Teaching a large-scale crystallography school with Zoom Webinar

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ABSTRACT
In order to address the loss of crystallographic training opportunities resulting from the cancelation of conventional schools around the world due to the COVID-19 pandemic, we have started an online crystallography school with live lectures and live Q&A using Zoom Webinar. Since we were trying to reach a large audience in a relatively short period, we have limited the school to ten 1 h lectures covering practical aspects of small molecule crystallography including data collection, data processing, and structure solution. In the school, we also covered some advanced topics that students commonly see in their work: absolute structure determination, twinning, and disorder. To round out the education, we provided lectures on macromolecular crystallography and powder diffraction. For students to practice on their own, we used freely available data reduction and structure solution software, as well as datasets with which to practice. To give students credit for course completion, we provided an online exam and an electronic certificate of completion. In this editorial, we will provide some insight into the issues of holding lectures with up to 750 students of very diverse backgrounds and review the efficacy of the school in teaching crystallography for the two cohorts of students.

INTRODUCTION
The lockdowns associated with the COVID-19 pandemic resulted in the cancelation of all the in-person crystallography schools for 2020. To address the significant loss of training as a result of these cancelations, we organized three online schools using Zoom Webinar. In-person schools that were canceled or postponed one year include the ACA Summer Course,1 The International School of Crystallography,2 European Crystallography School-6 2021,3 and the Basics of Single Crystal Diffraction held by the DGK.4 At the time of the ACA Annual Meeting in August 2020, we had held two of the schools, one in June 2020 and the other in July 2020. The third school was held on December 7–11, 2020, and focused on advanced topics.

For the schools held in June and July, we decided to concentrate on the basics of small molecule single crystal x-ray diffraction with a focus on practical applications and provided the following lectures: introduction to crystallography (including Bragg’s law, crystallization, data collection and strategy, data processing integration, scaling/absorption corrections, and merging/outlier rejection), solution and refinement, and reporting and checkCIF. We also covered some commonly encountered but more advanced topics such as absolute structure, twins with partially overlapped reflections, macromolecular crystallography, and general purpose XRD. As an example of the depth of material covered, the lecture on the absolute structure reviewed the source of anomalous diffraction, collecting data to optimize absolute structure determination, the parameters in the studies by Flack and Hooft et al., for example.

EXECUTION AND RESULTS AND DISCUSSION
The success of the school was based on three essential features: lectures taught via Zoom Webinar, easy availability of offline class
material and software, and an exam with certification. We will describe each of the items below.

Zoom Webinar has a number of features that make it amenable to the task of teaching a large group of students interactively. These tools include a chat window, a versatile Q&A tool, and the ability to record the lectures. Zoom Webinar also provides several levels of participation: host, cohost, panelist, and attendees, which make it easy to have all the instructors online for Q&A. The need to have many instructors available during lectures was made obvious by the fact that some days we received up to 150 questions during and after each lecture. For the two schools, we had a total of nine lecturers. Other authors of this paper provided organizational and online support before, during, and after the two schools. Over 550 person-hours went into preparation and execution of the 20-plus hours of lectures spread out over the two schools.

To make the learning process easier, we used a web-based forum to deliver course materials, including slide decks, videos, sample data, and software as well as to provide a mechanism for offline communication. To reach the broadest audience, we used freely available software that could be downloaded from either the Rigaku X-ray Forum (CrysAlisPro7) or OlexSys.org (Olex28). Olex2 provides its own structure solution and refinement programs, and so no other programs are needed.

For the exam, all the instructors created a database of multiple-choice questions, some easy, some difficult, but none requiring a calculator. To give ourselves flexibility and tracking ability, the software for the exam was developed internally and was written to create a unique exam for each student from the database of questions. The software also allowed, for each question in the database, the total number of responses and the total number of correct responses to be recorded to allow question difficulty to be assessed should adjustments be needed. For the first school, the exam ran three days and for the second school, five days. Each student had to complete 50 multiple choice questions in 75 min. Students could retake the exam once, but with a different, randomly chosen set of questions in a random order. As exams were online and unsupervised, this approach was intended to limit or prevent students from predicting questions and question order for a second attempt. The passing grade was 70%. A Certificate of Attendance was given for students that attended at least 50% of the lectures and attained a score of less than 70% on the exam. A Certificate of Achievement was given for students who attended at least 50% and achieved a score of 70% or better. By virtue of a software-driven exam, marking was automatic, and thus, the certificates could be generated instantly and automatically on completion of the exam. We tracked student participation through a daily report generated by Zoom and download records from the forum.

The June school was held over ten days, June 1–5 and June 8–12, from 0800 to 0900 Central Daylight Time (CDT). The July school was also ten days held July 6–10 and July 12–17 from 0600 to 0700 CDT. We had more than 1200 registrants and 771 students on the first day of the June school. For the July school, we had more than 1100 registrants and 615 students on the first day. The breakdown of students by country is shown in Fig. 1. For June [Fig. 1(a)], the US, India, the UK, and South Africa were the largest groups, 35%, 15%, 15%, and 5%, respectively. For July, India, China, the US, and the UK participated at the 27%, 16%, 8%, and 7% levels, respectively. The intention behind running the July School so early in the day for the US was to allow more students in Europe and Asia to attend the lectures live. We clearly achieved this goal with a much larger contingent of Indian and Chinese students for the July school.

As mentioned earlier, the exams were administered after the schools ended. For the June school, about 44% of the students took the exam, and of those, 89% passed. For the July school, 43% of the students took the exam, and 79% passed. The average for the exams was 78% and 75%, respectively.

In all, we generated 605 Certificates of Attendance and 512 Certificates of Achievement. Some students used the Certificates of
Achievement for credit hours toward their degree at their home institution.

At the end of the exam and before generation of the certificates, we asked the students to provide feedback, and so we could improve subsequent versions of the school. On average, both schools received high scores, and those leaving comments stating a preference suggested both that we had too much theory and too little theory but were equal in number, suggesting that the amount of theory was just right.

CONCLUSION

In summary, we were able to help over 1400 researchers either develop skills or improve existing skills in single crystal x-ray diffraction under COVID-19 lockdown. We were surprised to learn that students were getting course credit for the school. This provided feedback that we are making an important contribution to the community.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy restrictions.

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