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Communication

Introducing Video-Recorded Lab Experiments into Assignments for Surface and Colloid Chemistry Students

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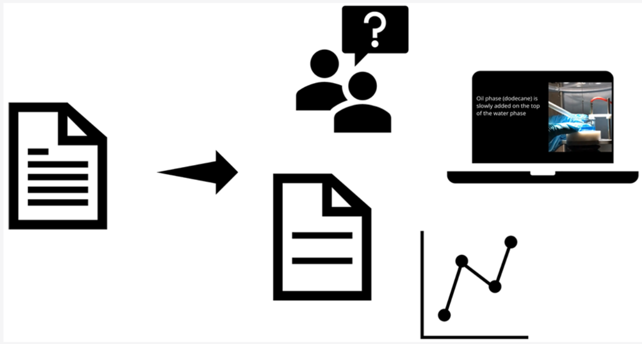
ABSTRACT: This communication describes our initial experience modifying traditional (written and calculation-based) assignments in the surface and colloid chemistry course given as a part of the chemical engineering program. The new exercises contain a more relatable context that is easier to understand and remember in terms of future challenges in student's professional career. These modified exercises deepen the level of the exercise by adding the working principle of the measurement and visualization of a lab experiment, instead of simply requiring the student to solve a set of problems. All videos were made and edited using in-house instrumentation and easily accessible tools (tripods, mobile phones, etc.). Analysis of the result of these new assignments showed that the average score was slightly below the means for the other exercises; interestingly, however, the students needed fewer attempts to solve these, which was possibly a sign of a better initial understanding of the questions. Furthermore, through a postassignment survey, we found that many students had a positive attitude toward this new form of introducing exercises and, in general, found them more engaging. Still, some comments pointed out a few shortcomings of the new type of exercises, which will be considered while continuously improving the existing exercises and formulating new ones. Overall, encouraged by the feedback, we plan to continue modifying the content of the assignments using this approach and consider other use of the prepared videos, for example, for instrument training purposes or promotional materials for the research group.



KEYWORDS: *Upper-Division Undergraduate, Multimedia-Based Learning, Testing/Assessment, Surface Science*

■ INTRODUCTION

Visual examples or demonstrations are often a great tool to explain a theoretical concept to students. As the level of education progresses, together with the complexity of the curriculum, there is also an increased focus on written materials, such as textbooks, presentation slides, or written assignments. Visual aids take more effort to prepare from an educator's perspective, especially when describing intricate theories. In this case, it is important not to deviate notably from the subject so that the intended germane cognitive load does not turn out to be extraneous, in which case the shown material will only confuse the students. Still, both from the personal experience and scientific reports, it can be said that students often enjoy and benefit from demonstrations and visualization of the written material.[1,2]

During the past few semesters, a majority of higher education institutions were forced to move all their teaching online due to the global pandemic of COVID-19. While it was a big challenge for the academic sector, it enabled the fast-tracking of many new concepts and introduced several innovative ideas into reality. In the context of the present paper, we will focus on teaching subjects connected with experimental work. This includes solutions such as prerecorded[3] or live lab demonstrations,[4,5] augmented or virtual reality (AR/VR) lab environments,[6,7] or even simple experiments to perform at home.[8,9] Necessity is truly the mother of invention.

The initial thought to improve the teaching quality in our course was to invite students into the laboratories for some planned experiments. The idea was to get them familiar with instruments, relate them to fundamentals studied in the course, perform measurements, and obtain the data required to solve a problem in the assignment. We hoped that this "hands-on" experience could be a more engaging alternative to the traditional written assignments. This optimistic concept, discussed internally at the end of 2019, quickly morphed into a real effort when the global pandemic hit in early 2020.

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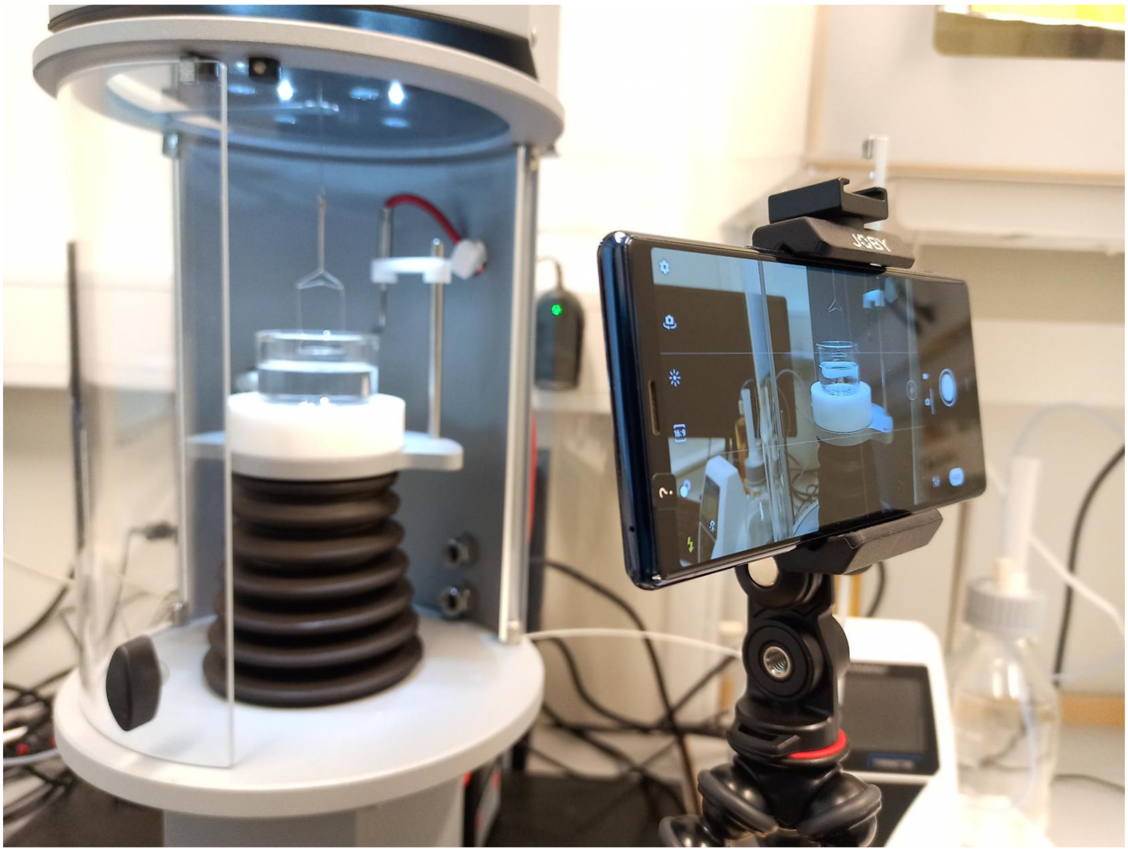

Figure 1. Mobile phone camera setup, mounted on a tripod, for recording one of the experiments (measuring interfacial tension with ring tensiometer).

At that point, it was decided to prerecord those laboratory exercises (like "dry laboratories",[10] but simplified) and create a more realistic problem to solve that will provide the student with a different angle on the theoretical knowledge from the lectures, and result in a better understanding of the experimental techniques and basic data treatment methods. Our hope was to modify the cognitive load carried by the written exercises and make the assignments less deductive and more inductive. Furthermore, the added visual (and experimental) aspect to the course could also serve as a recruitment tool into our research group. In this communication, we will describe our approach and thought processes and discuss the results and feedback from the students with regards to the added pedagogical and scientific value.

■ CONTEXT

Surface and Colloid Chemistry (TKP 4115) is a course given by the Department of Chemical Engineering for third and fourth year students studying at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway. The course is typically taken by 70−120 students and up to 10 PhD candidates, who follow the "mirror" doctoral course. The lectures are given two times a week (2 + 1 h) over 13 weeks, and the course is approved with a final written exam. Nine sets of exercises (assignments), which are the topic of this communication, accompany the lectures and provide a more practical approach to the theoretical knowledge. The course typically employs at least one teaching assistant (graduate student, later denoted as TA) and two to four student teaching assistants (usually students from previous years, later denoted as STAs) who help the students during the guided exercise hour and also evaluate the submitted assignments. For the semester when the modifications were introduced, there were approximately 70 students taking the course.

The assignments are a set of problems that complement the theory taught during the lectures. Depending on the assignments, *there are four to seven exercises in each assignment*, and *each exercise might have one or several questions*. The assignments are implemented in the virtual learning environment (referred to later as Blackboard). One example of a premodified set is available in the Supporting Information (Figure S1 in SI). Especially, in numerical exercises, there are often several questions to check and control the student's progress at each step of the exercise. Each question has a certain point score depending on its complexity. If the answer is a numerical value, the system provides immediate feedback regarding whether it is correct. The student has five attempts to answer correctly, after which the score for that question is zero. The students are also required to upload their calculation notes to spot any possible errors and receive feedback. After the submission deadline, the (S)TAs evaluate the manual entries such as texts, graphs, calculations, and derivations. In order to pass an assignment, the total percentage score of for all the exercises must exceed 40%, otherwise the assignment is failed. The students still receive feedback from the (S)TAs on the mistakes and can improve before the exam. Five out of nine assignments are required to be qualified for the exam, however often more are submitted, as it is considered good preparation for the exam. One week before the submission deadline for each set, there is also a guided exercise hour, where the (S)TAs

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help the students solve problematic questions. Attendance for this activity is not mandatory.

■ MODIFICATION

Three exercises in three different assignments were chosen for modification: one dealing with interfacial tension phenomena, one about sedimentation and diffusion, and one on the stability of dispersions, emulsions, and foams. The choice was partially based on the available instruments in the research lab and the known simplicity of the experiments, in this case, interfacial tension measurement with a ring tensiometer, bottle tests, and microfluidic coalescence measurements. To be clear, out of several exercises in each assignment, only one was modified or replaced with the new approach. In the future, we intend to add at least one of these types of exercises to each assignment.

Several people were involved in the implementation of the modified exercises at different stages. Planning was a group process including the faculty responsible for the course, TA, and lab engineers. The TA and lab engineers performed measurements, recorded and edited, and drafted the exercises. The final form of the exercise was then drafted and approved by the faculty member. Regarding technical resources, instruments or methods available within the research group's laboratories were used. For recording, mobile phone cameras mounted on a tripod were used (see Figure 1). Video editing was done in the WeVideo platform; drawings, graphs, and animations were done in PowerPoint, SigmaPlot, or MATLAB.

This section will focus on the exercise about interfacial tension measurements in different systems; however, the main idea for all the exercises was similar. First, the students receive a simple backstory (Box 1):

Box 1. Introduction Part of One of the Modified Exercises

The company you work for has chosen you to find a suitable surfactant that can be used to stabilize emulsions. This research is essential as the company wants to test the stability of wastewater from a big city and help the process become more efficient than the current technique. You choose two surfactants, SDS and Polysorbate 20, and you need to find the interfacial tension to understand its behavior.

As a result, the need for the measurement/calculation to solve a real-life problem was emphasized, and the exercise was used to show the students how the concepts are taught during lectures can be used in their future occupation. Afterward, some videos are shown. The first (Video 1 in SI) introduces the instrument, followed by the preparation phase (addition of the oil phase) and the beginning of the measurement (the ring moving up, starting to push against the interface, and searching for the force maximum). Then, another video reiterates the measurement principle (Video 2 in SI). Finally, the last video compares, side-by-side, the two systems, with and without surfactant (Video 3 in SI). Here, the intention was to visualize the physical difference between these two cases, which could give a clue to some of the questions for this exercise. It should be mentioned that there is no sound in the videos, and they contain English captions to make them more accessible for all the students, e.g., for those with hearing loss or international students who do not speak Norwegian. Screenshots from one of the videos are shown in Figure S2 in SI.

Finally, the students are given detailed information about the two systems [sodium dodecyl sulfate (SDS) and Polysorbate 20] and some additional information about the structure of surfactants. All the data from the experiments are given as values of interfacial tension over time. The students are first asked to plot the data and try to estimate the steady-state values (Box 2).

Box 2. Example of a Calculation Question in One of the Modified Exercises

Based on the data, estimate the equilibrium interfacial tension for 4 mM SDS with NaCl system.

As basic principles of surface chemistry dictate, more surface-active species will adsorb at the interface over time and affect the interfacial tension value, which manifests as an exponentially decaying function of the interfacial tension. In most cases, the reported interfacial tension values are for quasi-equilibrated systems after several minutes or hours of measurement. Thus, the learning potential for the student is to analyze the "real data" and decide how to estimate the steady-state value rather than just use a value provided in the question. Other questions quizzed the students to calculate surface excess and area per surfactant molecule at the interface. As mentioned previously, all numerical answers were automatically checked within the Blackboard system, and if wrong, the

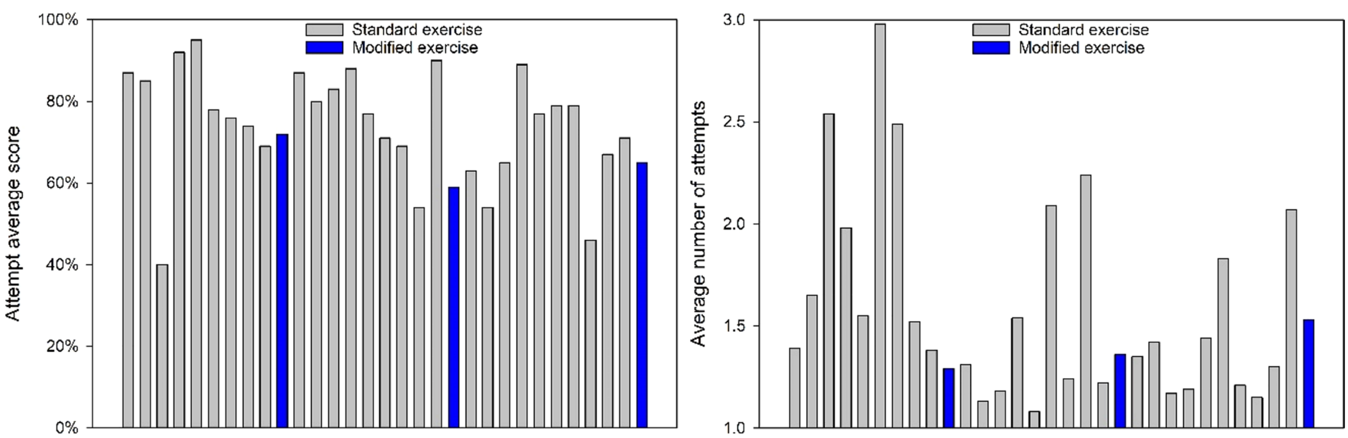

Figure 2. Overview of the results of all the exercises exported from the Blackboard system. Each bar shows information about one exercise from various assignments. Standard exercises are shown in gray, modified (with videos) in blue.

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online system would give the student an instant response. In the end, we also asked some open-ended questions, with Box 3 as an example.

Box 3. Box 3 Examples of Open-Ended Questions from One of the Modified Exercises

Based on the molecular area values, what is your interpretation of the results when comparing the molecular areas with and without salt for the anionic surfactant? **or** Based on the previously prepared plots, which system do you think would give the most stable emulsion and why?

Screenshots from Blackboard containg the information given to the students for this exercise along with some questions asked are available in Supporting Information (Figure S3 and Figure S4). For the students attending the weekly guided exercise meetings, the initial minutes were dedicated to briefly introduce and provide more context to the modified exercise by the TA for the assignments containing it. Afterward, the students could ask more specific questions about the concepts or the approaches to solve the new modified exercises. It should be mentioned that the TA was involved in preparing the exercise and making the videos while the STAs were only briefed about the new exercise to help them answer questions from the students. If the STAs are unable to answer, they ask the TA for further clarifications.

RESULTS

Figure 2 shows statistical information on the answers provided for the exercises in all assignments, exported from the Blackboard system. The gray bars show the results of the exercises which do not contain any vidoes and will be called "standard" exercise, while the modified ones are shown in blue.

Some exercises contained several questions; therefore, an average score is created for the whole set. Many exercises mix calculation problems and questions requiring a written answer (definitions or justifications of the results obtained before). The number of attempts signifies how many times the student, on average, had to answer the question in the exercise to get it approved; i.e., the lower the number is, the better the initial understanding of the question is.

Regarding the average attempt score, the modified exercises were slightly below the average for all the sets. This can probably be explained in two ways. First, many of the assignments are repeated from year to year, and therefore, some of the correct answers could possibly be passed by the students from previous years. However, all modified exercises

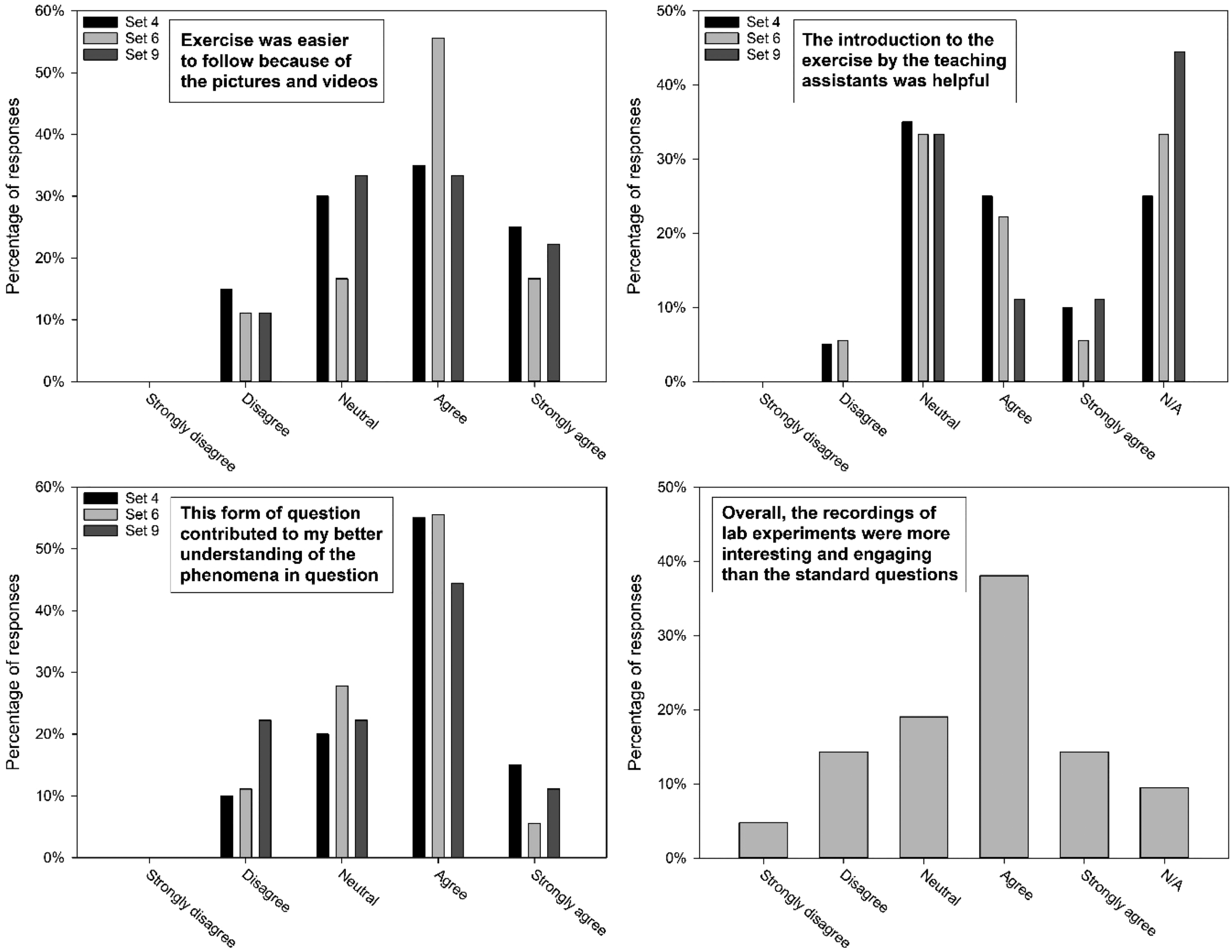

Figure 3. Summary of the results from the survey, based on the 24 responses (ca. 40% of the class).

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were new for the students. Therefore, a ca. 70% score might accurately indicate students' abilities and understanding of the topic. This was also found to be in line with the average exam scores. Second, the modified exercises were a bit more complex and had more questions to answer. While the other exercises had (on average) three questions to respond to, the modified ones had more than 10 per exercise. This high value was caused by the first exercise (both in order of preparing it and making it available for students), which was, in hindsight, toolong and tedious to do. However, after immediate feedback, this was quickly corrected, and the other exercises were of more reasonable length and complexity.

The average number of attempts for the modified exercises was much lower than the rest. This is seemingly a good result as it points to the fact that the students understood the exercise better the first time and managed to get it approved after fewer attempts. However, it could also be a result of introducing the exercises during the guided exercise hours and generally more questions asked by the students to the (S)TAs about the new exercises. Lastly, one could speculate that the videos and animations might have contributed to that effect, at least for some students, as seen in the results from the survey about the exercises.

The results of the survey, which were sent out to students after completing the last assignment, are presented in Figure 3, in which "Set 4" corresponds to the ring tensiometer experiment presented above. Three questions were asked about each assignment containing the modified exercises and one about the general impression of the modified exercises. In total, around 40% of the students from the course responded to the survey. In general, the students agreed that the exercises were easier to follow with pictures and animations. However, for two of the exercises, a more significant percentage (ca. 40%) of them disagreed or were neutral, which points to the need to improve the exercises' structure. Since this was our first attempt at exercise modification, each of the exercises was slightly different, and the feedback from the students, together with the exercise results, could point to the structure preferred by the students (possible improvements are discussed in the next section).

Regarding the second question, approximately half of the students did not find the introduction to the exercise by the TAs particularly useful. A large percentage also did not participate in the weekly guided exercise hours, hence the N/A bars in the chart. More than 60% of students agreed that the modified form of the exercise contributed to their better understanding of the topic, while only 10−15% disagreed with that statement. Finally, more than three-quarters of all the students were neutral or positive about introducing the new type of exercise. This, together with the direct feedback from the students (e.g., gathered during conversations in the guided exercise hours), suggests that most students had a positive, or at least non-negative, attitude toward the modified exercises presented in the course.

■ DISCUSSION AND OUTLOOK

As mentioned previously, our initial thought was to organize some practical lab exercises for the students. Keeping in mind the size of the class, the available human resources, and the lab capacity, it might have been a pretty challenging task. The global pandemic changed these plans, in our opinion, for the better, as we ended up with a more practical approach that can be executed regardless of the situation and with (most likely) fewer resources needed to achieve a similar goal. We are not reinventing the wheel here: The modified exercises were based on other existing examples, either previously prepared by the faculty member or available in textbooks. Our main intention was to make them multidimensional and easier to relate to, for example, by putting the measurements in the context of a real-life situation, visualizing the experimental techniques used to obtain the data, and showing that the values obtained are often not one ideal point, but often require some processing. In that way, the exercises were not "just another similar exercise to solve" but instead offer a more inductive way of solving a realistic problem that promotes holistic and critical thinking.[11]

Furthermore, in the current study program, the students spend limited time in laboratories, not to mention the extraordinary situation occurring over the past few semesters, so adding some more experimental know-how could prove useful later.[12] Motivated by the, generally positive, feedback from the students, we presented our approach on an internal arena for educators in our department. The meeting generated some good comments and could possibly be extended to other courses using parts of our approach, although not all courses can benefit from such a close relationship between the teaching content and research facilities as in our case. Recordings of the experiments could also potentially attract students to our research group. After all, visualization is always a great tool in promotional materials or activities.

The work done so far until has room for improvement. In fact, the first modified exercise made available to students was too long and had too many repetitive things to calculate. It also received immediate negative but constructive feedback, both coming directly from students and the STAs. Here, we humbly blame it on our initial enthusiasm and lack of experience with this kind of approach. Luckily, we had some time to prepare and modify the rest of the exercises to be more "acceptable" in the students' eyes. Some of the comments to the survey also highlighted that not all are interested in knowing the methodologies in more detail. However, this was considered from the start, as the students did not need to understand how the instrument works and watch all the videos to solve the problems given to them in the exercise. Therefore, we consider this modified content as extra material that could be helpful for the students. In other words, if they choose to, they can ignore most of the text, pictures, and animations; still get the exercise set approved; and successfully graduate from the course.

Our ambition is to add at least one such modified exercise to each assignment in the future. We do not intend to replace all of the questions with the new ones, as one of the students feared through their comments. Furthermore, we would like to involve the students in preparing the recordings of experiments (e.g., during summer internships). In that way, we can also get their perspective included in explaining different measurement techniques, as it was shown that students could be excellent video producers for their peers.[13,14] It also has the added benefit of reducing the workload of the teaching staff. Some additional elements could also be of interest, such as lab safety measures, as suggested by Woelk and Whitefield,[4] or a simplified (or even scripted) version of a similar experiment that one could perform safely at home. Lastly, these recorded measurements can also serve for other purposes, for example, as an alternative to printed procedures for instruments or specific measurements for lab classes or instrument users.

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■ ASSOCIATED CONTENT

Supporting Information

Supporting Information contains . Videos The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.2c00024.

Video introducing the intstrument and measurement (MP4)
Video with plot of force versus time (MP4)
Video comparing surfactant use (MP4)
Screenshots of the exercises, the videos used in the new assignments, and an example of data for one of the exercises (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

■ REFERENCES

(1) Walton, P. H. On the use of chemical demonstrations in lectures. *University Chemistry Education* **2002**, *6* (1), 22−27.

(2) Nadelson, L. S.; Scaggs, J.; Sheffield, C.; McDougal, O. M. Integration of Video-Based Demonstrations to Prepare Students for the Organic Chemistry Laboratory. *Journal of Science Education and Technology* **2015**, *24* (4), 476−483.

(3) Pilkington, L. I.; Hanif, M. An account of strategies and innovations for teaching chemistry during the COVID-19 pandemic. *Biochemistry and Molecular Biology Education* **2021**, *49* (3), 320−322.

(4) Woelk, K.; Whitefield, P. D. As Close as It Might Get to the Real Lab Experience—Live-Streamed Laboratory Activities. *J. Chem. Educ.* **2020**, *97* (9), 2996−3001.

(5) Weißl, M.; Kraft, G.; Innerlohinger, J.; Nypelö, T.; Spirk, S. Chemical Engineering Laboratory Projects in Student Teams in Real Life and Transformed Online: Viscose Fiber Spinning and Characterization. *J. Chem. Educ.* **2021**, *98* (5), 1776−1782.

(6) Karayilan, M.; Vakil, J.; Fowler, D.; Becker, M. L.; Cox, C. T. Zooming in on Polymer Chemistry and Designing Synthesis of High Sulfur-Content Polymers for Virtual Undergraduate Laboratory Experiment. *J. Chem. Educ.* **2021**, *98* (6), 2062−2073.

(7) Garcia-Bonete, M.-J.; Jensen, M.; Katona, G. A practical guide to developing virtual and augmented reality exercises for teaching structural biology. *Biochemistry and Molecular Biology Education* **2019**, *47* (1), 16−24.

(8) Orzolek, B. J.; Kozlowski, M. C. Separation of Food Colorings via Liquid−Liquid Extraction: An At-Home Organic Chemistry Lab. *J. Chem. Educ.* **2021**, *98* (3), 951−957.

(9) Easdon, J. Stay at Home Laboratories for Chemistry Courses. *J. Chem. Educ.* **2020**, *97* (9), 3070−3073.

(10) Kirschner, P.; Huisman, W. 'Dry laboratories' in science education; computer-based practical work. *International Journal of Science Education* **1998**, *20* (6), 665−682.

(11) Prince, M. J.; Felder, R. M. Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. *Journal of Engineering Education* **2006**, *95* (2), 123−138.

(12) Stieff, M.; Werner, S. M.; Fink, B.; Meador, D. Online Prelaboratory Videos Improve Student Performance in the General Chemistry Laboratory. *J. Chem. Educ.* **2018**, *95* (8), 1260−1266.

(13) Ryan, B. A walk down the red carpet: students as producers of digital video-based knowledge. *International Journal of Technology Enhanced Learning* **2013**, *5* (1), 24−41.

(14) Gallardo-Williams, M.; Morsch, L. A.; Paye, C.; Seery, M. K. Student-generated video in chemistry education. *Chemistry Education Research and Practice* **2020**, *21* (2), 488−495.

https://doi.org/10.1021/acs.jchemed.2c00024
J. Chem. Educ. 2022, 99, 2154−2159