ABSTRACT: This communication was to share the efforts made in developing the fully online courses in medicinal chemistry during the educational disruption due to the coronavirus disease 2019 (COVID-19) pandemic. In the academic year 2020, the online course was implemented for the first time at the Faculty of Pharmacy, Silpakorn University, Thailand. Various online teaching strategies were integrated, raising the question of whether the developed online courses would deliver similar learning outcomes to the traditional classroom. At the end of each semester, the teaching assessment report was conducted and evaluated in 4 parts: part 1, evaluation of lecturer; part 2, student’s self-evaluation; part 3, learning outcome development after studying the course; part 4, appropriateness of class environment and equipment. Overall, student responses toward parts 1−3 in the online class were as satisfactory as those in the previous on-site class. Lower scores toward part 4 were observed in the online class. In addition, student performance in terms of grade distributions between the on-site and online classes was different. On-site students earned the highest proportion of A grades, whereas online students earned a higher proportion of B+’s to F’s. While the pandemic persists and the need for online courses remains, we hope that this communication will provide some educational insight and strategies to help in the ongoing efforts to adapt and establish more successful online courses.

KEYWORDS: General Public, Curriculum, Distance Learning/Self Instruction, Testing/Assessment, Medicinal Chemistry

INTRODUCTION

Medicinal chemistry is a subject required for undergraduate students in pharmacy school in Thailand. The number of credits in medicinal chemistry subjects in most pharmacy curricula ranges from 6 to 9 credits, divided into 2−4 credit units for each course. At the Faculty of Pharmacy, Silpakorn University, a 3-credit course in medicinal chemistry I (MC I) is offered for third-year pharmacy students in the second semester, and a 4-credit MC II course is for fourth-year pharmacy students in the first semester in each academic year. Students’ learning objectives are to gain knowledge in the fields of drug discovery, design, and development, with an emphasis on relationships between chemical structures and drug-like properties such as pharmacodynamics and pharmacokinetics, to understand and achieve the effectiveness of drug administration in patients. Integral knowledge of various subjects from previous courses, such as organic chemistry, biochemistry, pharmaceutics, pharmacology, and so on, is essential for students in learning medicinal chemistry.

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To meet the objectives and to facilitate the students’ understanding and interest, the teaching scopes and framework for each semester have been collaboratively designed on the basis of the suggested comments from students and instructors in previous years. Seven credits of the lectures in two courses are divided into seven parts: part I, principle of medicinal chemistry; part II, drugs affecting neurotransmission; part III, drugs affecting central nervous system; part IV, drugs affecting hormonal system; part V, analgesic agents; part VI, chemo-therapeutic agents; and part VII, miscellaneous. A group of drugs to be discussed in each part is primarily focused on major drugs, especially those that appeared in the Thailand National List of Essential Medicine, and the emphasis on how to integrate relevant information from previous courses and to apply the structure–activity relationships (SARs) to predict the activity/physicochemical properties/pharmacokinetic properties/adverse reactions of some of the marketed drugs. The lecture-based classroom with active learning activities has been employed as a major teaching approach in medicinal chemistry courses to engage students in the frequent practice of higher-order cognitive skills and problem-solving and critical thinking skills.4−3

Since the first semester of the academic year 2020, the COVID-19 pandemic has caused the suspension of on-campus classes at the Faculty of Pharmacy, Silpakorn University. However, the abrupt news for school lockdown had been announced earlier in April 2020; fortunately, the first term had started in late June. By having approximately three months from the start of the news with the uncertainty of the situation, instructors in medicinal chemistry courses were strongly encouraged to prepare content for online teaching for the entire academic year.

### ONSITE VS ONLINE TEACHING STRATEGIES

The most traditional type of teaching and learning method for on-site classes is the face-to-face classroom. Live interaction between students and a teacher in a face-to-face class is important to create an engaging environment for learning.5 Face-to-face instruction provides immediate feedback and encourages students to engage more actively in their studies.5,6

In MC I and II on-site courses, instructors used various teaching styles, strategies, and tools, such as case studies, flipped classrooms, Kahoot and Socrative applications, and even a simple teaching technique, e.g., rewarding, all leading to the creation of a fun, enthusiastic, and active learning environment during face-to-face teaching to help students understand the course materials better. It has been common practice to combine traditional face-to-face instruction with different forms of online tools.7 Since 2018, on-site MC I and II courses at the Faculty of Pharmacy, Silpakorn University, have combined an online learning management system, such as Google Classroom and Silpakorn University’s e-learning service, as a supportive tool for additional communication platforms outside a regular class.

In the academic year 2020, the COVID-19 situation has caused a global disruption in the educational system. On-campus teaching and learning activities were nearly impossible to carry out in countries where the COVID-19 pandemic was severe. Many academic institutions around the world have been forced to make a rapid shift from face-to-face instruction to entirely online.8−12 During the transition, both students and instructors faced tremendous challenges, including technology-related, methodological, and psychological issues, such as unreliable internet, lack of proper teaching skills and techniques that support students’ engagement and adaptation for an online learning environment, little or no direct student–teacher interaction, and unnecessary stress.8−10 Aside from the challenges due to the technical difficulties and a substantial amount of workload and extra working hours toward the creation of suitable self-study materials for students, teachers also faced a problem in developing productive communication skills with compassion and care to support student success in online learning.

Technical and internet issues are a major challenge.4,9 In the MC I and MC II courses, our first step was to select the proper online tools in transitioning from on-site to fully online education in which the learning environment is mostly based on internet-accessed computers with no in-person or on-campus meetings. Google Classrooms, Zoom meetings, an e-learning service, and a Learning Management System (LMS) such as Canvas, Blackboard, and Moodle are popular technology platforms used by instructors to deliver study materials for online learning.13 Considering the ease of access and a simple installation, four familiar platforms, Google Classroom, Google Meet, Zoom, and an e-learning service, have been adopted for remote teaching and learning for medicinal chemistry courses at Silpakorn University.

Other concerns in developing an online lecture were about the increased workload, low-income students, student persistence, affordable internet-based equipment, and stability

### Table 1. Onsite vs Online Teaching Strategies and the Evaluation Criteria Integrated in MC I and II Courses

| Onsite Teaching Strategies | Evaluation Criteria  
|----------------------------|------------------|
| In-class lectures  
| (36%) | Midterm and final exams  
| (100%) |
| In-class lectures with self-assessment exercise  
| (52%) | |
| In-class lectures with case study approach  
| (12%) | |

| Online Teaching Strategies  
|----------------------------|------------------|
| Real-time virtual classroom  
| using the Zoom video teleconferencing platform with self-assessment exercises  
| (20%) | Online midterm and final exams via e-learning service  
| (54−58%) |
| Self-study video clips and handouts with self-assessment exercise, followed by a scheduled period for live online discussions of content summary and case studies  
| (80%) | Midterm and final exams on campus  
| (32%) |
| Pre- and postquiz via Quizizz and short assignments submitted via Google Forms  
| (10−14%) |

“Google Classroom and e-learning service were used as the communication platforms for both on-site and online classes.  

Percentages refer to the time allocation used for each strategy.  

Incorporated with active learning activities, such as game-based learning, questioning, rewarding, and interactive lecturing.  

Percentages refer to the criteria used for grading.  

A traditional method using a pen and hard-copy paper was used for on-campus exams.  

The platforms for online exams were the e-learning service and Zoom. The exam questions were embedded in the e-learning platform, and the faculty provided a management system for monitoring students during the exam via Zoom.
of internet connections. Reports and communications on the efforts to develop remote teaching and learning of chemistry and other courses in higher education were published.14−20 In the MC I and II online courses, self-study video clips and handouts were implemented as a major online teaching strategy. Instructors were asked to design a distance-learning framework and prepare a lesson plan with a carefully adjusted schedule of online teaching activities appropriate for the time provided and still achieve the learning objectives for each lecture. Different teaching strategies, such as real-time virtual classroom, self-assessment exercises, assignments, live online discussions on key points, content summary, and case studies, varied from one lecture to another, allowing a refreshing change and motivating students for active learning (Table 1). To encourage students to complete their assignments, points were sometimes awarded. For students without high-speed internet or proper electronic devices, all live online lectures were recorded and uploaded in the e-learning service for students to access at any time from anywhere.

Furthermore, up-to-date communication and announcements before the beginning of each semester were necessary to prepare students for the upcoming online classes. Students were notified with a detailed schedule on when to watch which topics on the prerecorded videos, stream online for live teaching, expect quizzes, and submit assignments. Communication with students via email, Line, Google Classroom, and e-learning web boards has been opened to any possible raising of issues and questions.

### STUDENT’S PERSPECTIVES AND ACHIEVEMENTS TOWARD ONLINE TEACHING

In the academic year of 2020, the fully online teaching method was implemented for the first time in medicinal chemistry courses at the Faculty of Pharmacy, Silpakorn University. Even though there were previous reports that showed that students in online and face-to-face courses did not differ in their performance,21−23 there were some reports on the differences in student performance in terms of grades between learning modes.24,25 The question of the effectiveness of online teaching in medicinal chemistry courses was still in doubt, especially regarding whether the online students could achieve similar learning outcomes and performances as compared to on-site.

At the beginning of the school lockdown, the remote teaching strategy implemented in MC II was conducted by giving students the assignments to watch video clips, study the handouts, and submit self-assessment exercises. Study materials to be taught from late June to July 2020 were posted online via Google Classroom one and a half months before the class schedule. Students were also required to attend live discussions for content summaries and open-ended questions. Detailed information about which topics were being discussed, when to participate online, and how to participate online was announced via Google Classroom. To encourage student participation in live discussions, the instructor’s role was to guide students through the process of discussing and focusing on the main concepts during an online class. Several students made interesting comments and questions. Many participated by sending short messages and replies via a chatbox. At some point during a 100 min live class, students were asked to complete an online quiz via Google Form. The quiz consisted of a series of simple multiple-choice questions based on the discussion materials. There were 152 students out of a class of 154 who submitted the form. Correct answers, frequently missed questions, and other remarks were provided as feedback and sent to each student after a manual review of the responses by the instructor.

At the third week of the shift to online teaching and learning activities, the initial surveys on students’ perspectives toward online teaching had been distributed to the students. The surveys included a questionnaire on the students’ attitudes toward the teaching process of the 6-period lecture on the medicinal chemistry of the steroid topic taught during the second and third week of the 14-week course and a commentary survey on general perspectives toward the online class. The responses were collected by the Faculty’s Academic Administration and Development Section. There were 109 respondents (from a class of 154) to the questionnaire. The report showed that students had good attitudes toward the overall online teaching process (Table 2).

| Teaching Process                                      | Score |
|-------------------------------------------------------|-------|
| Teaching aids                                         | 4.64  |
| Handouts                                              | 4.63  |
| Use a variety of appropriate teaching strategies, well-prepared and organized | 4.58  |
| Create a vibrant classroom with students involved and open to discussion and questions | 4.81  |
| Implement quality inquiry learning experiences that require students to analyze, connect, and investigate concepts and problems | 4.76  |
| Clearly demonstrate the relationships among topics in this course and other relevant subjects | 4.75  |
| Clearly demonstrate the significance of this lesson with respect to professional practice | 4.72  |
| Overall satisfaction with instructor’s teaching performance | 4.56  |

*Scores on a scale of 1 to 5 from very poor to excellent.

However, according to the commentary survey, approximately 25% of the class expressed their frustrations on the considerable workload from watching videos, self-study learning activities, and assignments due within a specific time frame. The students’ responses from the initial surveys raised a specific concern for dissatisfaction with the extra-hour learning activities. Therefore, the rest of the online lectures were adapted to provide more comfortable and appropriate online learning environments regarding study hours, workloads, and distance-learning capacities such as stability of internet connections, electronic devices, and equipment to access online tools. For example, rather than students having a time limit to watch video clips and submit assignments, students were allowed to complete the tasks over a longer period to lessen their time constraints. Self-study video clips and handouts were the primary online teaching tools for most lectures, allowing students to conveniently study and review the study materials at their own pace. However, at the end of each topic according to the course syllabus, roughly about one-fourth of the real-time periods, the instructors set up online live discussions which students were free to attend if they were interested rather than being mandatory. To encourage student participation, instructors explained the importance and benefits of online discussions whenever the opportunity arose. Points were occasionally rewarded. Real-time classrooms using the Zoom video teleconferencing platform to conduct live online classes according to the schedule were implemented for 20% of

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the lectures to maintain the virtual student–teacher interactions and face-to-face communications as close to a traditional classroom as possible. To alleviate the concerns about internet connection instability and problems with electronic devices during an online live class, instructors frequently used two different internet providers and multiple technological devices in case one of them failed. Additionally, a backup video of live teaching was recorded in case any students

Table 3. Teaching Assessment Report on MC I and II Courses in the Academic Year 2020

| Part: Evaluation of Lecturer                                                                 | Mean Scores ± SD |
|---------------------------------------------------------------------------------------------|------------------|
| Lecturer provided a teaching plan and explained course objectives as well as grading and evaluation criteria clearly and appropriately. | 4.40 ± 0.66      |
| Lecturer taught the course completely as stated in the teaching plan.                       | 4.38 ± 0.64      |
| Lecturer had suitable and up-to-date instructional materials and media.                     | 4.32 ± 0.67      |
| Lecturer was on time for class.                                                             | 4.26 ± 0.73      |
| Lecturer prepared and had strong intention for teaching.                                    | 4.34 ± 0.66      |
| Lecturer had an ability to explain/conclude main concept of the course contents clearly and sequentially. | 4.28 ± 0.68      |
| Lecturer had instructional procedures to stimulate student’s learning interest and analytical thinking. | 4.22 ± 0.74      |
| Lecturer provided opportunities to students for questioning, discussing as well as listening to students’ opinions/comments. | 4.30 ± 0.71      |
| Lecturer supported student’s self-study by recommending documents, books, and other information sources. | 4.25 ± 0.68      |

| Part: Student’s Self-Evaluation                                                             |        |
|---------------------------------------------------------------------------------------------|--------|
| Student attended class regularly and on time.                                               | 4.11 ± 0.76 |
| Student participated in questioning and discussing activities during the class.             | 4.14 ± 0.80 |
| Student reviewed and studied course contents outside classes.                               | 4.14 ± 0.70 |
| Student understood the purposes and the contents of the course.                            | 4.19 ± 0.69 |

| Part: Learning Outcome Development after Studying This Course                              |        |
|---------------------------------------------------------------------------------------------|--------|
| Student has developed moral and ethical aspects.                                            | 4.13 ± 0.75 |
| Student has developed knowledge.                                                            | 4.26 ± 0.67 |
| Student has developed intellectual skills.                                                   | 4.22 ± 0.72 |
| Student has developed interpersonal relationship skills and responsibility.                | 4.11 ± 0.78 |
| Student has developed communication skills and information technology usage skill.         | 4.04 ± 0.85 |
| Student has developed psychomotor skill and has applied the knowledge to operate work with quality, efficiency, and safety. | 4.16 ± 0.71 |

| Part: Appropriateness of Class Environment and Equipment                                    |        |
|---------------------------------------------------------------------------------------------|--------|
| Classroom environment                                                                       | 3.37 ± 0.90 |
| Audiovisual equipment                                                                       | 3.38 ± 0.94 |
| Equipment for teaching courses                                                               | 3.53 ± 0.85 |
| Computers and devices for information technology and communication                           | 3.65 ± 0.79 |

Scores on a scale of 1 to 5 from very poor to very good.

Figure 1. Graphical representation of the teaching assessment results of MC I and II courses in the academic years 2018−2020. A score, from very poor to very good, ranking on a scale of 1−5.

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went offline during the live session. The faculty also supported a study room equipped with electronic devices for students without access to these resources at home. A laptop computer was available for borrowing. Prepaid internet cards were also provided to those who requested them.

At the end of each semester, the teaching assessment survey which included 4 parts (part 1, evaluation of lecturer; part 2, student’s self-evaluation; part 3, learning outcome development after studying the course; and part 4, appropriateness of class environment and equipment) was engaged and reported to the instructors by the Division of Academic Administration, Silpakorn University (Table 3). The survey had a response rate of 97% and 99% students, from 172 third-year and 154 fourth-year students registered in MC I and II courses, respectively, in the academic year 2020.

From the assessment report, the students gave a good score value for the lecturer and teaching method (part 1), student’s self-evaluation (part 2), and learning outcome (part 3) in both courses. Interestingly, the overall assessment scores in parts 1–3 of the online MC I and MC II courses in the academic year 2020 were similar to those of the previous on-site classes in the academic years 2018 and 2019, except that the lower scores were obtained for the assessment result of part 4, appropriateness of class environment and equipment in the online class (see Figure 1). Apart from the scoring, similar comments were expressed in each academic year’s assessment reports as follows: a substantial amount of heavy content; the level of difficulty in exam questions for some topics; well-summarized key points with energetic teaching style but speaking too fast in some classes; and helpful self-test activities.

Figure 2. Grade distribution profiles (in percentage) of (A) the students in the on-site classes of MC I_2/2018 and MC II_1/2019 (159 students in both classes), (B) the students in the on-site class of MC I_2/2019 (155 students) and the online class of MC II_1/2020 (154 students), (C) the students in the on-site classes of MC I_2/2019 (155 students) and of MC I_2/2020 (172 students), and (D) the students in the on-site class of MC II_1/2019 (159 students) and the online class of MC II_1/2020 (154 students).
such as quizzes, exercises, and key points addressed by the instructors.

When considering students’ achievement as measured by grades, which were determined mainly on the basis of how well students performed on examinations. Evaluation criteria for the on-site MC I and II courses were 100% examination. For the online courses, examinations were still the primary evaluation criteria (see Table 1). Approximately 10–14% of the examinations were replaced by assignments. Multiple-choice questions were used in the exams. Each one-period lecture on a topic with grades based primarily on exams had four questions. Each question was worth one point. For example, a total of questions was similar in both online and on-campus exams. Thus, there was a total of 193 questions in the online exams. The difficulty of multiple-choice questions was similar in both online and on-campus exams consisting of questions with varying cognitive levels such as remembering, understanding, and applying.

In terms of exam administration, the exams in on-site courses were divided into two parts: midterm and final exams. Each exam lasted three hours. However, due to the COVID-19 situation in the academic year 2020, a faculty guideline stated that each exam, whether taken on-campus or online, could not last more than two hours. As a result, the exams for the online courses of 3-credit MC I and 4-credit MC II were divided into two (the midterm and final exams) and three (the midterm exam, late-midterm exam, and final exam) sections, respectively. Each section lasted two hours. All students were required to take and finish the exams at the same time. The on-campus exams used a traditional method with a pen and paper, whereas the online exams were given through the e-learning service and Zoom platform. Questions were embedded in the e-learning platform, and the faculty provided a management system for monitoring students during the exam via Zoom. Each student was required to have two electronic devices. One was for taking the online exam through the e-learning platform, and the other was a webcam device set up to ensure that each student was aware of being monitored. One teacher proctored 20–24 students via Zoom during the online examination.

From the similar responses on the teaching assessment reports of the on-site MC I and II courses in the academic years 2018 and 2019 (see Figure 1), it would be expected that the overall performance of the same student group, as measured by grades, for both classes should not be significantly different. For example, the grade distribution of a group of 159 students taking MC I in the second semester of 2018 should be similar to that of the same student group taking MC II in the first semester of 2019 (see Figure 2A). The grading report showed that this group of 159 students earned the highest proportion of A grades (37% (59/159) and 39% (62/159), in MC I and II, respectively), followed by B+’s and B’s with fewer C+’s, C’s, D+’s, D’s and no F’s.

However, the grade distribution of a group of students in the on-site MC I class in the second semester of 2019 and that group in the MC II class in the first semester of 2020 showed a different profile (see Figure 2B). A group of 155 students in the on-site MC I class in the academic year 2019 earned the greatest proportion of A grades (58% (90/155)), with only one student receiving an F. There were 154 students who passed the MC I class who enrolled in the following MC II class in the academic year 2020, which was delivered entirely online due to COVID-19. A large decreasing percentage of A’s and the increasing proportion of poor to average grades in the online class were observed. In the MC II online class, the report showed that the online students had the highest proportion of C grades (31% (48/154)). Furthermore, when comparing the grade distributions of the on-site and online courses (see Figure 2C,D), on-site students in MC I and MC II earned the highest proportion of A grades, whereas online students earned a higher proportion of B+, B’s to F’s.

The data gained from the teaching assessment reports and the grade distribution profiles of the student groups from on-site and online classes revealed that, regardless of the good score values toward the teaching method and learning outcome as seen in parts 1–3 of the assessment reports, there was a decrement in part 4 scores, appropriateness of class environment and equipment, reflecting that the limited distance-learning capacities, such as audiovisual equipment, computers, internet connection, and, particularly, student’s adaptability to the new classroom environment, seemed to be crucial for the student performance.

**CONCLUSIONS**

The COVID-19 pandemic situation forced drastic changes in the educational system on a global scale. Students and instructors have been working hard to improve themselves to be properly engaged in the online teaching and learning approach. With many challenges to overcome during the transition to online teaching, our efforts were put into the design and implementation of the online medicinal chemistry course that could deliver learning outcomes comparable to those of the traditional classroom. Overall, the students appeared to be satisfied with the current, online teaching approach. However, emotional constraints from new learning environments required more support and understanding. Although it is the primary responsibility of instructors to provide effective teaching that supports student learning, students’ accountability and adaptability to online education are also critical to the overall success of higher education under the pressure of the COVID-19 academic disruption. The observations gained from students’ perspectives and achievements toward online teaching of medicinal chemistry courses gave us as instructors more understanding. According to the data, our online students were satisfied with the lecturer and learning outcome and less satisfied with the online teaching and learning environments. Self-discipline strategies and effective communication with compassion and care would be beneficial on how to help students adjust to these challenges. Students should be encouraged to develop the mindset that they must take responsibility for their learning. By doing so, the faculty should occasionally provide short extracurricular activities for students, such as a few-hour lesson on how to develop self-motivation and self-discipline skills before beginning online courses and how to manage their time to succeed in an online course.

In addition, an approach such as an early warning system for students with difficulty adapting and a lack of self-discipline might be more frequently established throughout the course. The evaluation criteria for measuring student performance such as the proportional percentages between the exams and the awarded assignments during lectures should be appropriately adjusted. For the next academic year to come, if the COVID-19 pandemic situation continues to persist, online courses would have to be carried on, but, hopefully, with more
confidence and better success with learning outcomes and student achievements.

**AUTHOR INFORMATION**

**Corresponding Author**

Panadda Phattanawasin — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand; orcid.org/0000-0002-3300-4118; Email: phattanawasin_p@su.ac.th

**Authors**

Onoomar Toyama — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Theerasak Rojanarata — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Panjapol Laapoonpat — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Kanawan Pochanakom — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Chutima Limmavapirat — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Chanokporn Sukonpan — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Paiboon Nantanakorn — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Sathit Niratisai — Department of Pharmaceutical Chemistry, Silpakorn University, Amphoe Muang, Nakhon Pathom 73000, Thailand

Complete contact information is available at: https://pubs.acs.org/10.1021/acs.jchemeduc.1c00606

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