Pharmacy Students' Perceptions and Performance from a Microlearning-based Virtual Practical on the Elucidation of Absolute Configuration of Drugs

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https://doi.org/10.24191/ajue.v17i4.16187

Received: 15 July 2021
Accepted: 30 Sept 2021
Date Published Online: 31 October 2021
Published: 31 October 2021

Abstract: The Covid-19 Movement Control Order imposed by the government converted the delivery of lessons to online learning in the education sector. Pharmaceutical chemistry is a core subject for pharmacy students and first-year students were taught the elucidation of the absolute configuration of active pharmaceutical ingredients (API). The objective of this study is to investigate the pharmacy students' perceptions and performance on learning new knowledge related to the concept of absolute configuration on API through micro-learning. Students were introduced and assessed on the stereochemistry of new terminologies through micro-learning activities. Various 3D molecular model capture in video format was uploaded on YouTube(YT) and embedded in the Google Form(GF) online assessment. The students' video navigation was captured with YT video analytics, students learning performance was through GF quiz assessment responses, and the student's attitudes through questionnaire survey. In conclusion, the performance of student pharmacists in learning and applying new knowledge delivered through online distance micro-learning was comparable to face-to-face active learning. Both YT video analytics and GF responses allowed real-time monitoring and interventions. Nonetheless, students required more time to learn new knowledge online compared to face-to-face active learning. In conclusion, the designed virtual micro-learning enabled students to learn bite-sized new knowledge while training their spatial ability through the application of 3D molecular models with reinforcement through quizzes. The virtual micro-learning design is practical and economical without much technological investment or training for both the educator and learner with easy access in an open distance learning environment and post-Covid.

Keywords: Absolute configuration, Analytics, Micro-learning, Online assessment, Video

1. Introduction

The Covid19 pandemic has impacted all aspects of economic and social development globally. Without an available vaccine, the only option to curb the spread of the virus infection was by issuing a lockdown or temporary prevention of population movement. In Malaysia, the government imposed the Movement Control Order (MCO) resulted in the sudden shift of all teaching and learning activities in universities to online distance learning (Samat et al., 2020).

Fundamentals of pharmaceutical chemistry is a compulsory core subject for pharmacy students as this subject relates to the chemistry of drugs and the interaction of pharmaceuticals to the biological system. Pharmaceuticals are comprised mainly of organic molecules. The understanding of the basic structure of an organic molecule with its three-dimensional (3D) structures is essential in understanding the physical properties, interactions of the drugs with the biological system, and correlation of the structure-activity-relationship of the drugs to its pharmacological effects. The unambiguous identification of a drug and its analogues, impurities, or metabolites is important knowledge for pharmacists in the manufacturing, research and development, product development, or drug regulatory agency. Moreover, regulations related to the new drug substances or products were outlined in the International Council for Harmonisation (ICH) Guidelines, for example, ICH Q3 and ICH 6A. These serve as regulatory guidelines for the registration of new chemical or molecular entities. Thus, it is essential to equip pharmacy students with basic knowledge of organic chemistry.

The complex and abstract nature of chemistry makes learning and understanding chemistry challenging. Many researchers have reported on students' conceptions of fundamental, underlying chemistry concepts indicating that the fundamental concepts were not constructed adequately, more advanced concepts that build upon the fundamental were not fully understood (Abraham et al., 1992). The knowledge to elucidate the absolute configuration of an active pharmaceutical ingredient (API) is essential for pharmacists as there is an increase in the registration of new enantiomeric pure chiral drugs with its established absolute configuration (Calcaterra & D'Acquarica, 2018).

In the fundamentals of pharmaceutical chemistry course, remote online teaching and learning during the pandemic involved synchronous and asynchronous sessions. The theoretical concepts were live streamed to all the students for 1-2 hours at scheduled times. The recorded live-stream videos and lecture notes were later uploaded in Google Classroom (GC) as a reference for the students.

The stereochemistry practical laboratory, however, was re-designed to suit remote online learning. Typically, in the pre-Covid-19 pandemic, the face-to-face active learning practical session allows students to explore various poses and configurations of drugs and API by the use of molecular models and a set of self-guided questions. Studies found that many students lack the ability to form three-dimensional (3D) mental images, let alone mentally rotate the 3D images by viewing two-dimensional (2D) chemical structures (Tuckey et al., 1991). Penny et al., (2017) indicated that manipulating physical models offered a long-term cumulative effect on students' understanding. Therefore, the molecular model kit was employed to enhance the visualisation of the 3D projections of atoms or molecules in an API. In the absence of a physical molecular model, the entire practical session was converted to an online micro-learning activity utilising Google Form (GF). In the micro-learning activity, the hands-on manipulations of the molecular models during the practical were replaced by pre-recorded bite-size videos showing the molecular models in several poses and configurations followed by questions that the students have to answer.

In addition, micro-learning activity can facilitate the learning process to new learners by breaking down a lengthy content into shorter, bite-sized content or referred to as micro-content. Micro-content design and development are consistent with the three assumptions of Mayer's Cognitive Theory of Multimedia Learning. In the first assumption, the theory proposes two different channels for the acquisition and processing of visual and auditory information. Building on Sweller's Cognitive Load Theory (Sweller, 1988), the second assumption points out that each channel has a limited capacity and can deal with only a few pieces of information at a time. Concurrent usage of both channels maximizes the working memory capacity but either channel can be overwhelmed by a high cognitive load. This provides justifications for judicious microlearning designs with an emphasis on organising small learning units in a logical, multimedia-based micro-learning activity having a clear and consistent structure for online distance learners. It helps learners to focus on learning about a specific topic before moving on to the next one. Thus, the micro-learning approach can facilitate learners in constructing their understanding of an area or subject, one learning unit at a time.

The approach is also congruent with the third assumption: learning is an active process. During micro-learning activities, learners are provided with multiple opportunities for active processing (select, organize, integrate information), thus allowing "meaningful learning" to occur and enabling the retrieval and application of information stored in long-term memory (Mayer & Moreno, 2003). In supporting and fostering effective learning in the digital age, the micro-learning approach affords flexibility and confers some sense of autonomy; it can be given to learners progressively to be

completed according to their schedule and readiness (Redondo, 2021). The bite-sized micro-learning approach is gaining acceptance both in the education and industry sectors as learners can understand easily complicated topics. (Hegerius et al., 2020; Beste, 2021).

Some criteria in creating a successful micro-learning activity are interactive, real-life examples, accessible on multiple devices, and flexible lesson plans or strategies. Learners must be engaged in either quizzes, simulations, interactives, or games to create an environment for learning and assessment. Topics in micro-learning should be related to their future actual work situations or learning objectives. These micro-learning activities should be able to be assessed using multiple devices so they can be assessed anywhere and anytime. Finally, it is used as part of a bigger learning strategy. Micro-learning is based on the idea that students remember information better when it is presented in small chunks, especially followed by reinforcement.

The objective of the present study is to investigate students' perceptions and performance in the online stereochemistry practical using a microlearning approach that combines short videos with self-guided questions on the absolute configuration of a drug substance.

2. Method

Fundamentals of pharmaceutical chemistry course is a first-semester course for first-year undergraduate pharmacy students. Google Classroom (GC) was utilised as the learning management system (LMS) and all the students were invited to enrol in this course. The announcement on the briefing session through live stream and the assessment questions were posted a week earlier. Students had two weeks to apply the new knowledge gained from the lectures and micro-contents delivered via the Google Form before the assessment.

2.1 Micro-content creation

The micro-content consists of primarily short videos. The videos were designed to emphasize a small portion of a fixed online lecture topic that was taught a week earlier. The lecturer-in-charge used molecular model kits to demonstrate the 3D structures of a chemical substance. The demonstrations of the 3D-molecular structure of each question were captured using a Sony RX100 camera and exported as MP4 video format. Later, the videos were trimmed using Movie Maker software. The trimmed videos were uploaded on YouTube (YT). Each of the videos lasted between 12 to 62 seconds; the speed of the videos was accelerated twice the normal speed. The video on the Introduction section was edited with PowerPoint software; it has the longest playback time of 9:27 min. All micro-content videos uploaded in YT were embedded in the newly designed GF. Another video labelled Question 1 was used to explain the R and S assignment according to the Cahn-Ingold-Prelog priority system with the questions shown in the same video lasted 2:34min. The quiz questions were displayed using Google Form (GF) with the YT link or embedded video (Fig. 1). Students were given approximately a week to complete the online assessment. The quiz was comprised of 11 sections with 55 questions directly converted from face-to-face (F2F) active learning of 3hr practical session.

Fig. 1 Part of assessment in GF

2.2 Micro-content and assessment design in Google Form

The relevance of this micro-learning activity to their pharmacy profession was described at the beginning of the GF. It intends to make the first-year students aware of the importance of the topic to their profession. The absolute configuration topic was selected to be a micro-learning topic because of the importance for the pharmacist to be able to accurately determine the absolute chemical structure of an active pharmaceutical ingredient (API). Enantiomeric pure drugs affect the pharmacology, safety and efficacy compared to their racemic mixtures. Due to the high volume of the new chemical entity with enantiomeric pure isomers were submitted for registration, the guideline, ICH Topic Q 6 A, on the Test Procedures and Acceptance Criteria for New Drug Substances and New Drug Products on Chemical Substances, was created as guidance for pharmacist regarding on the setting and justification of acceptance criteria and the selection of test procedures for new drug substances which have not been registered previously.

The microlearning-based virtual practical was delivered with GF embedded with video and quizzes. Students were required to complete a total of eleven sections. The first section of the Google Form was designed to collect student information, e.g. email address, student i.d. number and assigned group. The second section featured a short video that introduces some of the critical stereochemistry terminologies, e.g., enantiomers, diastereomers, racemic, *RS* convention, stereogenic carbon, optically active compounds. This video lasted for 9:27 minutes.

The assessment questions started from the third section. In Section Three to Five the simple optically active molecule, namely, 2-chlorobutane was used. The concept of stereogenic carbon and RS-convention according to the Cahn-Ingold-Prelog (C.I.P) priority was applied to identify the enantiomer pure isomers. Section Four and Five involves the identification of molecular conformations with various projections and representations e.g., Sawhorse, Fisher, and Newman projections.

The concepts of stereogenic carbon, enantiomer, mesomer, diastereomer, RS convention, configuration, conformer, were applied to 2,3 dichlorobutane model (Section 6 to 8), 1,2-dichloro cyclopentane (Section 9), 1,4-dichlorocyclohexane (Section 10), and the final section 11 was an application of this new knowledge on a drug molecule, namely Alprostadil to match the nomenclature or molecule name with the absolute configuration with the definition listed in a pharmacopeia monograph. A list of the sections, topics and short videos is outlined in Table 1.

Table 1. The content of eleven sections in Google Form

Section	Topics	Number of videos	Total duration (min)
1	Students' information	0	0
2	Video introduction to stereochemistry terminologies	1	9:27
3	Concepts in Stereogenic carbon Cahn-Ingold-Prelog using 1,2-chlorobutane	1	2:34
4 - 5	Conformations with different projections and representations e.g. Sawhorse, Fisher, Newman projections	2	1:59
6 - 8	Applications on stereogenic concepts to 1,2-chlorobutane	12	6:24
9	Applying concepts in stereochemistry to 1,2-dichlorocyclopentane	4	0:55
10	Applying concepts in stereochemistry to 1,4-dichlorocyclohexane	2	1:04
11	Applying concepts in stereochemistry to a drug i.e. Alprostadil	0	0

2.3 Micro-learning Evaluation

One week after the micro-learning briefing, students needed to answer all the quizzes in the eleven sections of GF. The assessment grades were released after the deadline. The results from their scores indicated the level of understanding.

2.4 Research Design

In this session, there were 116 students (24% male and 76 % female) enrolled as the first semester students in the Bachelor of Pharmacy course. The Bachelor of Pharmacy students have a minimum CGPA of 3.50 from pre-university programmes, namely, Foundation, Matriculation Programmes, or Diploma of Pharmacy with a minimum of 2 years working experience. The study adopted a qualitative approach where the data was collected online using Google Form. After the micro-learning session, students completed the online questionnaire survey that evaluates their perceptions towards the effectiveness of the course. Questions were related to the students learning schedule, motivation to get information, and ease of using GF or YT during their assessment earlier.

3. Results and Discussions

3.1 Students learning profile

There were 22 short videos uploaded in YT which were embedded in the GF with 55 quiz questions. Students were allowed to view the videos and discussed with their peers and individually submit the completed GF quiz online. The YT analytics below showed that most students previewed the videos and started preparing two days ahead of the briefing (Fig 2).

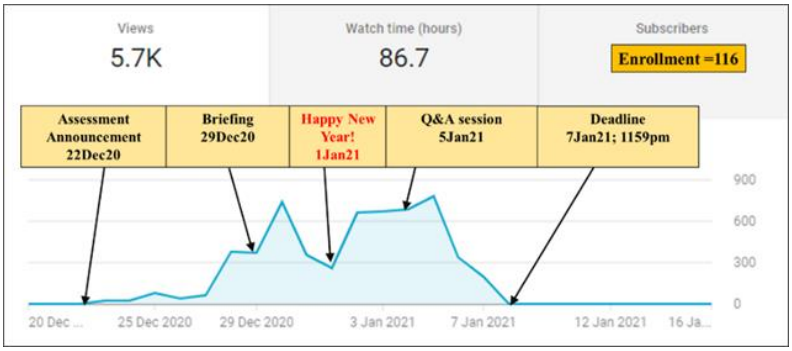

Fig 2 Timeline on the number of views from YT analytics of combined videos embedded in GF

The quiz responses were automatically graded using the GF and were automatically recorded in the linked Google Sheet (GS). From the GS, the students' responses were double the number of students enrolled for this activity thus, showing each student attempted submission twice. The number of viewers started to drop one day after the briefing as everyone was preparing for the New Year holiday celebration. The number of viewers started to pick up again after the New Year celebration and peaked two days before the submission deadline. Students started posting questions in the GC comments and emailed lecturers for further clarifications. The students initiated an impromptu question and answer online session using Google Jamboard and a WebEx session was scheduled (5 Jan 21) two days before the submission deadline which lasted 40 minutes.

From the GS timestamp, the majority of the students started submitting the completed quiz five days before the deadline between 5 pm to 2 am (Fig. 3) after their scheduled online distance lecture hours. This may be related to students' other commitments during learning from home, for example family and work commitments. Thus, having the flexibility to manage their study and assignments seems to be one of the top priorities for students doing online distance learning. This observation is in line with previous studies on students' perceived benefits of flexibility and convenience of online learning (Soffer et al, 2019).

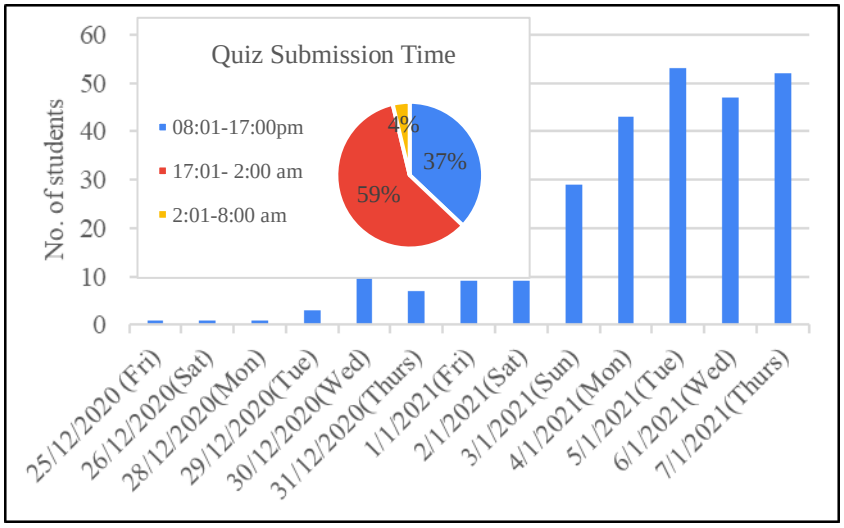

Fig 3. Students quiz submission schedule.

3.2 Student's time management

There were 91 respondents (78%) to the questionnaire survey. As this was the first time students were exposed to new knowledge regarding the absolute configuration of API and completed through online distance learning, we were interested to know the amount of time a student needed to learn this new topic. This will help the management to plan for the Student's Learning Time (SLT) for online distance learning.

From the questionnaire survey, 75% of students spend 1 to 10 hours searching for information to complete the quiz (Fig. 4i). Interestingly, most spent around 1-3 hours (Fig. 4ii) discussing with peers to find solutions for the quiz questions. Therefore, the preparation time for an online distance learning of a new topic related to the absolute configuration of an API was a minimum of 13 hours which was double the usual allocated face-to-face (F2F) preparation time of 6 hours for active learning allocated in the course plan. In the impromptu online Q&A session (5 Jan 21) initiated by the students, most of the questions were to clarify the application of the terminologies on the visualisation of the 3D molecular model. The students' misconceptions on the application of these terminologies on the 3D molecular model were easily corrected on the spot during F2F active learning. Comparatively, in the online virtual lab, students have the time to study at their own pace to find the solutions from open resources thus enabling deep learning. The observation of a 3D molecular model requires the development of the spatial ability of a person. According to the review (Harle & Towns., 2011), interventions or training can improve spatial ability which will develop over a person's lifetime.

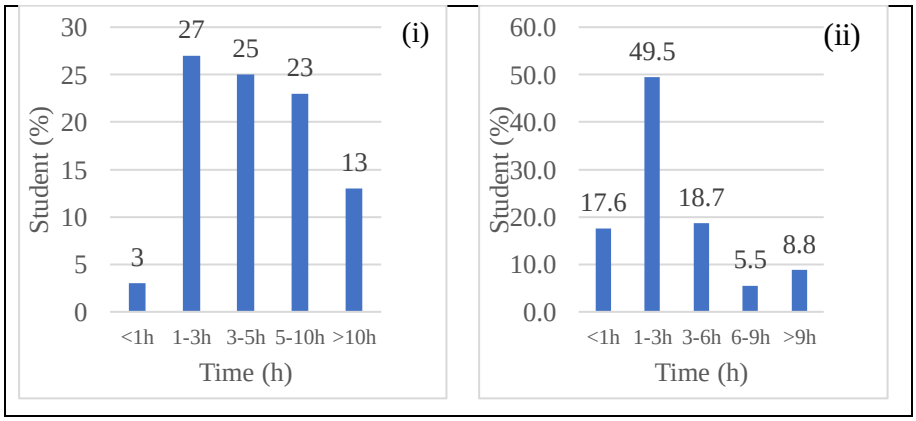

Fig 4. (i)Time used to search for answers and (ii) Time used for discussion

3.3 Student's Resources

Terminologies and theories are important aspects of learning chemistry (Chui, 2005). Thus, the students were surveyed on the time taken to observe and identify the molecular model kit in the video to solve questions related to the terminologies related to absolute configuration, namely, enantiomers, racemic mixtures, optical rotation, conformer, configuration, and *RS* convention.

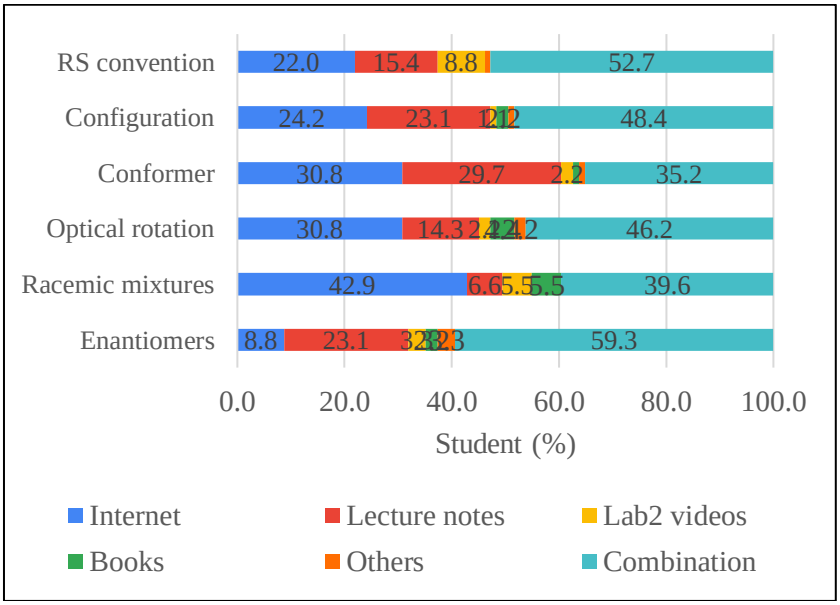

Fig 5. Students' information resources on various terminologies

Most students were resourceful in using various resources, namely the internet, lecture notes, books & eBooks, and Lab2 videos to acquire relevant information to help them in answering the quiz questions (Fig 5). Information from the internet was the most accessed single form of resources related to the terminologies used in the elucidation of the absolute configuration of an API (Fig 5). This may be due to the ease of accessibility of free information from the internet and ease of understanding through watching the video rather than reading the monotonous text from a book or static eBook without animations (Lim et al., 2020). Students also appeared to use the internet to seek information on three key terminologies (racemic mixture, optical rotation, and conformer), whereas interestingly less so for the term 'enantiomers' which could be obtained from the lecture notes and other resources. The usage of traditional books or eBooks recorded a low, 6% usage among this group of Generation Z.

3.4 Ease of accessibility and students' engagement with online micro-learning material

Since the quiz and videos were accessed entirely through the internet, the ease of accessibility to GF and YT was evaluated to find out if the integration between GF and YT were seamless and posed a minimal hindrance to their motivation level throughout the one-week period. From the YT video Analytics, most students accessed the videos through their computers and laptops (90%), followed by mobile phones (8%) and tablets (2%). In a survey conducted by Dello Stritto & Linder (2018), students have different preferences of devices for accessing different information from the internet. Both the computers and laptops were preferred devices for viewing video content and learning with simulations and games. Most respondents cited both laptops and computers were preferred because of larger screen sizes. The size of the molecular model kit shown in the embedded videos was small and difficult to see using a smartphone or tablet screen compared to a larger desktop screen. Although the embedded video links were provided in the GF, students preferred copying the link to watch on a new tab with larger screen size on either a desktop or laptop.

The Introduction video showed the theoretical concepts related to the absolute configuration using the molecular model kit in Section Two of the GF has a playback duration of 9:27min. Data from the YT video analytics showed an average view duration of 4:05 min (43.3%) but it was viewed 369 times, that is about 3.4 times views per student. Surprisingly, 93.4 % of the students do not find the duration too long. This observation was similar to an earlier report by Redondo et al (2021) indicating

that students only watch videos related to theoretical concepts or declarative videos between 2 and 3 minutes of the presentation (regardless of their length), even though they normally watch them on more occasions, skipping parts of the video more frequently.

The majority of the students found the quality of the audio (93.4%) and visual (97.8%) of the video was good and it runs smoothly without getting hanged (93.4%) while watching. The ease of access to good quality video is important as it does not frustrate the students while engage in watching and learning (Shahzad et al., 2020). Although the video playback time was fast, between 12 seconds to 62 s, most of the videos (58%) recorded more than 100% average view duration with another 26 % of the videos recorded between 80-100 % average view duration indicating students may have paused and playback certain parts of the videos. The high students' engagement (a combined 84% for over 80% average views duration) with the short videos could suggest that the design of the virtual practical using microlearning contents and embedded questions stimulate deep learning in students during these asynchronous sessions. In a study predicting students' engagement characteristics with academic success and online course completion, Soffer and Cohen (2018) found that students who completed their online courses were highly engaged with video content.

3.5 Closing the loop

Feedback provides information about performances to students, helps them adjust their thinking and understanding that often lead to actions. Using technology in teaching, students' feedback and answers can be monitored easily. A lecturer can adjust the instructions accordingly, address learning gaps, thus effectively give feedback to help closing the loop for students. In our case, GF provided real-time access to the students' answers to the embedded questions highlighted "frequently missed questions" in the GF response section. This feature allowed the educator to include "hints" in the YT video comments that are linked to low scores of the identified quiz questions. Almost all the students (99%) find these "hints" invaluable, and this shifted the class median grade from 87% to 91%. Singh (2019) reported a strong relationship was observed between lecturer feedback and student academic success. The "hint" provided facilitative feedback to the students to help guide the students in their revision and conceptualization.

The "hints" also prompted students to be more inquisitive to enquire more information related to the topic through virtual interaction or online discussion using WebEx, GC comments, YT comments, emails, Telegram, and WhatsApp. This asynchronous discussion may have provided more time to reflect and participate deeper cognitively (Hrastinski, 2008). The students' inquisitive mind has also prompted an impromptu virtual discussion on WebEx. This also leads to a "tailor-made" or personalised learning experience for this group of students. Indirectly, the time used by both the learner for discussion and the educator to monitor the student's progress in this online micro-learning activity is longer but more satisfying than the usual face-to-face active learning.

3.6 Submission time

From the survey, most students (48.4%) took more than 60 minutes to submit the quiz and 65% of the students submitted it once or twice. A great portion of the student (63.7%) was familiar with or had previously used GF for their assessment. Most students have no trouble during the answering and submission stage using GF (Fig. 6). In total there were 55 questions, but the students do not find the number of questions, neither too many (68%) nor difficult (86%). This response was similar to previous F2F active learning classes. Practicing their newly learned knowledge and being able to apply this newly learned knowledge to different chemical structures might have increased the student's motivation and confidence.

Overall, the majority (96.7%) of the students enjoyed this online distance micro-learning activity but similar to the findings by Chung et al. (2020), given a choice, 91.1% of the students still prefer the F2F active learning in a lab practical.

3.7 Students perception vs performance

There were 116 students enrolled in the micro-learning related to the absolute configuration of an API. A total of 111 (95.7 %) scored distinctions. The remaining five students scored B. Surprisingly, this performance profile corroborated with the previous batch's F2F active learning performance profile. From the above questionnaire survey on the student's time management/ usage of time, students spend at least 13 hours answering the quiz questions, and about 94% of the students showed a high level of confidence towards the understanding of this topic. As mentioned earlier, they

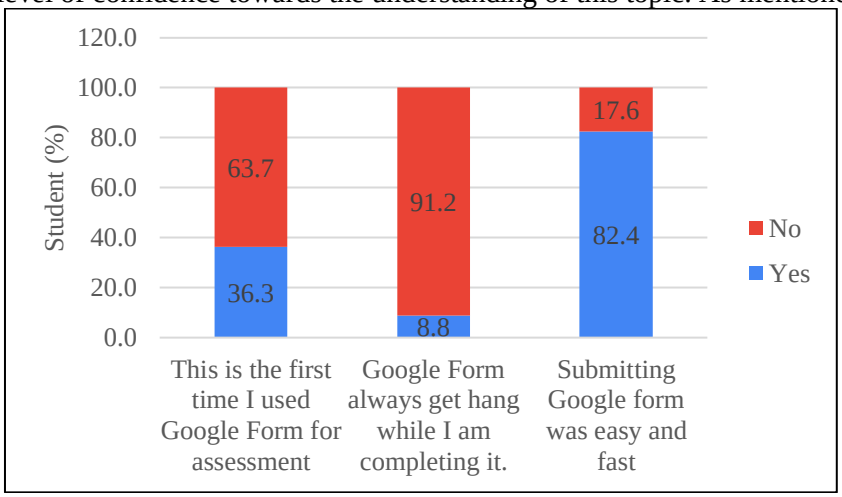

Fig 6 Ease of using Google Form

were also highly engaged with the short videos, which could be a predictor of activity completion. Thus, the student's grades corroborated with their confidence level and high engagement levels with the micro-learning contents.

4. Conclusion

In conclusion, our study shows that micro-learning activity motivated the students to be resourceful, shown an inquisitive mind, and built their confidence to enquire more questions related to a narrow but critical topic in the absolute configuration of a drug substance. The design of micro-learning activity organises the topic in small learning chunks and a clear and coherent structure provided and facilitated flexible learning for distance learners. The use of technology in remote teachings such as GF, YT, and WebEx allowed convenience, accessibility and provided support to students during the Covid-19 pandemic and lockdowns. The learner's perception of their level of confidence matches with the assessment grades. The limitation of this study was the data were from the first-year pharmacy students enrolled in our university. In the future, this could be expanded to include students from other universities. The course plan on the student learning time and educator preparation time may require adjustments for remote learning on this topic. From the academic perspective, the micro-learning with bite-size content provided an easy way to learn new topics while training their spatial ability through the application of 3D molecular models with reinforcement through quizzes. The virtual micro-learning design is practical and economical without much technological investment or training for both the educator and learner with easy access in an open distance learning environment and post-Covid.

Acknowledgement
This work was partially supported by grant P3077.

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