KIMIKA Volume 34, Number 1, pp. 21-35 (2023)

ISSN 2508-0911
https://doi.org/10.26534/kimika.v34i1.21-35

Redesigning an organic laboratory course for remote learning: incorporating Lab@Home kits and other techniques for teaching organic chemistry online

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ABSTRACT

Many cities in the world were placed under various lockdowns to combat the spread of the COVID-19 pandemic, which also forced many schools to shift into full online mode of teaching and learning. In the Philippines, partial onsite classes only resumed after nearly 2 years of strict online classes. Of critical concern then was the teaching of laboratory courses. This necessitated the re-design of the usual laboratory experiments to a Lab@Home course to provide a semester's worth of an organic laboratory course to college students of the Ateneo de Manila University. Here, we present a Lab@Home curriculum that covers core organic chemistry concepts, such as purification and separation of organic compounds, reactivity and qualitative tests, stereochemistry, and molecular spectroscopy (IR and NMR). This Lab@Home course involved sending boxed kits containing laboratory materials and reagents that allowed students at home to perform small-scale experiments. Aside from reinforcing key concepts in the accompanying lecture class, it also provided them with experiential learning of practical laboratory techniques such as setting up an experiment and real data collection. Safety first is maintained, and aside from providing the usual protective gear, safety is further assured with two important features: (1) the hazards classification of the reagents in the kit would not exceed the everyday life hazards of common household chemicals (e.g., kitchen cleaning reagents) and provided in very small amounts, and (2) running of experiments were done with online synchronous supervision majority of the time. The success of the course is the achievement of the CLOs, from the assessments as well as from feedback taken from surveys and interviews with students and instructors at the end of the semester. Overall student performance showed an average final grade of 85%, and student response to the curriculum was generally positive. Further improvements should be implemented to make experiments more enriching and ensure Lab@Home can become an effective tool for teaching remote laboratory classes.

Keywords: *Chemistry teaching; Organic chemistry; Laboratory Classes; COVID-19*

INTRODUCTION

Across the world, various sectors have experienced the devastating effects of COVID-19, and one of the most severely affected is education. At the height of the pandemic, governments worldwide declared regulations to mitigate the spread of the virus. These included wearing face masks, restricting local and international travel, avoiding mass gatherings, etc. As a direct consequence of these restrictions, more than 94% of the world's student population was forced to either halt their schooling or shift online (Pokhrel and Chhetri, 2021). Academic institutions scrambled to convert their courses into an online-centric format, adopting new learning management tools like Zoom and Google Meet, and training their educators on how to teach effectively in this new normal.

The Importance of Teaching Laboratory even Remotely. While certain courses were able to shift to an online medium without much struggle, subjects that were heavily based on experiential and hands-on learning, such as laboratory courses, were at a standstill. These subjects were predicated on the idea that the students had access to a laboratory, where they could be taught practical skills. Science majors requiring college chemistry courses, for example, are expected not just to gain a mastery of the theory but also to learn hands-on skills such as safe handling of chemicals, preparation of solutions, setting up of experiments, analysis of compounds, collection of data, running of chemical instruments and analysis of data, etc. Laboratory courses assist with retaining concepts and serve as valuable training for those pursuing science as a career (Bretz, 2019), so simply doing away with laboratory courses during the pandemic would severely compromise the training of science students.

At the onset of the pandemic and the strict lockdown in March 2020 in the Philippines, it was uncertain when face-to-face classes would be allowed again. Thus, one could delay the delivery of the lab classes in future terms or resort to virtual lab classes, or both. These would not be sustainable given that the lockdowns were predicted then to possibly last long because there was no vaccine available then and the mutations that were happening worldwide. Indeed, it did—for nearly 2 years, the Philippine government imposed no in-person teaching of classes at all levels. Delaying labs could result in delays in the graduation of students and/or inundating the departments with too many sections for back-log lab offerings, whereas virtual labs are useful but offered hardly any experiential learning. The Department of Chemistry faculty at the Ateneo de Manila University, therefore, knew then that it was imperative to develop a new way to deliver course learning outcomes (CLOs) of laboratory courses—especially those that are not limited to only a laboratory room. Laboratory, in essence, is not just confined to a lab room, but it also offers real, hands-on experiences to students to learn practical lab skills. This could be done at home through especially designed and assembled lab kits that could be shipped to students.

METHODS

Design Framework for the Lab@Home Organic Chemistry Kit. The concept of doing experiments at home is not new, given the many DIY demonstrations one can view on science-oriented YouTube channels, as well as commercial chemistry lab kits that are designed for home use, such as that one can buy from science museums. However, these are largely marketed for children. At the beginning of the pandemic, there was no such kit available that offered the possibility of achieving structured learning outcomes specific to college-level curricula, much so, for organic chemistry laboratory courses. The Department of Chemistry at the Ateneo de Manila University had developed several Lab@Home kits for Physical Chemistry, General Chemistry, or Analytical Chemistry for the B.S. Chemistry students that were offered since the August term of 2020—these all focused on CLOs that can be demonstrated by experiments done at home by the students. Recently, Mojica and Upmacis (2021) shared their experience with a general chemistry online course that they offered to college-level general chemistry students relying on kitchen-based chemicals. The Ateneo faculty thus reviewed the learning outcomes of the curricula of their offerings and moved topics around so that many of those that can be taught through lab kits at home were taken care of, and those that could only be done in a real laboratory (e.g., requiring fume hood or involve unstable intermediates) would be postponed for latter courses.

Organic chemistry offered a unique challenge because of the notion of organic solvents and the toxicity of some of these compounds and because this is the lab course where synthesis is done. It was obvious then that many of the typical organic synthesis experiments would have to be postponed for a later lab. For B. S. Chemistry majors, these oftentimes happen in the second semester of the course, anyway. However, the first-semester organic lab could be handled by the Lab@Home kits. At the Ateneo, the textbook or lab manual by Guidote et al. (2005) is used, and so this is shared with the kit using the book to provide the background on selected experiments as well as the procedure for what it would be if done in the lab. In essence, only the procedure was modified in the Lab@Home kit, but they were doing experiments for the same topics as outlined in the book. Thus, the book is included as part of the kit. The framework taken in the development of these kits, in terms of safety, was the classification of the chemicals vis-a-vis "everyday life hazards." We live in a chemical world, and the kitchen is a place where there are a variety of chemicals—from non-toxic, mildly toxic, or irritant, to toxic and corrosive (typically, the cleaning agents). The kits were designed with this in mind—classifying the chemical content not to exceed the hazards found in the household, and to limit quantities, for added safety and compliance for disposal. This framework then also complied with general restrictions on the shipment of the kits, which required declaration of the chemical content and their safety data sheets. Re-designed experiments at home were also necessarily scaled down in amounts. For example, ester synthesis in the laboratory, which would typically use 20 mL of alcohol and 12 mL of carboxylic acid, along with a few drops of concentrated acid, now had to be translated to just a few drops of isoamyl alcohol and 2 mL of household acetic acid (vinegar). Heating by high heat was avoided, and all experiments were flameless, and all chosen reactions that required heating could be achieved using a hot water bath (below boiling temperature).

Given these, the following topics were chosen for the Lab@Home Organic Chemistry one-term curriculum: decolorization, recrystallization, extraction, thin-layer chromatography, ester synthesis, qualitative tests, stereochemistry, and IR and NMR spectroscopy.

Implementation of Lab@Home. First, students are instructed not to perform the experiments without the instructor's go signal, as is also the practice in the usual lab course pre-pandemic. Like onsite laboratory classes, each student was expected to submit pre- and post-laboratory reports. The prelab report included a table containing the hazards and first aid measures for each reagent involved in the experiment, as well as the procedure in flowchart form. The hazards table ensured that the students and their families knew what to do in case of an emergency, while the flowchart guaranteed that the students were already familiar with the procedure and could work more efficiently. Postlab reports included worksheets designed to reinforce the concepts behind the experiment and to enhance their critical thinking and problem-solving skills on these concepts. Before the experiment proper, instructors delivered a prelab discussion, which covered the concepts involved in the experiment, hazards, troubleshooting tips, and waste disposal instructions.

It was highly recommended that the experiments be done synchronously, with cameras on. This allowed instructors to provide better and more prompt feedback to students throughout the experiment. It also instilled time management skills in the students, as they only had the given class period to complete the experiment. However, should the student be unable to perform the experiment on camera, they were allowed to do it asynchronously, but were required to submit video documentation of themselves performing the experiment, and again with prelab guidance from the instructor.

Course Learning Outcomes. To assist in assessing student outcomes and determining the success of the Lab@Home modality, several CLOs were drafted. The course objectives from onsite laboratory classes were used as the basis for these, with slight modifications to account for the limitations present in Lab@Home. These CLOs will also be reviewed using overall student performance (based on lab performance, lab reports, and exams) and a survey given at the end of the semester. The CLOs for the class were as follows:

1. Develop a mastery of basic organic chemistry techniques,
2. Be able to know when to use organic chemistry techniques when dealing with a problem,
3. Develop an inquiry-based approach to learning organic chemistry laboratory techniques, and demonstrate critical thinking in analyzing and related problems,
4. Gain experience in working in a laboratory setting, evaluate basic experimental data to draw conclusions, and check the validity of results in light of scientific knowledge and skills,
5. Appreciate the limitations and implications of the techniques in experimental design,
6. Demonstrate a strong sense of ethical behavior,
7. Develop collegiality, good work ethics, leadership qualities, and interpersonal skills, to be able to work effectively, whether alone or as a contributing member of even culturally diverse groups of people in different work environments
8. Interpret experimental results by connecting the data with the theories learned in class and draw reasonable conclusions in written laboratory reports,
9. Use information resources in chemistry, including primary literature, tabulated data, and online resources in writing laboratory reports, and
10. Perform micro-scale reactions and synthesis of organic compounds.

Kit Contents. The contents of each organic chemistry Lab@Home kit are laid out in Figure 1. Some items were sourced through online retailers like Lazada, while chemicals and reagents were packed in 0.5-10 mL quantities by the department staff. Other reagents needed in large quantities, like distilled water and 70% isopropyl alcohol, were acquired by the students themselves.

IR and NMR Spectroscopy Demo Videos. One of the unfortunate drawbacks of remote learning is that the students do not have access to the instruments available at home. In onsite learning, they would have had the opportunity to receive valuable hands-on training on the operation of these instruments. By including video demonstrations in their online course, they are still given the opportunity to learn how to prepare samples and operate the instruments. Instead of relying on ready-made demonstration videos online, however, our course produced instructional demonstration videos for the instruments available at Ateneo, namely the FTIR and NMR spectrophotometers (Figure 2). Doing this with our own instruments made the learning of the topics more relatable, which was better for the students, as they show exactly how things are done in Ateneo, their own school. This would also facilitate reinforcements of learning once they could return to campus. Additionally, they are introduced to the standard operating procedures of the department with respect to access and use of these instruments and related facilities (e.g., the signing of the user logbook, etc.). Besides these video demonstrations, students were also taught how to interpret IR and NMR spectra through additional exercises from spectra collected from the demo videos or collected from samples run using the lab kits.

Purification of organic substances: decolorization and recrystallization. The first part of the course involved decolorizing brown sugar solution using activated charcoal. Students were taught how to prepare a gravity filtration setup and fold filter paper through a video demonstration. For recrystallization, the students were tasked with purifying a sample containing 150 mg of aspirin and 25 mg of caffeine using an alcohol-water solvent system. Dissolution of the sample was done with the help of a hot water bath.

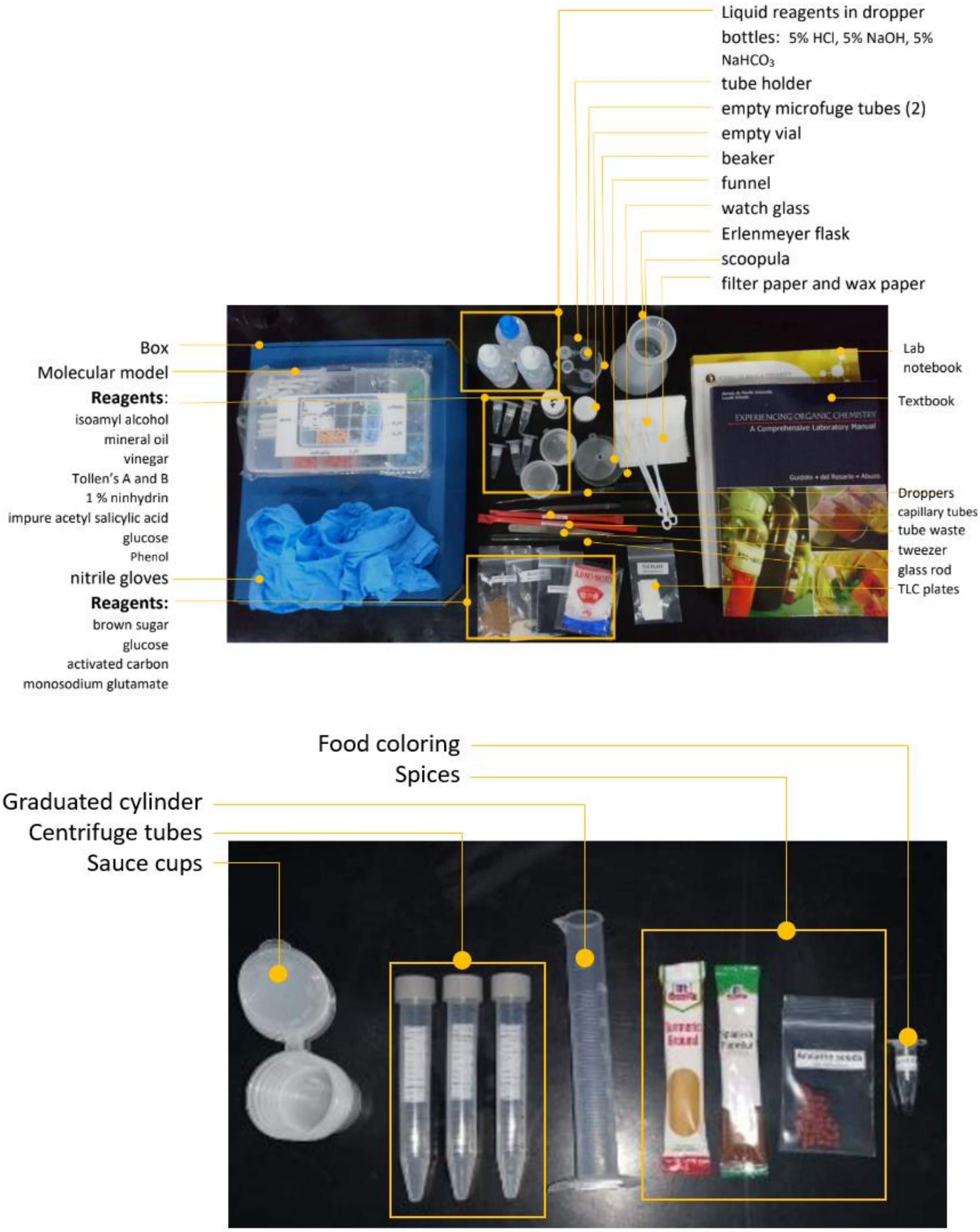

Figure 1. Contents of Ateneo de Manila University's Organic Chemistry Lab@Home kit

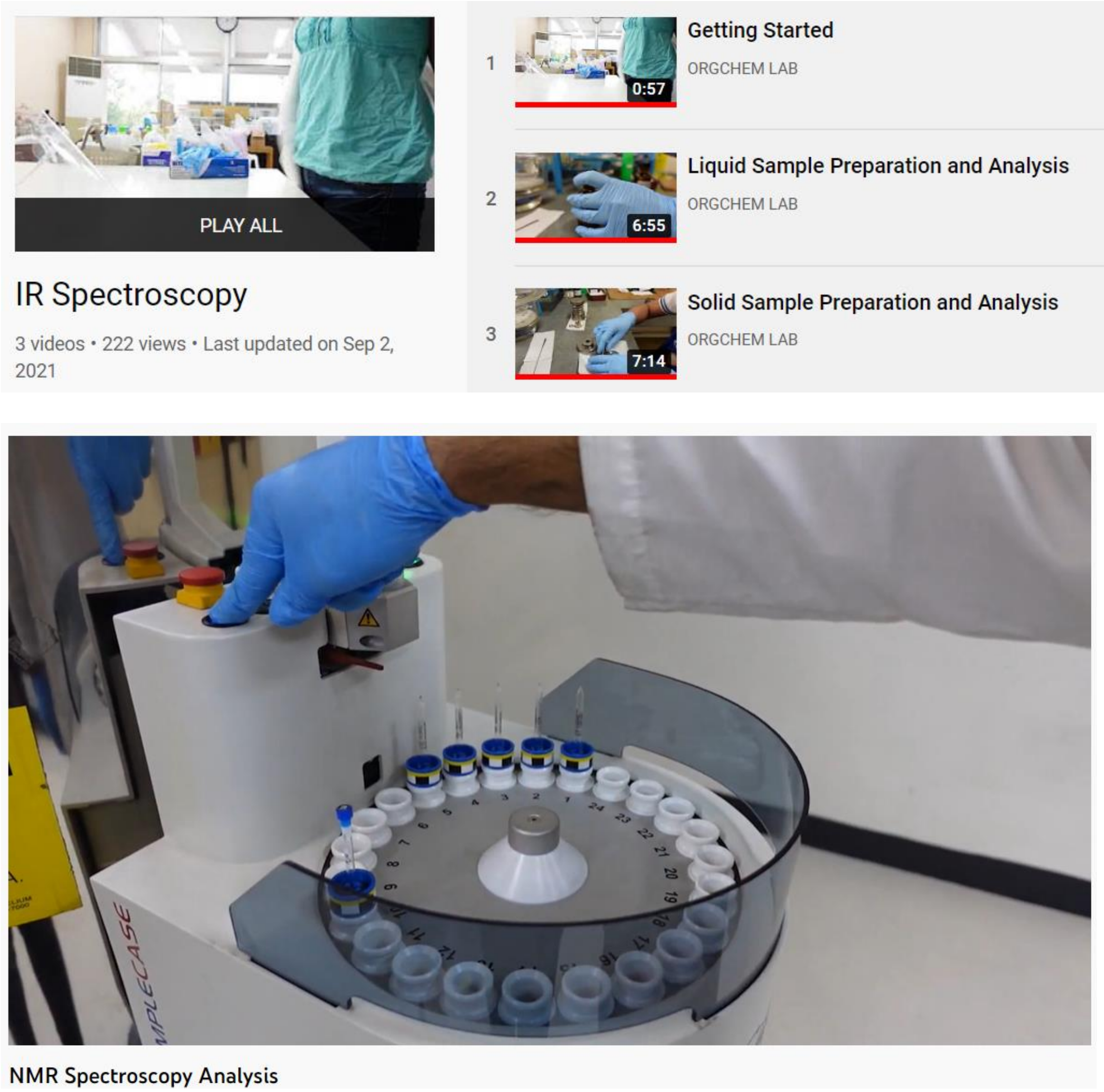

Figure 2. Screenshots of videos recorded and uploaded on YouTube for teaching IR and NMR operations (https://www.youtube.com/watch?v=wtKJun1jqQg)

Extraction and Thin-Layer Chromatography. Through this experiment, students learned how to perform thin-layer chromatography (TLC) and extract compounds from various samples. They first used TLC to assess the purity of the crystals obtained from their own recrystallization experiment and used water-alcohol as a developer solvent. Part two of this experiment had them extract pigments by liquid-liquid extraction using various spices: Annatto, Spanish paprika, and turmeric. These yielded extracts with colors ranging from yellow to red-orange, and these were combined with a blue aqueous solution made from food coloring to create green mixtures. Mineral oil was added as the other liquid phase, and these were shaken together. The non-polar solutes for each mixture combined with the oil layer, making the polar phase blue again, which proved that the nonpolar colored extracts from the spices were extracted by the oil layer (Guidote et al., 2010) as shown in Figure 3.

Figure 3. Progression photos of the extraction of spices experiment, illustrating the transfer of the yellow pigments to the nonpolar oil layer

The third part of this experiment involved extracting chromophores from green, leafy vegetables. Leaves were crushed and added to a microtube with 70% isopropyl alcohol and stirred frequently to encourage the transfer of solute. The extract was then subjected to thin-layer chromatography (Figure 4) to separate and identify the different pigments extracted from the leaf, which included the chlorophylls, of course.

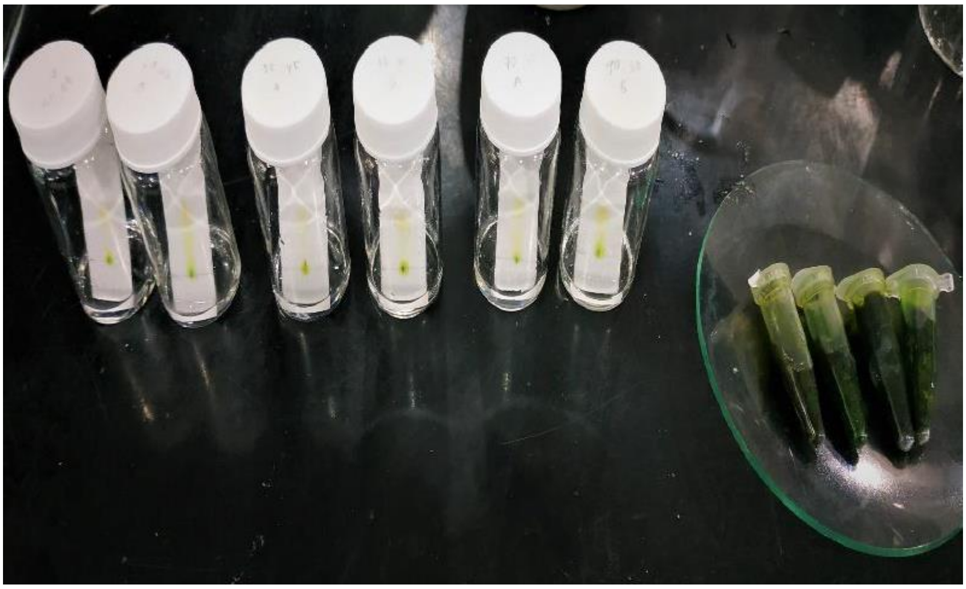

Figure 4. Developing TLC plates for the Extraction and TLC of Chromophores experiment

Ester Synthesis. Since most of the synthesis was postponed for the latter lab, at least one can experiment was done to illustrate the reactivity and reaction of functional groups, such as an esterification reaction. The students were provided with household vinegar (acetic acid) and a small volume of isoamyl alcohol. Due to the absence of a strong acid catalyst, they needed to heat the mixture in an 80 °C hot water bath for 45 minutes to push the esterification reaction forward. The product is obvious as a characteristic banana odor that was expected from their reaction vials. The students were instructed how to properly waft the ester scent towards the nose, and not to sniff directly.

Qualitative Tests. Perhaps one of the most difficult experiments to convert to the Lab@Home format was qualitative tests, mainly because many classical qualitative tests involve hazardous reagents. An example of this is Lucas' reagent, a solution of anhydrous zinc chloride in concentrated hydrochloric acid. However, it was imperative that qualitative tests be included as they illustrate the reactivity of many organic functional groups. We thus developed a safer version of Tollens' A and B test solutions, to test for the aldehyde in glucose. Less than 1 mL volumes of the reagents were provided in separate microtubes, formulated with reduced reactivity, and these were directly used in the testing of the presence of reducing sugar through the formation of the silver mirror on the tube directly. A ninhydrin test was provided to test for amine functionality. Solubility tests of different organic compounds were done using distilled water and small volumes in dropper bottles with 5% NaOH, 5% HCl, and 5% $NaHCO_3$ included in the kit. Glucose was used to demonstrate a positive Tollens' test, while monosodium glutamate (MSG) was chosen for the Ninhydrin test (Figure 5).

Figure 5. (Left) Results for the Ninhydrin test of MSG; (Right) Result for the Tollens' test of glucose.

Stereochemistry. Students were provided molecular modeling kits and a list of molecules to model. This exercise was designed to help them visualize how stereochemistry, particularly the nature of enantiomers. It also helped them identify whether stereocenters are R or S isomers, and to understand better the ring-inversion for the chair conformation of cyclohexane and its derivatives (Figure 6). Besides the physical models, the exercise was also linked with molecular modeling software like ChemSketch.

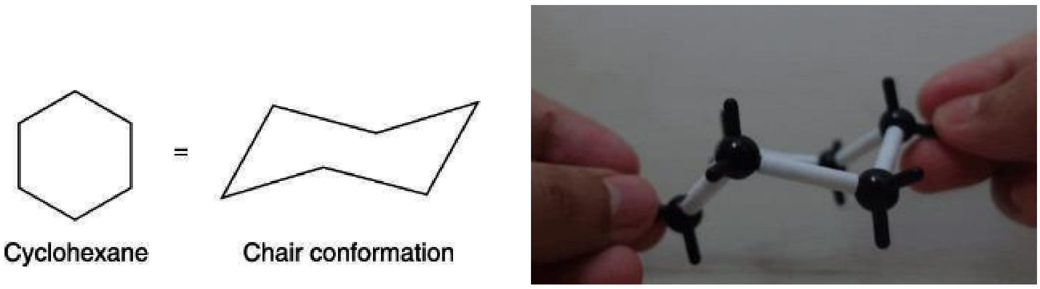

Figure 6. Using molecular models to demonstrate chair conformations for cyclohexanes.

Grading Assessments. Students are graded based on the quality of their pre- and post-laboratory reports, their grade in the final exam, and their lab performance. Lab performance is determined by the criteria in Table 1. If a student is unable to perform the experiment synchronously, they are to submit video documentation of themselves performing the experiment. Overall student performance will also be used to assess the achievement of CLOs.

Table 1. Criteria for grading lab performance

<table>
<tr><th>Criteria</th><th colspan="6">Ratings (Points)</th><th></th></tr>
<tr><td>Setup</td><td colspan="2">2
The setup is complete, accurate, and neat.</td><td colspan="2">1
The setup is messy or incomplete.</td><td colspan="2">0
Incomplete or no submission.</td><td>2</td></tr>
<tr><td>Safety</td><td colspan="2">3
The student was wearing appropriate safety gear and handled the reagents properly.</td><td colspan="2">2
The student was wearing appropriate safety gear, but handled the</td><td>1
The student was not wearing any safety gear.</td><td>0
Incomplete or no submission</td><td>3</td></tr>
<tr><td>Execution</td><td>5
Student carried out all the steps correctly and in an organized way</td><td>4
Student carried out most of the steps correctly and in an organized way</td><td>3
Student carried some of the steps correctly and in an organized way; Sometimes lost as to what the steps were</td><td>2
Steps are done out of order and with no clear logic</td><td>1
Student carried out erroneous steps or used the wrong reagents; Clearly unprepared and did not listen during the prelab discussion</td><td>0
Incomplete or no submission</td><td>5</td></tr>
<tr><td colspan="7">TOTAL</td><td>10</td></tr>
</table>

RESULTS AND DISCUSSION

Overall Student Performance. From a total of 108 students from 2 Chemistry major sections and 3 non-major sections, the average grade was 85%. Figure 7 presents the overall grade distribution, showing that the scores are skewed heavily to the right. This is higher than the typical median for a laboratory class and demonstrates that the students performed well throughout the course. The Chemistry majors' classes were taught primarily by a senior faculty member while the non-majors were taught by a junior faculty member.

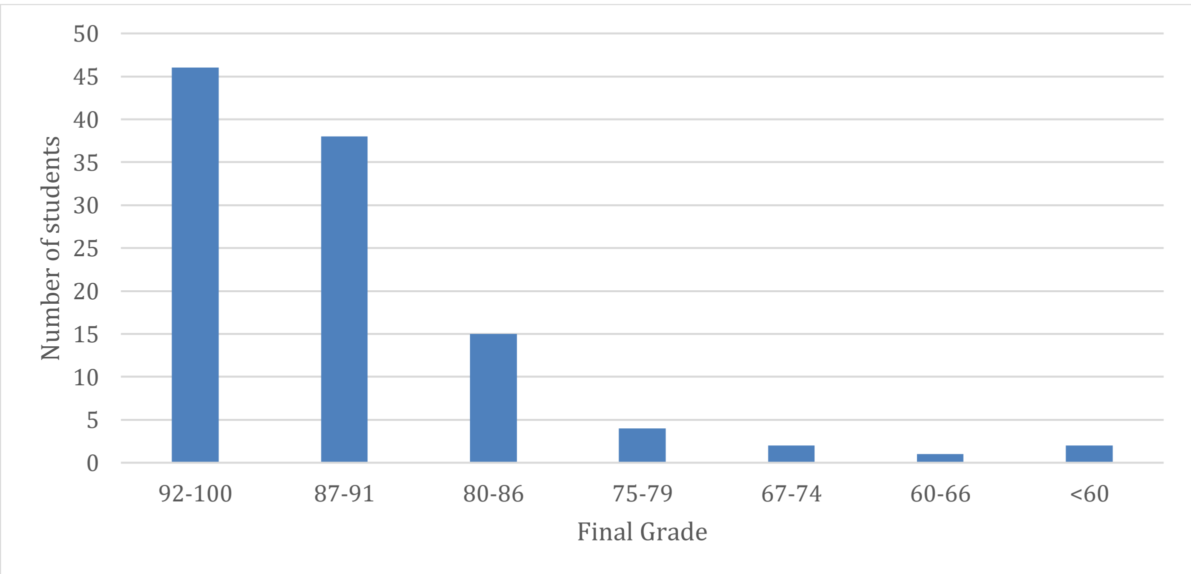

Figure 7. Lab@Home students' final grades (Number of students = 108)

Student Response. An example of student feedback from four sections of the Lab@Home kits has been generally positive among 95 respondents from five different sections (Figure 8-9, Table 2). One student claimed that the system allowed them to feel like they were *in a face-to-face class*. Others also commended how it was a *more interactive learning experience* compared to other online laboratory classes, which relied on simulations and videos only. Providing them with the opportunity to handle laboratory equipment and reagents themselves also helped students practice good laboratory habits like wearing proper safety gear and being mindful of the hazards of the reagents they're working with. There was also praise for how the laboratory was structured, providing ample time for the students to complete all the requirements allotted for each experiment, namely the prelab, lab performance documentation, and post-lab worksheet. Based on these responses and the overall student performance, it can be concluded that most of the CLOs were achieved. The students deepened their understanding of Organic Chemistry and gained experience in performing laboratory techniques, albeit in a simplified context. However, a limitation present in Lab@Home is their inability to work on experiments in groups, which is a valuable skill as teamwork and cooperation are necessary qualities when they venture out into any field. While most of the experiments in the onsite lab are done individually, some experiments require the students to work in pairs or groups so they may learn how to delegate tasks and work with diverse groups of people.

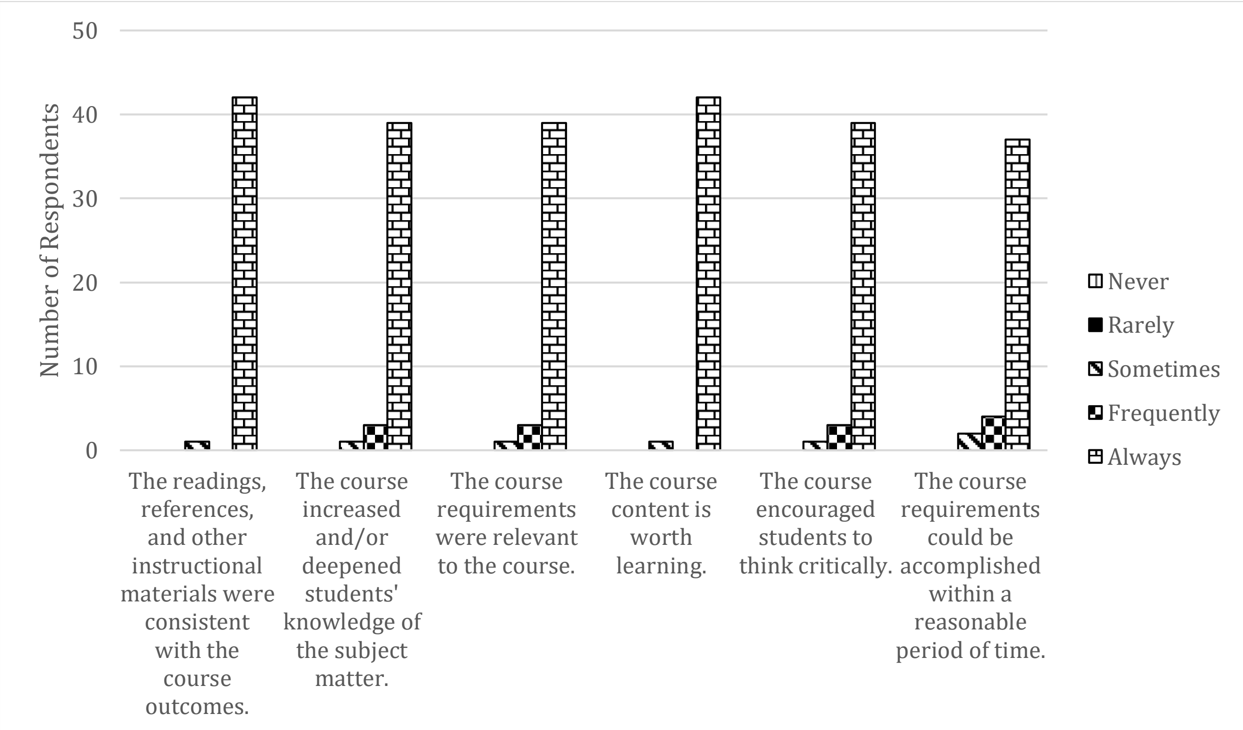

Figure 8. Chemistry majors' responses to post-semestral student survey assessing the effectiveness of online Organic Chemistry Lab (Number of respondents = 43)

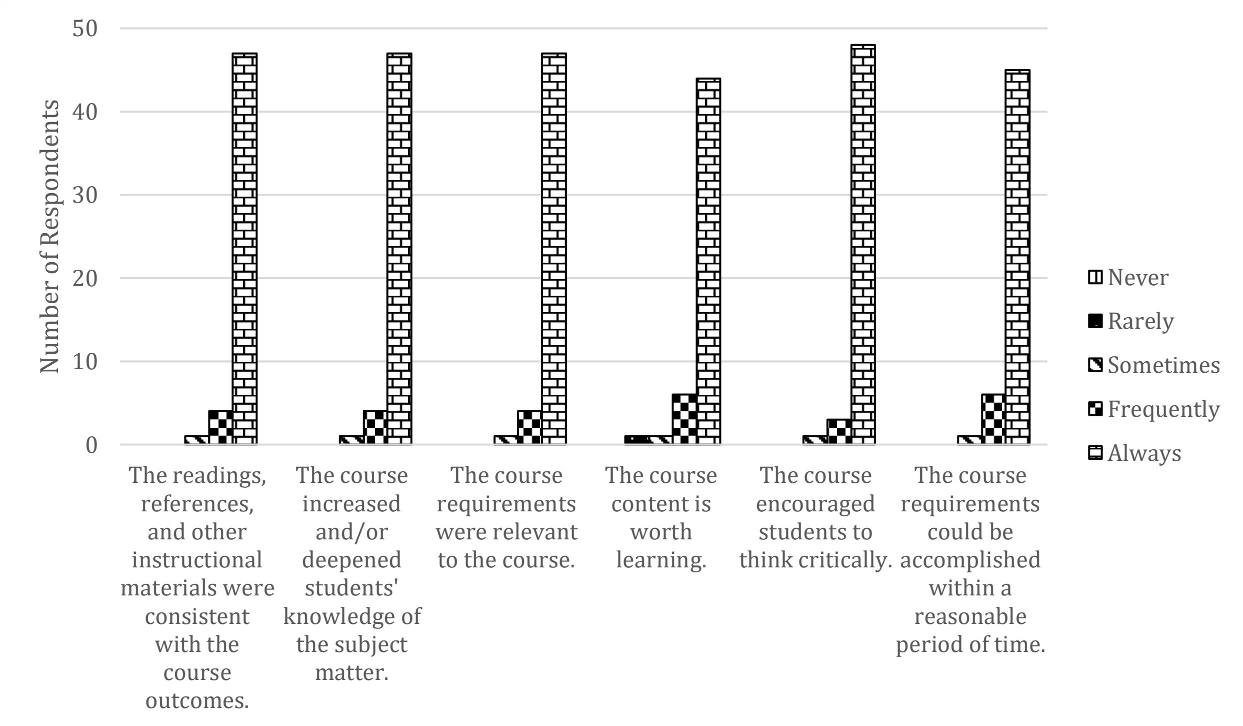

Figure 9. Psychology and Health Science majors' responses to post-semestral student survey assessing the effectiveness of online Organic Chemistry Lab (Number of respondents = 52)

Table 2. Collated comments from responses to post-semestral student survey assessing the effectiveness of online Organic Chemistry Lab.

Module Design	Experiments/Lab Kit	Assessments
Modules were organized and well put-together.	The experiments were interesting	Requirements are reasonable in terms of quantity and effort required
I am able to understand the lab class modules more easily.	I like doing experiments synchronously	The workload was manageable and reasonable
The modules are easy to grasp.	I am also very grateful for having the opportunity to conduct experiments still, albeit at home.	The submissions were not too much for a weekly schedule
This was such a fun class for an online setup, it didn't feel very online and somehow managed to make students feel like we were still in a face-to-face class.	Add more wet-lab-type experiments.	The workload matches the estimated learning time. The professors are hands-on.
I liked that the course was practical based. Since we were done with the corresponding lecture class. I also liked that it supplemented the lecture class well.	The materials provided were enough.	The class has really good pacing and requirements that fit to the class hours indicated in the syllabus.
The course was very interactive and encouraged participation in the class.	The book accompanying the OrgChem Lab kit was not utilized well.	I liked that they also gave a manageable workload and were always very considerate.

Module Design	Experiments/Lab Kit	Assessments
The prelab discussions were relevant and helped addressed the learning gap we might have had with the lecture class conducted last year. This was the best lab@home experience. I feel like we were able to get a good idea of some lab techniques without feeling burdened by the makeshift lab setup. This course was designed very well.	I enjoyed the experiments, and it was the lab class that is really close to an actual lab setup.	I like the fact that the experiments can be done synchronously and open camera because the professor really monitors what you are doing.
This is the best online class we had so far ever since the pandemic. The professors are very approachable, the workload is light, we do lab experiments synchronously, the discussions are thorough, and students are really participating in the discussions.	Secure the reagents better and the materials, a lot were broken when they arrived at our homes.	Relatively easy-to-follow lectures + not-so-demanding requirements
The modules are well-structured	Home labs tend to invade the entire household's lives and so this was very hard to demand compromise from the people I lived with.	The learning hours are just right or even less at times since the coursework or readings are all accomplished during class hours synchronously.
I still hope that lab classes can be done onsite. Experiments feel too watered-down.	Some experiments were too time-consuming and filming was hard to set up.	

However, there was also some negative feedback on the kit, with some students expressing dissatisfaction with how the modules were designed or how some materials were packaged. A student commented that some experiments were too long and should be split into separate laboratory sessions. It was also observed that some kits would arrive with broken glassware or spilled reagents. Some students also expressed difficulty in finding a suitable space to conduct experiments. Some had to resort to using dining tables or kitchens throughout the duration of the class, which can be a disturbance to their housemates. Students also expressed the desire to have excess reagents in the kits in case of mistakes or accidents that occur during the experiment. Many still insisted that lab courses should be done exclusively onsite, rather than watering down the experiment to suit a Lab@Home setting. There were also concerns regarding privacy issues, especially among students who carried out experiments synchronously, with cameras on. These students admitted a degree of insecurity regarding other classmates seeing their living quarters and experiment setup.

Some students based outside the country encountered a unique challenge with Lab@Home. Due to stricter rules on cross-country shipments, international students could not simply order lab kits from the department, instead having to source equipment and chemicals themselves, which proved extremely difficult and expensive as chemicals are almost always sold in bulk or are hard to find. This was especially challenging for the qualitative test modules, forcing international students to take a dry lab instead.

Faculty Response. The faculty are unanimous in their assessment that while the Lab@Home system helps with supplementing the lectures and providing students with a taste of what onsite laboratory classes would have been like, it is not a substitute for onsite laboratory classes (Table 3). In the onsite lab, instructors could quickly correct any mistakes because they are directly supervising students as they perform the experiment. However, in an online lab, even with the camera on, it was still easy for instructors to miss errors due to lag or poor video quality. Some students who could not perform the experiment synchronously may have questions, and since these students were prone to doing the experiment outside of office hours, their inquiries would not get answered until the next day. This interrupts the student's workflow and may even cause their experiment to fail, affecting their results and subsequent grade.

Table 3. Collated comments from responses from faculty assessing the effectiveness of online Organic Chemistry Lab.

Safety	Experiments	Grading Assessments
There should be hazard symbols on the box itself to warn of the contents.	It is harder to troubleshoot students' setups because of different environments.	Lab performance is hard to grade due to the quality of some video recordings
Some students perform lab activities at late hours.	It is harder to address questions, especially for asynchronous students.	Some experiments should include a characterization step or a color change to confirm successful synthesis to make online experiments easier to grade.
Some students develop poor lab practices like wearing shorts/slippers while doing an experiment.	Some experiments are too watered-down.	

Some instructors have also expressed concern about student safety. In the onsite lab, instructors are well-equipped to render first aid should anything happen. However, that is not possible in an online lab. Even if the reagents are generally safer, untoward incidents are still possible. Some of the students who do not join the synchronous laboratory class session even openly admit to doing the experiments when everyone in their home is asleep to avoid disruptions. However, this poses an even greater risk, because nobody can assist them should they encounter an emergency. Even though students are required to include a list of hazards and first aid measures in their prelab reports, there is still no one more qualified to aid in a lab-related emergency besides the instructor.

There is also the issue of grading student output. In the onsite lab, students are graded based on the success of their experiment. Often, this is based on product quality or the results of their characterization, aside from laboratory performance. For example, after a synthesis experiment, students are expected to use IR spectroscopy to confirm the identity of their product. Obviously, in an online lab, this is impossible as they have no access to these instruments. Instead, they rely on physical properties and observations, which is difficult for the instructor to confirm. This is a glaring issue with the ester synthesis experiment, as the only success indicator for the reaction is the presence of a banana smell.

Recommendations. It is no exaggeration to say that the pandemic and subsequent lockdowns came as a shock to everyone and that most institutions had little to no risk-management strategies for such a scenario. However, now that we are aware of the vulnerabilities in our current educational system, it is wise to continue refining the Lab@Home curriculum in case schools providing practical laboratory courses are forced to undergo another prolonged lockdown in the future. This includes improving the experimental design, packaging, production, implementation, and evaluation.

Experiments like ester synthesis could be reworked so that teachers have a more concrete way of grading student output, like providing students a way to send their synthesis products to campus so that instrumental analysis can be performed. TLC can also be incorporated into the extraction of spices experiment to further prove that the compounds were successfully separated through liquid-liquid extraction. For experiments with quantitative data like TLC, more TLC plates could be included to allow students to perform multiple trials. This provides them the opportunity for more in-depth statistical analysis of their data. It also makes the experiment more forgiving in case they make mistakes.

A special curriculum could also be designed specifically for international students so that they do not have to undergo the unexpected difficulty of procuring their own reagents and materials. This could include a fully virtual laboratory, taking advantage of resources like Labster or the Journal of Virtual Experiments (JoVE). One of the students also recommended live streams rather than prerecorded videos for experiment demonstrations and instrument operation.

However, one must also be cautious of incorporating too many teaching strategies all at once. Using many different techniques, resources, or software also means each instructor needs to be adequately trained in all of them to be effective. The Lab@Home curriculum should strike a balance between maximizing the students learning without overworking the instructors.

A more concrete form of evaluation should also be implemented. Rather than relying on the standard evaluation form students fill out at the end of a semester, a specialized survey for those who took the Lab@Home curriculum should be distributed to ensure more concrete and quantitative feedback. This survey should also be structured to assess the effectiveness of each individual experiment. This will aid greatly in improving future iterations of online laboratory classes.

It is also recommended that instructors extend more grace and patience to students who are experiencing a great deal of strain during these difficult times. Some students could be struggling to accomplish requirements due to family members testing positive for COVID-19, or even testing positive themselves (Guidote, 2020). The prolonged lockdowns have been proven to cause increased anxiety, depression, and psychological stress among the population (Xiong et al, 2020), and instructors should take this into account when implementing deadlines and penalties. Clear communication and flexible teaching should be applied to accommodate the unique complications our students face during these trying times (Petillion and McNeil, 2022).

CONCLUSIONS

It is undeniable that the ideal scenario is that students learn practical laboratory skills onsite, in a proper laboratory setting, and with the direct supervision of a professional. However, Lab@Home shows great potential as a strategy that can help academic institutions avoid learning gaps in the event of a prolonged lockdown. Once onsite classes resume, students are still expected to receive proper training on the laboratory skills necessary for their careers as future scientists. Students who took the Lab@Home classes expressed largely positive sentiments on the experience. Future studies should focus on refining the experiments in the Lab@Home curriculum to include other critical skills like characterization, and to improve the kit to include excess materials and better packaging to minimize breakages and spills.

REFERENCES

Bretz SL. Evidence for the importance of laboratory courses. J Chem Educ. 2019 Feb; 96(2): 193–195. https://doi.org/10.1021/acs.jchemed.8b00874

Corrales N. Target: 100% in-person classes by November. https://newsinfo.inquirer.net/1622503/target-100-in-person-classes-by-november. Last accessed 20 July 2022.

Guidote Jr A, del Rosario D, Abuzo A. Experiencing Organic Chemistry: A Comprehensive Laboratory Manual (2005), Ateneo de Manila University.

Guidote Jr AM. Teaching college chemistry in the time of COVID-19 pandemic: A personal account of teaching in the old normal vs. the new normal. Kimika. 2020 Jan; 31(1):70-75. https://doi.org/10.26534/kimika.v31i1.70-75

Guidote Jr AM, Ribo-Ramos MO, De Leon DGL. Extraction experiments using commercially available spices. Kimika. 2010 March; 23(1):32-37. https://doi.org/10.26534/kimika.v23i1.32-37

Mojica ERE, Upmacis RK. Challenges encountered and students' reactions to practices utilized in a general chemistry laboratory course during the COVID-19 pandemic. J Chem Educ. 2021 Dec; 99(2):1053-1059. https://doi.org/10.1021/acs.jchemed.1c00838

Petillion RJ, McNeil, WS. Student experiences of emergency remote teaching: impacts of instructor practice on student learning, engagement, and well-being. J Chem Educ. 2020 Aug; 97(9):2486-2493. https://doi.org/10.1021/acs.jchemed.0c00733

Plummer, R. Monkeypox: WHO declares highest alert over outbreak. https://www.bbc.com/news/health-62279436. Last accessed 27 July 2022.

Pokhrel S, Chhetri R. A literature review on impact of COVID-19 pandemic on teaching and learning. High Educ Future. 2021 Jan; 8(1):133-141. https://doi.org/10.1177/2347631120983481

Xiong J, Lipsitz O, Nasri F, Lui LMW, Gill H, Phan L, et al. Impact of COVID-19 pandemic on mental health in the general population: A systematic review. J Affect Disord. 2020 Dec; 277:55–64. https://doi.org/10.1016/j.jad.2020.08.001