Converting a Two-Week Chemistry Course for High School Students to a Virtual Format During COVID

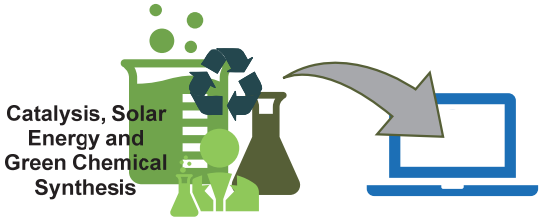
Haley Albright, Corey R. J. Stephenson, Corinna S. Schindler

Department of Chemistry, University of Michigan, Ann Arbor, Michigan 48109-1055, United States

ABSTRACT

A short course for high school students was converted from a two-week, in-person laboratory course to a remote and virtual four-week course due to the COVID-19 pandemic. Students met virtually each day to participate in activities that included the following: presentations, demonstrations, interviews, group discussions, lessons, and virtual tours and field trips. The virtual version of the course was able to maintain the same learning objectives and activities when compared to the in-person session and integrated additional expanded lessons, kitchen chemistry activities, and an emphasis on careers in science in order to increase student engagement. Student feedback indicated that interest in a career in STEM was increased overall and the incorporation of some of the newly introduced activities can be implemented into future versions of the course.

GRAPHICAL ABSTRACT



KEYWORDS

General Public, High School / Introductory Chemistry, Organic Chemistry, Curriculum, Computer-Based Learning, Distance Learning, Catalysis, Green Chemistry, Natural Products, Reactions, Synthesis.

INTRODUCTION

The challenges imposed by COVID-19 in 2020 required many aspects of daily life to become virtual experiences and this includes education.[1] At all levels, instructors converted their in-person classrooms and curriculum to a remote format[2-5] and also to varying levels of synchronous and asynchronous

learning.[6] In many cases, this transition took place despite limited training and experience for both the students and faculty. Furthermore, the conversion to a virtual classroom has also included outreach.[7,8] Over the summer, the University of Michigan hosts multiple sessions of a two-week camp for high school students from across the country and from around the world called MMSS (Michigan Math and Science Scholars).[9] The program was unsurprisingly in jeopardy as the COVID-19 pandemic hit the US in the spring of 2020 and instructors for each course had to decide if and how they would convert their programs. Notably, many of these courses are designed to be entirely in-person and involve hands-on activities that are performed in Michigan facilities and now faced cancellation if not converted to a completely remote experience.

We felt that it was important to continue our commitment to this outreach program, which required our course "Catalysis, Solar Energy and Green Chemical Synthesis"[10] to be transformed in order to allow for a successful, remote, and virtual experience for the students. Many high school students attend the two-week camp to learn new techniques, bulk up their resume for college applications, and to have an on-campus experience before going on to pursue their undergraduate studies. Over the previous 5 years that we have administered the course, the students that we met and worked with have been able to take away some exceptional experiences in the lab space, in the classroom, and with their peers on campus. Despite the difficulties associated with transferring an in-person laboratory course to an online format, we decided to take on this challenge to provide the students with a chance to learn and increase their interest in STEM. STEM outreach initiatives,[11] such as MMSS, not only play an important role in encouraging students to pursue careers in the sciences but also develop scientific curiosity in the general public.[12-15]

In this article, we will discuss the steps we took to transfer our two-week short course for high school students which relies heavily on in-person and on campus laboratory experimentation to a completely virtual four-week course. We will also discuss student perceptions following the completion of the course and the successful changes or additions that can be implemented in future iterations of the in-person course.

COURSE DESIGN

Online Transition Goals

The overall objective for our team of faculty and graduate students for the 2020 session of our course was to provide an interactive and engaging experience for the high school students in a virtual setting. Specifically, we focused on the following goals:

1. To convert the in-person course that was developed over 5 years to an online format.
2. To engage students in the virtual setting and allow for the learning goals to be maintained.[10]
3. To maintain the integrity of University of Michigan MMSS experience in the course.

We anticipated there to be numerous obstacles for the completion of this task, particularly with the requirement to create and maintain student engagement in the virtual setting. The "Catalysis, Solar Energy and Green Chemical Synthesis" course heavily relies on the ability to perform undergraduate level experiments in the laboratory on campus. These experiments were chosen and designed to require a variety of equipment and safety features that only an academic lab space can provide. Additionally, the experiments and activities were updated and optimized over the previous 5-year period to maximize hands-on student involvement and minimize "down time" in the two lab sessions on each day of the camp. The primary benefits of the MMSS program include the opportunity for the high school students to be on campus, to have interactions with their peers and classmates in the teaching laboratories, and to be immersed in the experience of college life at the University of Michigan. We were concerned that the inability to host students on campus would not allow the incorporation of these aspects and consequently result in a loss of the intimate Michigan experience that students would otherwise have. Our course re-design kept this aspect in mind and aimed to incorporate many of the original activities as well as alternate activities that could emulate the otherwise in-person experiences.

Setting and Participants

MMSS was previously designed as a two-week camp for high school students that are both from the United States and other countries around the world. Students can select from the courses that are offered which focus on topics in chemistry, math, physics, engineering, astronomy, biology, forensics, or statistics.[3] Students stay in the campus dormitories or commute each day and attend two 3-hour sessions on each weekday (10 days in total) with a lunch break in-between. The MMSS program provides

alternate activities for the weekend and in the evenings when students are not participating in their specific course.

The virtual version of MMSS for the summer of 2020 was re-organized to a four-week program (20 weekdays total) that was offered twice over the summer. Each day students signed on to a virtual meeting taking place *via* Zoom for 3 hours in the afternoon led by the individual course instructors. No prerequisite courses or preparation was required prior to attendance. Students ranged from ages 13-17 and were primarily rising sophomores, juniors, and seniors in high school (Table 1, below). Each session included 2-4 international students that were virtually attending in the middle of the night, based on their respective locations. The ratio of male to female students was approximately 1:1 over the two sessions. Two graduate student instructors (GSI) typically led the activities for each day allowing for students to interact with numerous graduate students from multiple backgrounds and with a variety of specialties.

Table 1. Student Information

Student Data	2020
Year 8 (Middle)	1
Year 9 (Fresh.)	0
Year 10 (Soph.)	9
Year 11 (Junior)	11
Year 12 (Senior)	14
International	6
US	29
Female	18
Male	15

Table 1 includes data on the high school students, including: school year, country of origin, and gender.

Course Text

The "Catalysis, Solar Energy and Green Chemical Synthesis" course utilizes a lab manual that includes references tables and detailed background information, experimental instructions, and follow-up questions for each experiment that students perform during the in-person course. Therefore, this lab manual had to be updated to reflect the additions and changes to the course in the virtual setting. Instead of a printed copy, the students received the lab manual as a PDF document that was both emailed to them and posted on Canvas (an online course management system that Michigan employs for all courses) which was used to administer content for the online course. The lab manual includes a short introduction to the course, write-ups for each experiment or activity, and follow-up questions for

students to answer during and after the conclusion each activity. Reference tables and additional information were also included in the manual. The complete and 2020 version of the lab manual can be found in the Supporting Information.

Adjusting Experiments

The following section outlines how we were able to convert the previously in-person course to a now completely remote and virtual course operating on a different schedule and timeline (Goal #1). Based on the previous, in-person schedule (shown below, in Figure 1) we had to address the following aspects and activities:

1. Laboratory experiments
2. Field trips
3. University of Michigan on-campus experience
4. Student interaction with their peers
5. One 3-hour session per day instead of two 3-hour sessions per day

IN-PERSON: 2019

Day: 1	2	3	4	5
Safety Amide Bond[16]	Wittig Olefination[17]	Natural Product Isolation[18]	Tie Dye[19] & Botanical Gardens	Metathesis Reaction[20] and Project Prep.
6	**7**	**8**	**9**	**10**
Aldol Reaction[21]	Presentations & Industry Tour	Click Reaction[22]	Solar Cell Assembly[25]	Fun Day

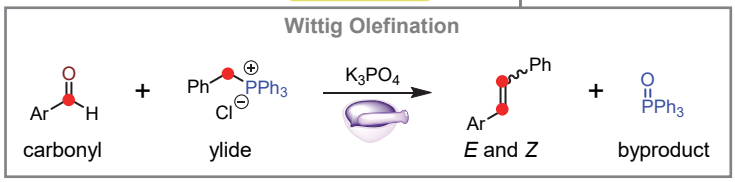
- 10 days to 20 days
- 2 sessions per day to 1 session per day
- Only remote instruction

REMOTE: 2020

Day: 1 2 3 4 5

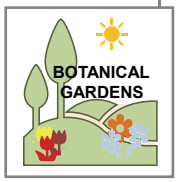
Introduction and Intial Info. → Virtual Campus Tours & Green Chemistry

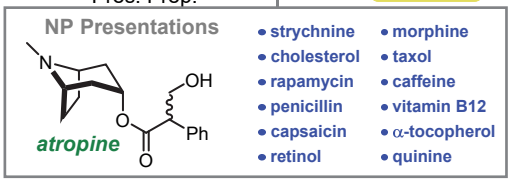
Lab Safety & Amide Bond → Nomenclature and Drawing Structures → Wittig Olefination

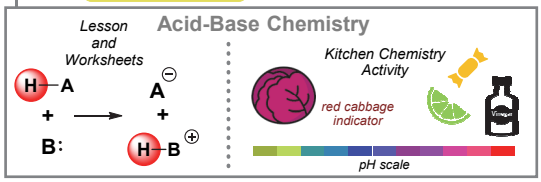


6 7 8 9 10

Natural Product Isolation → Botanical Gardens & Pres. Prep. → Acid-Base Chemistry → Careers in Science - Part 1 → Natural Product Presentations

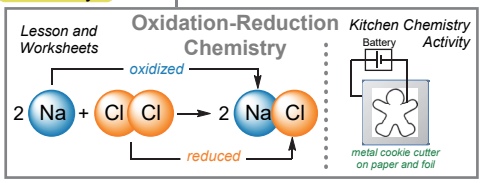


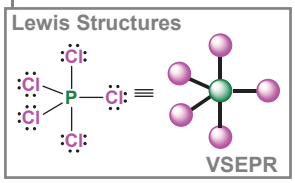


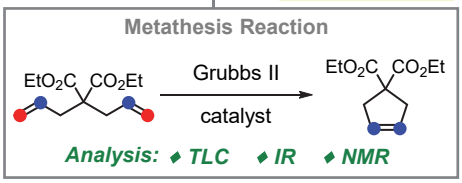


11 12 13 14 15

Redox Chemistry[26] → Aldol Reaction → Lewis Structures & VSEPR → Metathesis Reaction → COVID Pres. & Group Proj. Prep.

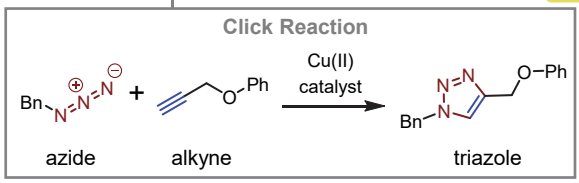


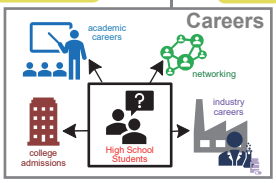




16 17 18 19 20

Click Reaction → Solar Cell Assembly → Careers in Science - Part 2 → Group Presentations → Fun Day





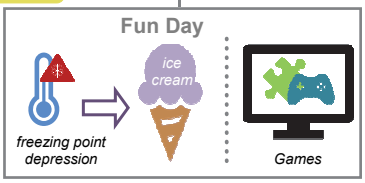


Figure 1. Two-week course calendar for the in-person 2019 session and the updated four-week course calendar for the remote 2020 session. Activities highlighted in yellow were added into the virtual 2020 session.

Labeled in yellow, in Figure 1, are additional activities that were included in the virtual course. The first of these was an initial introduction and information session (Day 1, Figure 1) that allowed the students and instructors to work through any technical difficulties and to ensure that students had access to all pertinent content. Video tours of the University of Michigan campus and chemistry building were added on Day 2 to allow for students to learn more about the campus (Goal #3) and this was paired with a presentation and Q&A session about green chemistry. These additions allowed for an earlier explanation of one of the major themes of the course whereas previously, in-person sessions had interspersed the Green Chemistry principles throughout the lab experiments. Two sessions were dedicated to "Careers in Science" (Days 9 and 18, Figure 1) which included interviews with industrial chemists, current graduate students and post-doctoral researchers in the Chemistry Department at the University of Michigan, presentations outlining the typical pathways from education to jobs in various fields of science (mostly focused on chemistry related positions), and an information session with members of the Admissions Office at the University of Michigan to provide the students an opportunity to ask questions about the application and admissions process. Lastly, a second project was added that allowed students to work in small groups to present their findings about recent recipients of the Green Chemistry Challenge Awards.[27] The revised and extended schedule also provided space for sessions that were dedicated solely to lessons on various topics in chemistry whereas these were previously included only in the "down time" during laboratory experiments. The ability to spend the entirety of one session on topics that included nomenclature and functional groups, Lewis structures and VSPER, acid-base chemistry, and redox chemistry allowed for a more in-depth discussion of the topics and each lesson was accompanied by an interactive activity. These activities included kitchen chemistry, stick-modelling, matching games, and group work on worksheets.

The majority of the laboratory experiments were also maintained (Goal #2) in the virtual session. Instead of the students performing these in the teaching labs on campus, the graduate students were able to perform them "live" during the virtual meetings and "bring" the course participants with them as

they worked in the lab space.[29-32] Some reactions required longer reaction times which called for additional preparation, before the afternoon session began. For example, the Click reaction[22] stirs at 60 °C for 1-2 hours and this time has previously been dedicated to the lunch break during the in-person sessions. The shortened, virtual session required a Click reaction to be set up ahead of time, prior to the session, so it would be completed during the shortened time window and could be worked up while the students looked on. Many of the other experiments were transitioned to the single, 3-hour time frame more easily as they were now performed by graduate students that prepared everything ahead of time in comparison to the in-person sessions where the high school students performed each task which can typically take twice the amount of time as it includes more instruction, regular check-ins, and monitoring.

We expected the main challenges for the virtual session to be a potential lack of verbal interaction with students and the ability to effectively engage them through a computer screen.[23,24] However, we were pleasantly surprised to find that the students were eager to talk with us, answer questions, and get to know their classmates (Goal #2). We also regularly provided opportunities for students to ask questions, placed students in breakout rooms to chat in small group settings, asked for feedback as the program proceeded, and included at least two short breaks in each of the 3-hour sessions for students to step away for a few minutes to prevent screen time fatigue.

ADDITIONAL ACTIVITIES

In order to fill the remaining days in the extended virtual schedule and to allow for as many interactive activities as possible *via* remote learning, we added a variety of activities and were able to dedicate more time to in-depth lessons on fundamental chemistry topics. Prior to the start of the session, we mailed small packages containing PPE (lab goggles and gloves) and a few supplies for most of the following activities. Students were required to have an adult at home with them when they were performing any of the following experimental activities.

Kitchen Chemistry

The ability for students to perform hands-on experiments is one of the main reasons that students enroll in the “Catalysis, Solar Energy and Green Chemical Synthesis” course of MMSS. We offer the opportunity for students to have an early laboratory experience in combination with the introduction to advanced

organic chemistry topics. The remote version of the course could not allow for the same level of experimentation conducted by the students themselves (Goal #2). While we were able to show them the various reactions that they would have performed had they been on campus, we wanted to provide the students the opportunity to learn about a concept and perform a coinciding experiment in their own homes during the session. This limited the types of experiments that could be performed, thus we focused on reactions in everyday life that could be completed at home, also known as "kitchen chemistry".[33] The students performed the experiments "in-view" of their camera so the GSIs could monitor their progress and provide feedback. For example, we taught a lesson about acid-base reactions in organic chemistry and then reacted sour candy with baking soda[34] and also used red cabbage as a pH indicator[35] to measure the approximate pH of a variety of foods and household products, such as lime juice, milk, bleach, soap, and vinegar to name a few (Figure 2). The students also learned about Lewis structure and VSEPR by modeling molecules with toothpicks and candy.[36] They ran a TLC plate (thin layer chromatography) with markers and paper in water[37] to separate the various dyes after learning about how TLC is employed when monitoring organic reactions. Students were also able to perform chemistry that they could eat by recrystallizing sugar to make rock candy[38] and a lesson about freezing point depression was paired with ice cream making.[39] Students placed the ice cream ingredients in a bag and then surrounded it with ice and salt to freeze the mixture as they shook it to end the session during the Fun Day on Day 20 (Figure 1).

Virtual Scavenger Hunt and Natural Product Presentations

In order to convert the field trip to the botanical gardens into a virtual activity, we were able to create an online scavenger hunt for the students to complete (Goal #2). The Matthaei Botanical Gardens[40] (Figure 2) has an extensive website with a thorough map of their gardens which allowed the students to find many of the plants that they would have seen during the in-person excursion. The ability to convert this field trip was important as it pairs well with the natural product presentation project that the students also prepared and delivered, virtually.

Green Chemistry Challenge Group Project

The additional weeks in the virtual schedule provided the option to include a second project for the students and we opted for a group presentation project that focused on innovations in green chemistry.

The group aspect was an intentional choice on our part as it encouraged and facilitated more interactions between the students in the virtual setting (Goal #2). One of the main components of the on-campus MMSS experience is the fact that the students get to know each other and often become long-term friends with their classmates. As this type of personal interaction is difficult to achieve in the virtual setting, it was imperative that we provide many opportunities for the students to simply talk to each other, even about non-course related topics. The group project not only provided them with a goal to collectively pursue but also encouraged them to get to know each other in the respective breakout rooms when preparing the presentation slides during class time. The group project asked each group of 2-3 students to prepare a 20-minute presentation on a recent Green Chemistry Challenge Award[27] recipient. The EPA's Office of Chemical Safety and Pollution Prevention sponsors the Green Chemistry Challenge Awards in partnership with the American Chemical Society Green Chemistry Institute®.[41] The Green Chemistry Challenge significantly reduces the hazards associated with designing, manufacturing, and using chemicals by recognizing groundbreaking scientific solutions to real-world environmental problems. After choosing a recent recipient of the award (Figure 2), students were asked to prepare a PowerPoint presentation that outlined the background of the company or researcher that was awarded the honor along with a description of the development and how it directly applies to the 12 principles of green chemistry[42] that the students had been learning about during the previous weeks of the course.

Careers in Science

Many of the high school students that attend MMSS are interested in the STEM fields but are not very aware of the abundant career opportunities that accompany them. Often, the high school students ask the GSIs about why they chose to go to graduate school, how they selected a college or picked a major, and what their plans are after graduation. We wanted to expand on these types of casual conversations and be more intentional when offering the students information and opportunities to ask questions. The virtual setting and extended schedule of the 2020 MMSS session was very amenable to this task. Specifically, we built in two days dedicated to "Careers in Science" (Figure 2) that included prepared presentations on the typical track for students going from high school to college to post-undergraduate studies and then to the variety of career options based on major, degree and interest. Initial surveys were given to the students on Day 1 and included questions about their current interests and possible

career aspirations. This allowed us to tailor the presentation to address as many interests as possible. For example, many of the students in the first session were interested in engineering while the other session had more interest in chemistry and biology.

The high school students also requested more information about the application and admission process for undergraduates to the University of Michigan. We were able to incorporate an information session with a few members of the Admissions Office during the second of the Career Days (Day 18, Figure 1) where these members joined our virtual call for the afternoon and provided videos and PDF handouts and also held a Q&A session with the high school students. This was particularly useful for the international students as many were interested in applying to US schools but were not very familiar with the institutional setup or application process.

In order to replicate opportunities for conversations that students previously had with the graduate students about their educational and career journeys (Goal #2), we scheduled 3 types of interviews or panels on the "Careers in Science" days (Day 9 and Day 18, Figure 1). These were held with current graduate students, post-doctoral researchers, and faculty in the chemistry department from our individual research groups. Each interviewee provided a brief personal background, an educational history, career pathways or aspirations, and a summary of their current research. Moreover, the course participants were asked to prepare questions for each interviewee in breakout rooms at the beginning of the session and were later given the opportunity to ask these questions in order to interact with and learn more about each person.

While the ability to tour a nearby chemical company was not an option during the pandemic, we were able to schedule information sessions and virtual tours with former graduate students that are now in their early years at Millipore Sigma and Pfizer. Depending on pre-approved accessibility, the virtual tours included walk-throughs of the industrial research lab spaces and campuses at each company. The students were able to learn more about career opportunities following a graduate degree in chemistry and once again, asked their pre-prepared questions to both former Michigan graduates.

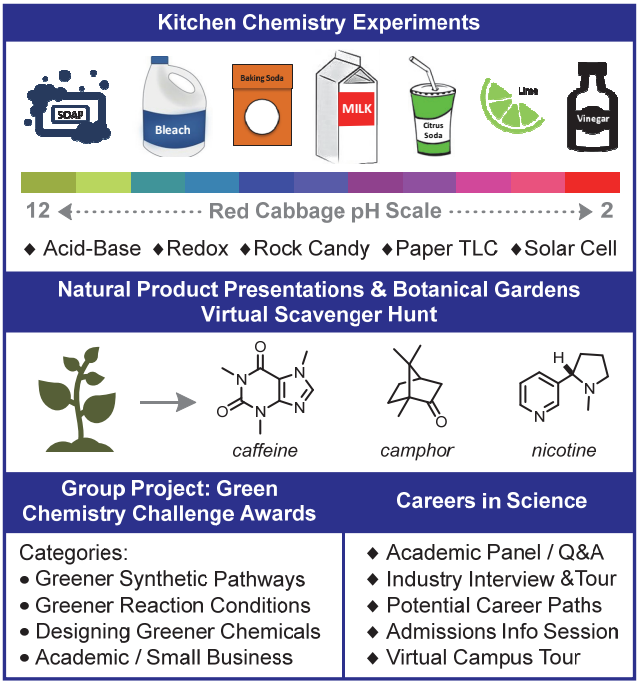


Figure 2. An outline of the additional activities in the remote session: kitchen chemistry experiments, natural product presentation, group project, and career pathway topics.

STUDENT PERCEPTIONS

At the end of the session, the high school students were asked to complete a closing survey which inquired about their thoughts on each day of activities and their overall interest in science and the STEM fields. 91.4% of the 35 students that participated in the two sessions replied that their interest in a STEM related career had increased over the duration of the course (Figure 3). The lessons, kitchen chemistry activities, and "Careers in Science" days were the most popular amongst the students (Figure 3, below) while the experimental and tour/field trip days were slightly less favored. We attribute the lower rating to the limited opportunities for the students to interact or be directly involved during those sessions.

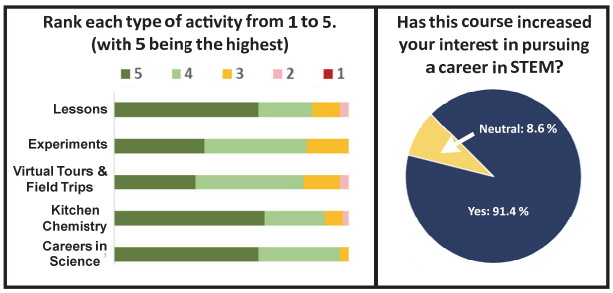


Figure 3. Student perceptions of each category of activity and overall interest in pursuing a career in STEM.

Additionally, we compared student perceptions on the experimental days from the previous, in-person session of the course in 2019 with this remote session in 2020. The natural product isolation[7] experiment was highly rated by both groups as this experiment includes the extraction of caffeine from energy drinks and soda along with the distillation of thymol from thyme and students regularly mention their appreciation for this direct correlation to their daily lives. The solar cell assembly[12] activity was also rated highly by both groups of students. Interestingly, the amide bond formation,[5] Wittig olefination,[6] and Aldol reaction[10] experiments were rated overall higher by the remote students. One explanation for this outcome is the ability for the high school students to focus more on the actual reactions while only viewing the process in the virtual setting instead of being distracted or overwhelmed by the many new lab techniques and directions that students are also experiencing in the in-person lab setting. These two experiments were also paired with kitchen chemistry activities (the rock candy with the Wittig experiment and paper TLC with the aldol experiment) which could also contribute to the rating.

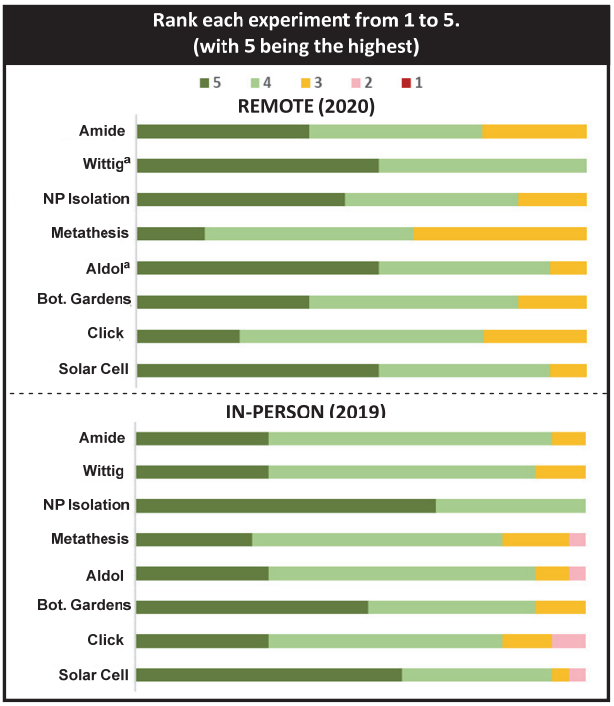


Figure 4. Comparison of student perceptions of experiments in the remote (2020) and in-person (2019) sessions. [a]Experiments that were accompanied by a kitchen chemistry activity in the remote session.

SUMMARY

In summary, we were able to convert our in-person, two-week course for high school students to a four-week remote and virtual setting (Goal #1). We were able to achieve a high rating, of a 4 or 5 with 5 being the highest, for most activities with categories that included more student participation being rated the highest. The majority of students had an increased interest in pursuing a career in STEM following the completion of the course. The course aims to teach students about green chemistry, catalytic organic reactions, and solar energy through experimentation. By including many of the original experiments in the virtual setting from the in-person format, we were able to maintain the student learning goals (Goal #2) and the integrity of the University of Michigan MMSS experience (Goal #3). We were also able to determine that a number of activities from the virtual course could be implemented in the in-person MMSS course experience, such as: the replacement of one of the experimental days with a "Careers in Science" day, the use of simpler, kitchen-safe chemistry experiments, and the option for a group or an individual project with the Green Chemistry Challenge Awards presentation project. With these insights about the course enhancements in hand, we expect to have an even more robust "Catalysis, Solar Energy and Green Chemical Synthesis" course in the future, in-person or virtually.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.XXXXXXX. [ACS will fill this in.] Example brief descriptions with file formats indicated are shown below; customize for your material.

2020 Lab Manual (PDF)

Student Survey Tables (PDF)

AUTHOR INFORMATION

Corresponding Author

Corinna S. Schindler

*E-mail: corinnas@umich.edu

ACKNOWLEDGMENTS

This work was supported by the National Science Foundation (CHE-1654223) and by the Michigan Math and Science Scholars program. We gratefully acknowledge the numerous Schindler and Stephenson group members who contributed to and helped to convert and run the course, as well as the many students who have participated in our course over the last 6 years.

REFERENCES

1. (a) Resources for Teaching Your Chemistry Class Online: A Free to Read Collection from the American Chemical Society & the ACS Division of Chemical Education. https://pubs.acs.org/page/jceda8/vi/teaching-chemistry-online (accessed 2021-04). (b) Cullen, D. Resources for Teaching Chemistry Online. https://www.chemedx.org/article/resources-teaching-chemistry-online (accessed 2021-04).
2. Holme, T.A. Chemistry Education in Times of Disruption and the Times That Lie Beyond. *J. Chem. Educ.* **2020**, *97*, 5, 1219-1220.
3. Babinčáková, M.; Bernard, P. Online Experimentation during COVID-19 Secondary School Closures: Teaching Methods and Student Perceptions. *J. Chem. Educ.* **2020,** *97*, 9, 3295-3300.
4. Donovan, W. J. The Whiplash of a COVID-19 Teaching Pivot and the Lessons Learned for the Future. *J. Chem. Educ.* **2020**, *97*, 9, 2917-2921.
5. Anzovino, M. E.: Mallia, V. A.; Morton, M. S.; Barker Paredes, J. E.; Pennington, R.; Pursell, D. P.; Rudd, G. E.; Shepler, B.; Villanueva, O.: Lee, S. Insights and Initiatives While Teaching Organic Chemistry I and II with Laboratory Courses in the Time of COVID-19. *J. Chem. Educ.* **2020**, *97*, 9, 3240-3245.
6. Arnaud, C.H. Tips for Teaching in the Time of Coronavirus. *C&EN Global Enterprise* **2020**, *98*, 12, 20-23.
7. Science Goes Virtual: Moving Outreach Opportunities Online Amid the Pandemic. https://www.sju.edu/news/science-goes-virtual-moving-outreach-opportunities-online-amid-pandemic (accessed 2021-04).
8. Education and Outreach Programs: STEM Outreach. https://www.anl.gov/education/stem-outreach (accessed 2021-04).

9. Michigan Math and Science Scholars. https://sites.lsa.umich.edu/mmss/ (accessed 2021-04).
10. Albright, H.; Stephenson, C. R. J.; Schindler, C. S. The Design of a Two-Week Organic Chemistry Course for High School Students: "Catalysis, Solar Energy and Green Chemical Synthesis". *J. Chem. Educ.* XX, XXXX-XXXX.
11. (a) University of Toledo, http://www.utoledo.edu/nsm/sgce/ (accessed 2021-04). (b) Doxsee, K.; Hutchison, J. E. *Green Organic Chemistry: Strategies, Tools, and Laboratory Experiments*; Brooks/Cole, Cengage Learning: Belmont, CA, USA, 2004. (c) Environmental and Green Chemistry, University of Minnesota, https://chem.umn.edu/research/environmental-green-chemistry (accessed 2021-04).
12. Leonard, K. Engaging Parents in Kids' STEM Education. U.S. News & World Report, June 2015.
13. National PTA STEM + Families. Increasing Students' Access to Opportunities in STEM by Effectively Engaging Families; National PTA, 2016.
14. Godínez Castellanos, J. L.; León, A.; Reed, C. L.; Lo, J. Y.; Ayson, P.; Garfield, J.; Alva, M.; Ureño Moreno, M.; Drake, M. D.; Gordon, M.; Phillips, S.; Alemán, E. A. Chemistry in Our Community: Strategies and Logistics Implemented to Provide Hands-On Activities to K–12 Students, Teachers, and Families. *J. Chem. Educ.* **2021**, *98*, 1266-1274.
15. Bopegedera, A. M. R. P. Chemistry in the Public Library: A Long-Standing, Valuable Community Partnership. *J. Chem. Educ.* **2021**, *98*, 1256-1265.
16. Hailstone, E.; Huther, N.; Parsons, A.F. A Polymer-Supported Organic Reaction: Seeing Is Believing. *J. Chem. Educ.* **2003**, *80*, 1444-1445.
17. Leung, S.H.; Angel, S.A. Solvent-Free Wittig Reaction: A Green Organic Chemistry Laboratory Experiment. *J. Chem. Educ.* **2004**, *81*, 1492-1493.
18. Torres y Torres, J.L.; Hiley, S.L.; Lorimor, S.P.; Rhoad, J.S.; Caldwell, B.D.; Zweerink, G.L.; Ducey, M. Separation of Caffeine from Beverages and Analysis Using Thin-Layer Chromatography and Gas Chromatography–Mass Spectrometry. *J. Chem. Educ.* **2015**, *92*, 900-902.
19. Alpha Chi Sigma. Tie Dye Outreach Program. https://www.alphachisigma.org/about-us/outreach/bonding-with-color (accessed 2021-04).

20. Schepmann, H.G.; Mynderse, M. Ring-Closing Metathesis: An Advanced Guided-Inquiry Experiment for the Organic Laboratory. *J. Chem. Educ.* **2010**, *87*, 721-723.

21. Hammond, C.N.; Schatz, P.F.; Mohrig, J.R.; Davidson, T.A. Synthesis and Hydrogenation of Disubstituted Chalcones. A Guided-Inquiry Organic Chemistry Project. *J. Chem. Educ.* **2009**, *86*, 234-239.

22. Hansen, T.V.; Wu, P.; Sharpless, W.D.; Lindberg, J.G. Just Click It: Undergraduate Procedures for the Copper(I)-Catalyzed Formation of 1,2,3-Triazoles from Azides and Terminal Acetylenes. *J. Chem. Educ.* **2005**, *82*, 1833-1836.

23. Zuidema, D. R.; Zuidema, R. H. From Passive Observers to Active Participants: Using Interactive Remote Demonstrations to Increase Student Involvement in Online Chemistry Instruction. *J. Chem. Educ.* **2021**, *98*, 843-849.

24. Nickerson, L. A.; Shea, K. M. First-Semester Organic Chemistry during COVID-19: Prioritizing Group Work, Flexibility, and Student Engagement. *J. Chem. Educ.* **2020**, *97*, 3201-3205.

25. (a) Smestad, G.P.; Gratzel, M. Demonstrating Electron Transfer and Nanotechnology: A Natural Dye-Sensitized Nanocrystalline Energy Converter. *J. Chem. Educ.* **1998**, *75*, 752-756. (b) University of Wisconsin-Madison. Nanocrystalline Solar Cell Kit.

26. Kuntzleman, T.S. Electrochemistry with Simple Materials to Create Designs and Write Messages. *J. Chem. Educ.* **2019**, *96*, 1178-1181.

27. EPA, Information about the Green Chemistry Challenge. https://www.epa.gov/greenchemistry/information-about-green-chemistry-challenge (accessed 2021-04).

28. Green Chemistry. https://www.acs.org/content/acs/en/greenchemistry.html (accessed 2021-04).

29. 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.

30. *Undergraduate Professional Education in Chemistry*, ACS Guidelines and Evaluation for Bachelor's Degree Programs, Spring 2015, American Chemical Society, Committee on Professional Training, Section 5.11 Online and Virtual Instruction, pp 15−16.

31. Cresswell, S. L.; Loughlin, W. A.; Coster, M. J.; Green, D. M. Development and Production of Interactive Videos for Teaching Chemical Techniques during Laboratory Sessions. *J. Chem. Educ.* **2019**, *96* (5), 1033−1036.

32. Pölloth, B.; Teikmane, I.; Schwarzer, S.; Zipse, H. Development of a Modular Online Video Library for the Introductory Organic Chemistry Laboratory. *J. Chem. Educ.* **2020**, 97 (2), 338−343.

33. A few examples to describe kitchen chemistry include: (a) Jacobsen, E.K. Kitchen Chemistry. *J. Chem. Educ.* **2011**, *88*, 1018-1019. (b) Whitmer, J.C. Kitchen Chemistry. *J. Chem. Educ.* **1975**, *52*, 665. (c) Bruce, C.B. Kitchen Chemistry (Ted Lister, with Heston Blumenthal). *J. Chem. Educ.* **2007**, *84*, 41-42.

34. Leavitt, Loralee. *Candy Experiments*. Andrews McMeel, 2013.

35. Fortman, J.J.; Stubbs, K.M. Demonstrations with red cabbage indicator. *J. Chem. Educ.* **1992**, *69*, 66.

36. (a) Atoms and Molecules. https://goopenva.org/courses/atoms-and-molecules-2/view (accessed 2021-04). (b) Molecular Modeling with Candy. https://www.cae.tntech.edu/~dcashman/demos/demo_candy.html (accessed 2021-04).

37. Home Science Tools. Color Chromatography. https://learning-center.homesciencetools.com/article/colorful-chromatography-science/ (accessed 2021-04).

38. Science Bob. Make your own Rock Candy. https://sciencebob.com/make-your-own-rock-candy/ (accessed 2021-04).

39. Jansen, K. Making liquid-nitrogen ice cream safely. *C&EN Global Enterprise* **2018**, *96*, 4.

40. Matthaei Botanical Gardens and Nichols Arboretum https://mbgna.umich.edu/ (accessed 2021-01).

41. American Chemical Society. 12 Principles of Green Chemistry. https://www.acs.org/content/acs/en/greenchemistry/principles/12-principles-of-green-chemistry.html (accessed 2021-04).

42. Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*; Oxford University Press: New York, 1998.