teaching and learning environment to complete the online learning and work remotely [3]. Instructors charged with skills-based education that typically occurs in laboratories and other simulated environments are finding creative ways to accomplish learning outcomes [4].

Colleges of pharmacy have moved incrementally in the past two decades toward increasing use of digital technologies including online instruction, a trend that accelerated sharply in 2020 and may continue in the future. Key principles of effective online teaching suggest a need for timely support of academically to promote student self-efficacy, online engagement, and prevent failure [5]. Nowadays pharmacy students are comfortable with and use social media and online learning methods for academic and course purposes. However, students prefer a more blended approach, which includes both in-class, active, team-based learning sessions and online recorded lectures. It is interesting to note that students preferred a blended approach and not an online-only course [6].

Flipping the classroom represents an ongoing paradigmatic shift in education from teacher-centered instructional strategies (e.g., lecturing) to learning-centered instructional strategies (e.g., active student engagement). The flipped classroom (also called reverse, inverse, or backwards classroom) is a pedagogical approach in which basic concepts are provided to students for pre-class learning so that class time can apply and build upon those basic concepts [7]. The flipped classroom format refers to a model that promotes active learning by "flipping" the timing and location of class and homework activities. It is intended to allow for self-pace learning and to maximize class time for students to interact with learning materials in the presence of a faculty member, who is the content expert. [8]. This allows the classroom to serve as an active learning environment where students can work through more complex cases with the added benefit of learning from peers and receiving direct guidance from instructors. Successful implementations of the flipped classroom in pharmacy courses have been reported [9]. Pre-class learning methods for flipped classroom have an impact on learning outcomes, such as knowledge retention. This is especially important in flipped classroom settings because the in-class learning and higher order activities are built upon having a good foundational knowledge, which comes from the pre-class learning [10].

Previously, the 564 305 Pharmaceutical Analysis Laboratory II course at Faculty of Pharmacy, Silpakorn University was delivered using a live experiment-performing format. According to the COVID-19 pandemic and the faculty policy, all laboratory courses had to facilitate in online format to avoid physical contacts in laboratory room in 2020, and 2021 courses. These circumstances gave us the opportunities to strengthen 21st century skills of students via online format. To address these challenges, online flipped laboratory was developed as a new way to teach and deliver content and skills. This flipped laboratory was implemented using digital technology for education to strengthen the online collaborative skills. The aim of this study was to conducted action research to evaluate benefit and

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The authors are with Faculty of Pharmacy, Silpakorn University, Nakorn Prathom, Thailand (e-mail: sriphong_l@su.ac.th, niratisai_s@su.ac.th, sukonpan_c@su.ac.th).

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disadvantage of this online laboratory learning and key point for improvement since this was the first time to complete laboratory experiences by the flipped online model and online collaborative learning format.

II. Instructional Design

A. Online Flipped laboratory

The online flipped-learning process was conducted in 564 305 Pharmaceutical Analysis Laboratory II course at Faculty of Pharmacy, Silpakorn University, Thailand in 2020, and 2021. The course is a compulsory course for the third-year pharmacy students, emphasizing on pharmaceutical analysis for quality control of raw materials and pharmaceutical products according to pharmacopoeias, data analysis, and data interpretation in pharmaceutical quality control tasks. The course contains of experiments including drug analysis by spectrometric and chromatographic methods. The flipped online model (Fig. 1) was designed for the laboratory topic "Calibration of Ultraviolet Visible Spectrophotometer". Learning outcomes were as in Table I.

Pre-class learning activities for students were consisted of online lab briefing, online group working, online flowchart preparation, online data analysis, and online report preparation (Fig. 1). On the flip side, pre-class online collaborative learning was developed in Google classwork throughout group working for flowchart preparation, data analysis, and report preparation (Fig. 2) outside the classroom. Students conducted most of active learning tasks before attending the classroom. Whereas a traditional laboratory, only flowchart preparation was carried out before attending the classroom. In that case, data analysis and report preparation were completed after the traditional classroom. Online face-to-face (F2F) learning was conducted for lab briefing (only in 2020), group presentation, and discussion between teachers and students (Fig. 1) instead of experiment in laboratory room. As regard that, more active and team-based learning was incorporated into this flipped online model.

TABLE I: Learning Outcomes of "Calibration of Ultraviolet Visible Spectrophotometer" Laboratory

Learning outcomes
1. Understand and be able to describe the spectrophotometer calibration process and criteria for evaluation
2. Interpret and evaluate information of spectrophotometer calibration
3. Conclude an important evaluation for spectrophotometer performance
4. Practice digital technology skills by employing online learning program
5. Develop online collaborative skills during group working to accomplish online tasks

B. Teacher Roles

In the year 2020, a teacher gave online lab briefing using power point slides about 20 minutes, explaining the process of spectrophotometer calibration, the tasks for online group working, data providing and timeline for the laboratory. Online lab briefing was conducted 5 days prior to the day of lab practices. However, in 2021, two videos for lab briefing were created instead of online presentation. YouTube was employed as a platform for these online videos.

Teachers assigned technicians to operate the experiments of ultraviolet visible spectrophotometer calibration instead of students. Hence the data including spectra and absorbance values of reference material were gathered and converted to pdf files. Teachers provided learning materials including learning documents, lab instruction, and data of experiments in pdf files which students could access online in Google Classroom.

Teachers created an online quiz to evaluate the knowledge of spectrophotometer calibration using Google Forms. Multiple choice questions were made an answer key and assigned point in each question. The quiz was delivered in classwork assignment and started at the beginning of online F2F classroom. Quiz-time was 5 minutes. The score of each student was recorded in Google response spreadsheet immediately after submission of quiz.

Teachers performed as facilitators during group presentation in online F2F laboratory (Fig 1). After group presentation, teachers provided formative assessment to flowchart, data analysis and report by giving feedback and comments on doubtful results and clarified for the possible error that could be found.

C. Student Activities

In 2020, every student in each group prepared flowchart about the spectrophotometer calibration process and criteria in a shared file on Google Slides. Mind mapping diagram was used to increase participation and understanding a whole process in the same time. However, this activity was changed to studying the videos prepared by teachers in 2021 without mind mapping preparation.

Students performed data analysis for control of wavelengths, control of absorbance and limit of stray light radiation in an online spreadsheet using Google Sheets program. Everyone could work together in the same spreadsheet in the same time and different time. They could edit, analysis and discussing the results together.

Students prepared an online report of spectrophotometer calibration in an online document using Google Docs program. Also, everyone could work together in the same document in the same time and different time. Records of data, discussion, and conclusion of results were written in this report. Completed reports after class discussion were printed to pdf files and submitted the attached files in online classwork assignment. Each group had to send a picture of online group working in a report as in Fig. 2.

Each student completed online quiz using Google Forms at the beginning of online F2F classroom. In 2020, each group presented the online flowchart to explain the process of spectrophotometer calibration and the criteria to evaluate the instrument performance in mind mapping slides at Google Meet classroom on the day of laboratory. The data analysis was commented by teachers at the end of laboratory. Contrastingly in 2021, each group presented only the results of data analysis in Google Sheet and Google Docs at Zoom

classroom on the day of laboratory.

Students were encouraged to clarify when the flowchart and results were suspect and questionable. Then teachers described the key knowledge during the online discussion. Lab experiment summary was concluded. Afterward students revised lab report after correction from the comments. The final report was converted to a pdf file and sent in online classwork assignment.

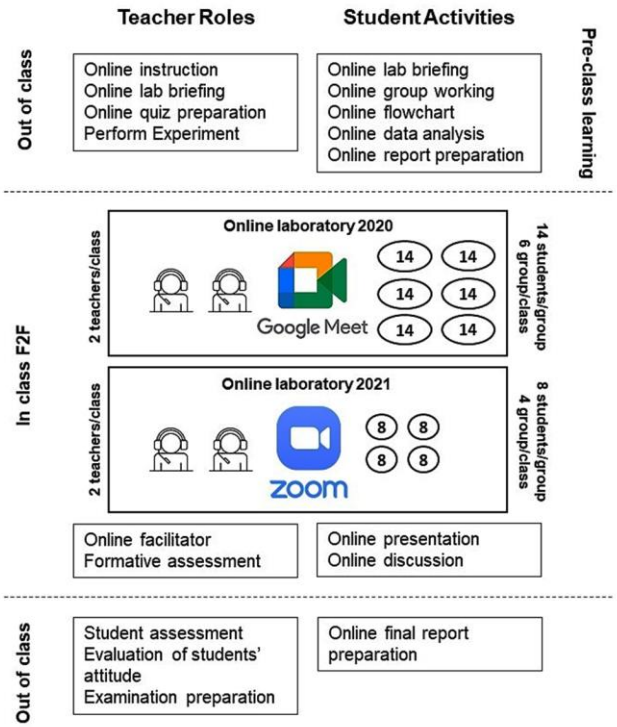

Fig. 1. Instructional design for learning process and activities: the flipped online model.

III. Implementation

In the year 2020, online flipped laboratory (Fig. 1) was operated in August 2020 (2 classrooms). There were 6 groups consisting of 14 students per group in each classroom. Google Classroom (classroom code 6ph6xl4) were created as an online laboratory room. The student was present with video-communication service, Google Meet (Google Inc, Mountainview, CA).

In 2021, online flipped laboratory (Fig. 1) was conducted in July 2021 (6 classrooms). There were 4 groups consisting of 8 students per group in each classroom. Google Classroom (classroom code afkq647) was created as an online laboratory room. The student was present with video conferencing software, Zoom Meeting (Zoom Video Communications, Inc). Total number of students who have enrolled in the academic year 2020 and 2021 was 170 and 189, respectively. All students were enrolled to online classroom using @silpakorn.edu account.

Using digital technology like Google Classroom, Google Meet, Google Slides, Google Sheets, Google Docs and Google Forms provided the most possible choice of fully implementation for laboratory experiments. Google Classroom was the main platform to communicate with students via Stream and Classwork for announcement, lab instruction, learning material, and assignment. Google Meet and Zoom Meeting were employed as platform for online F2F laboratory classroom.

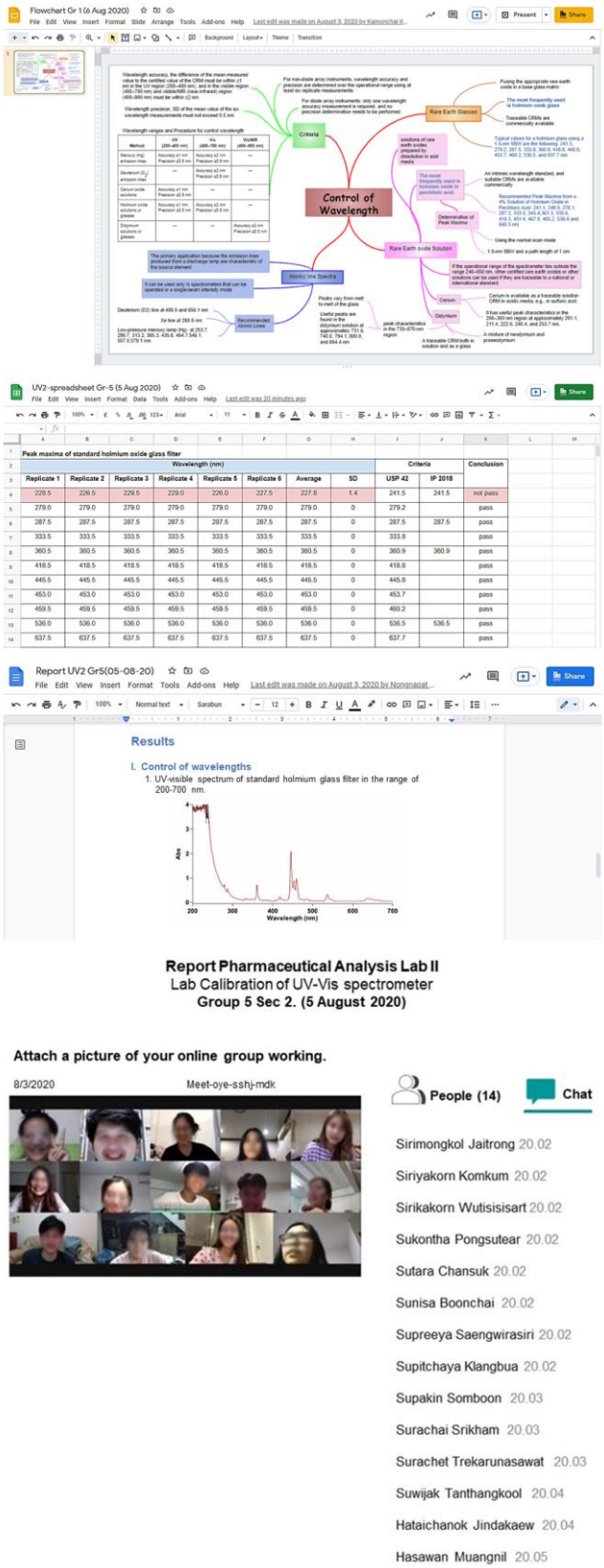

Fig. 2. Online collaborative learning activities outside the classroom.

IV. Assessment and Evaluation

The students were evaluated according to quizzes (10

scores), activity including online flowchart, data analysis and presentation (15 scores), report (15 scores), and paper examination (60 scores). Total score is 100.

The knowledge outcomes in traditional course were evaluated by quizzes, flowchart, lab operation techniques, report, and paper examination. On the contrary, data analysis and presentation were evaluated instead of lab operation techniques in this flipped laboratory since there was no lab operation. All assessment was conducted during the laboratory classroom except paper examinations which were conducted in September 2020 and August 2021, respectively.

At the end of class, evaluation of students' attitudes towards online laboratory was administered using an online survey. Students were able to evaluate by opening Google Forms link in Classwork assignment. The survey consisted of 8 items, using the following 5-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree. Specific areas for students to evaluate included students' satisfaction, ability to use digital technology and ability to develop collaborative skills. The analysis of surveys was summarized using Microsoft Excel 2019.

V. Results and Discussion

A. Students' Performance

All students who enrolled in the course had accessed and exercised an online laboratory "Calibration of ultraviolet visible spectrophotometer" in Silpakorn network system using Google Classroom as a main platform of digital learning. The online presentation platform was changed from Google Meet in 2020 to Zoom Meeting in 2021 according to Silpakorn University's policy. However, both video conference services provided an excellent communication platform just the same during the online F2F laboratory.

The year 2020 was the first year for online experience, thus the number of students per group was larger than the normal number performed an experiment in lab room. The larger group (14 students per group) could reduce individual tasks since students spent more time for group appointment and communication in online working. However, with regard to an effective collaborative learning process for online discussion, data analysis, and preparation of flowchart and report, the number of students per group was decreased (8 students per group) in 2021.

The mean score for quiz, activity (flowchart preparation, data analysis and presentation), and report were quite high in both academic year (see Table II). This demonstrated that students performed online laboratory very well and had high responsibility for their learning. Since the reduction of student number in group and removal of mind-mapping preparation, the students' performance in 2021 is significantly ($p < 0.05$) better than the year 2020 (Table II), especially the scores of paper examination (26.2 and 32.2 in 2020 and 2021, respectively) which indicated the more knowledge gained with respect to a smaller group of learning and the more data analysis and discussion. Even though the mind mapping preparation would support the understanding of a whole process of calibration of spectrophotometer, but the students were able to learn by the videos for lab briefing in 2021 and spent more time for data analysis process.

High mean scores of activities (13.0 and 14.5 in 2020 and 2021, respectively) in Table II indicated that the students enabled to describe the spectrophotometer calibration process and criteria for evaluation, interpret and evaluate information and conclude an important evaluation for spectrophotometer performance. The presentation in F2F online class can be revealed the understanding of the laboratory. Every student had to present as a member of group working. In teacher view point, the students performed their presentation quite well in 2020 and 2021. However, the students had to prepare and present the mind mapping of calibration process in 2020. Thus, the scores for data analysis of calibration information in 2020 were less than in 2021. Teachers can evaluate the collaborative activity by accessing a list of reversion history in an online report. Besides, the students had to show the evidence of their group working in the report. Accordingly, the collaborative skills were developed among the students in both years.

TABLE II: The Assessment of Students' Performance

Performance	Year 2020 N = 170 Mean (SD)	Year 2021 N = 189 Mean (SD)	*t*-test (One-tailed)
Quiz	9.3 (1.1)	9.8 (0.8)	$p < 0.05$
Activity	13.0 (0.7)	14.5 (1.6)	$p < 0.05$
Report	12.0 (0.2)	13.3 (2.2)	$p < 0.05$
Paper examination	26.2 (13.9)	32.2 (14.9)	$p < 0.05$
Total	60.4 (14.1)	69.8 (15.2)	$p < 0.05$

The students showed fast development of digital skills in this online learning process. They were able to prepare online flowchart, data analysis and report by themselves (Fig. 2). They ably used Google Meet and Zoom Meeting without difficulty for video conferencing. Stability of internet is the only major risk for online F2F learning. Consequently, the effective collaborative learning was established during online group working. Overall the students achieved learning outcomes (Table I), obtaining knowledge of instrument calibration, digital technology skills, and online collaborative skills.

The flipped online model is student-centered, treating each student as an independent and self-directed learner, and group learning outside the classroom. Active engagement of students in higher orders of thinking and problem solving was developed inside the classroom. In addition, the benefit of this online flipped classroom is the opportunity of formative assessment during the presentation. Teacher can provide some correction for misunderstanding and mistakes to all student in the synchronous F2F environment. There were few questions in classwork about the understanding of data provided, so there were a few mistakes in data analysis to meet learning outcomes.

B. Students' Attitude

One hundred-seventy and one hundred eighty-three students completed the course survey (100 % response rate) in 2020 and 2021, respectively. Students' attitudes (see Table III and IV) were highly positive regarding participation to teamwork (4.46 and 4.42 in 2020 and 2021, respectively),

and collaborative working and responsibility awareness (4.39 and 4.43 in 2020 and 2021, respectively). Students' perception revealed the benefit of this flipped laboratory to effective collaborative and teamwork skills. Although all members in group were able to perform laboratory asynchronously by themselves in any place and anytime but the characteristic of tasks was designed for synchronous participation to share the knowledge and have a discussion for lab results.

Students worked together and share more idea to prepare online flowchart in contrast with traditional laboratory that students prepared their own flowchart for laboratory procedure. Mind mapping is an effective way to illustrate all important concept in a single diagram and more flexible to write than workflow format. Students' performance on the flowchart presentation was very good during online F2F class meeting in 2020. Moreover, the concept of spectrophotometer calibration was more clarified and understood by online flowchart presentation. Mind mapping flowchart is useful and supported lab practicing (4.08) but provided moderate understanding the knowledge (3.88) in 2020. This leaded to the improvement of learning process by changing from mind mapping preparation to self-learning by lab-briefing videos on YouTube in 2021. Therefore, the students in 2021 spent more time with group discussion for data analysis. Consequently, not only all performance scores (see Table II) but also the attitude toward knowledge gained was increased (4.05) in 2021.

TABLE III: STUDENTS' ATTITUDES (N = 170) IN THE YEAR 2020

Items	Mean	SD
I participated and help team group to complete flowchart and report	4.46	0.67
Team members worked together to complete group reports	4.39	0.71
Mind mapping flowchart is useful and supported lab practice understanding	4.08	0.88
Online flowchart preparing is easy and comfortable to access	4.00	0.93
I understand more about calibration of UV-vis spectrometer	3.88	0.93
Lab instruction is clear and understanding	3.73	0.89
Practicing lab online is enjoyable	3.58	1.13
Practicing lab online is better than in lab room	3.15	1.24

TABLE IV: STUDENTS' ATTITUDES (N = 189) IN THE YEAR 2021

Items	Mean	SD
Team members worked together to complete group reports	4.43	0.76
I participated and help team group to complete flowchart and report	4.42	0.73
I understand more about calibration of UV-vis spectrometer	4.05	0.80
Lab instruction is clear and understanding	4.03	0.79
Online flowchart preparing is easy and comfortable to access	3.97	0.85
Practicing lab online is enjoyable	3.93	0.91
Lab-briefing video are useful to support lab practice understanding	3.85	0.87
Practicing lab online is better than in lab room	3.32	1.29

Although online laboratory has many benefits for digital and collaborative learning, but students could not operate the instruments by themselves and fairy agreed that online laboratory is enjoyable (3.58 and 3.93 in 2020 and 2021, respectively). Obviously, students' attitudes reflected their opinion that online practicing is not better than practicing in laboratory room. Students were fairly satisfied to online learning (3.15 and 3.32 in 2020 and 2021, respectively). For students with a strong preference for traditional laboratory learning, the perception of the learning experience was negatively affected by the flipped laboratory design.

In traditional laboratory, students performed their own experiment practices such as operating the spectrophotometer, setting parameters to measure absorbance and scanning absorption spectrum, and measuring the reference material for control of wavelengths, absorbance scale and limit of stray light. In contrast with online laboratory, all process in laboratory room was compensated by online demonstration format. As a result, the remembering level of cognition according to Bloom's revised taxonomy was developed instead of guided response level of psychomotor domain. This limitation should be noted. Nevertheless, the higher levels of cognitive (analyzing and creating of mind mapping) domain, and effective collaborative skills was developed. In the future, where the situation of COVID-19 pandemic is ongoing, the continual improvement for lab-briefing video should be focused on virtual-laboratory simulation to improve students for developing psychomotor skills.

VI. CONCLUSION

Online flipped laboratory has been developed to provide engaging learning experiences during the COVID-19 pandemic where physical distancing was prevailed to avoid coronavirus infection. It showed a great benefit for future learning to offer opportunities for pharmacy students to increase digital skills and online collaborative skills. An effective collaborative learning was established through online learning activities when students worked together to accomplish the assigned tasks. However, the disadvantage of online flipped laboratory is that it was not able to compensate for experiment practicing in a laboratory room. Accordingly, the key point for improvement is the development of virtual platform for laboratory simulation in reality, in order to assist students' psychomotor skills by online learning.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Lawan Sriphong conducted the research, analyzed the data, wrote the article; Sathit Niratisai and Chanokporn Sukonpan conducted as co-facilitators and evaluated during the synchronous online laboratory; all authors had approved the final version.

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Lawan Sriphong is currently an associate professor of the Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University, Nakhon Pathom, Thailand, 73000. She graduated in pharmacy (BSc in pharm) from Chulalongkorn University (Thailand) in 1986. Then she received her master of sciences (MSc in pharm) from Chulalongkorn University (Thailand) in 1990. She started her academic career as a lecturer at the Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University in 1989. Her research interest are new education technology and pedagogy.

Sathit Niratisai is currently an assistant professor of the Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University, Nakhon Pathom, Thailand, 73000. He graduated in Pharmacy (BSc in pharm) from Chulalongkorn University (Thailand) in 1991. Then he received his master of sciences (MSc in pharm) from Chulalongkorn University (Thailand) in 1994 and doctor of philosophy (medicinal chemistry) University of Minnesota in 2003. He started her academic career as a lecturer at Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University in 1991. His research interest are new education technology and pedagogy.

Chanokporn Sukonpan and is currently an assistant professor of the Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University, Nakhon Pathom, Thailand, 73000. She graduated in pharmacy (BSc in pharm) from Chiang Mai University (Thailand) in 1988. Then she received her master of sciences (MSc in pharm) from Chulalongkorn University (Thailand) in 1993 and the doctor of philosophy (pharmaceutical sciences) University of Wisconsin-Madison (USA) in 2002. She started her academic career as a lecturer at the Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Silpakorn University in 1993. Her research interest are new education technology and pedagogy.