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Facilitating meaningful and authentic learning experiences in remote and online STEM courses

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I always wanted to create a lab course where students complete an experiment and apply the concepts learned in context, to explain current issues and the world around them. Previously the online chemistry laboratory for non-science majors consisted of cookbook labs and had a face-to-face component (students signed up to do 4 labs in one day) because of a firm belief that students needed hands-on lab experience to learn chemistry. Students completed labs either under instructor supervision (weekend on-campus lab) or on their own (web-based labs) and turned in standard lab reports (reported their data, summarized their results and conclusions, etc.) However, when the pandemic began, we needed a completely online lab that students could do with household materials. Luckily, I was on professional development leave in Spring 2020 and saw this as an opportunity to completely revamp the course to create an engaging, inquiry-based, and authentic experience. I was excited because students could engage with the content and produce original work, but worried about how the course would be received, because the revamped course would be a lot more writing intensive, including draft versions of each writing assignment. I also recognized that rubrics would be essential in giving students feedback to help them improve their writing skills and the key to maintain consistency in grading by multiple course (teaching) assistants (each course assistant is assigned 20+ students).

Using a combination of virtual simulations and kitchen chemistry experiments, I began by redesigning existing labs and creating new ones to be more inquiry-based and serve as a springboard to help students understand the scientific concepts underlying real world phenomena. I wanted them to apply this knowledge to explain the world around them, examine data, and interpret available information to construct an informed point of view on a scientific topic/phenomenon and synthesize a reasonable argument. I retained the lab reports to help develop skills of recording, examining, and interpreting data, as well as synthesizing and reporting conclusions (scientific communication). In addition, I incorporated scaffolded writing assignments and discussion forums (used less frequently in science lab courses). I collaborated with a faculty member from the English department to design prompts that allow students to clearly articulate and communicate their ideas, supporting them with reasoning and logic, including proposing possible solutions and evaluating proposed solutions. For example, after completing several labs exploring the concept of pH, students participated in discussions about acidification of oceans and alkaline water. Students engaged with the course content and each other, focusing on understanding how chemistry is relevant to real world issues like second-hand smoke and vaping, vaccinations, and the coronavirus pandemic.

I taught this revamped lab originally in Summer 2020 and every semester since. There is a widespread perception that teaching chemistry labs online has limited effectiveness. However, surveys, student evaluations, and feedback from the course (teaching) assistants all show that students are engaged and excited about learning chemistry, and, most importantly, they see the relevance of the course to their careers and daily lives. I am currently exploring incorporating new phenomena into the course to keep the content relevant and fresh (and prevent plagiarism). This is time consuming, but it is a valuable investment because it enhances student engagement and learning. I still believe, when possible, students, especially non-majors, will benefit from "hands-on" experience of being in a real lab environment working under the direction of an experienced instructor, allowing them to put in perspective how science and scientists work. I hope to revise other lab courses in hybrid and face-to-face modalities using these same principles.

In Fall 2020, I also taught General Chemistry I, a large enrollment gateway course for STEM majors, the first course in a two-semester sequence. Before the pandemic, at every class meeting, students worked on worksheets/activities in groups, with undergraduate Learning Assistants (LAs) and the instructor as facilitators. In the remote setting, I continued to teach the course in an active learning format, facilitating group work with the help of LAs who worked with groups of students in break-out rooms on activities. Using clickers to boost class participation and evaluate student understanding, I encouraged students to become stakeholders in course decision making – having their responses to content questions guide me in setting the progress and pace of my class meetings, letting them vote on due dates of certain assignments, allowing them to choose between two homework systems they explored, and whether certain assignments should count for credit. My colleague Sonia Underwood and I were teaching the same course with common exams and common syllabus.

To reduce stress, we moved away from the "three midterms and a final exam" model. The summative assessments were rebranded as Mastery Checkpoints (MCs). The MCs were mostly multiple-choice questions with a couple of essay responses, allowing students to demonstrate their understanding of the core ideas within the course (and receive partial credit for the same). There were six cumulative MCs in the course (since the course builds on itself) and were administered every 2 weeks. At the end of the semester, the average of a student's MCs also replaced their lowest MC, allowing students to recover from a sub-par performance. In university surveys, students overwhelmingly favored MCs over exams but also pointed out that having an MC every alternate week was exhausting (and the faculty agreed!). So, the MCs are here to stay (for the foreseeable future), however we now have 5 MCs (instead of 6) spaced 3 weeks apart to keep the students, and instructors, from assessment burn out. In discussing this with colleagues from other departments, they find it to be a great model and are considering adopting it.

I admit I was skeptical that we could administer the MCs online to evaluate student learning in a fair manner without opening the door to wide-spread academic misconduct. However, an open conversation with my students revealed more anxiety about the monitoring programs (because of unfavorable experiences) than about the MCs themselves. I realized that I was looking at it all wrong and I needed to trust my students while finding other ways to ensure the integrity of the assessment, and these two were not mutually exclusive. I ended up having another open conversation with my students explaining that trust was a two-way street and that they had to work hard to win and keep my trust. With an academic integrity statement at the beginning of each MC and a firm time limit on the MCs (administered within Canvas), multiple versions of each question, shuffling answers, and reminders sent out before each MC, there were no questions from our MCs posted on any of the usual “help” sites and the averages remained consistent with previous years. This semester our MCs are still online. I intend to continue the messaging and will set high expectations for students because I know they will rise to meet them.

The final exam was also replaced with a final project. I teach an alternative chemistry curriculum called CLUE and the course is built on four core ideas - Atomic/Molecular Structure and Properties, Matter and its Interactions, Energy, and Change and Stability in Chemical Systems. Each student had to select two of these core ideas and create an infographic highlighting one phenomenon for each of the selected core ideas and a third phenomenon connecting the two chosen core ideas together. Students also presented their project to their classmates in breakout rooms to share their synthesis of information and ask questions on the projects of two other classmates. This assignment helped to make the course relevant and allowed students to connect concepts learned during the course to everyday phenomena. The rubrics for both the project and the presentations were released well in advance. However, the grading for this was intense given the class size (200 students). I am considering something smaller next time around. From the infographic submissions, I also realized that I needed to do a more thorough job highlighting and tying phenomena and concepts they learn in the course to core ideas. I have started working on it this semester and the work will continue during the upcoming semesters.

This has been an amazing learning experience, allowing me to overcome my biases and engage in more authentic and transparent learning practices. I took a leap of faith and succeeded because students are open to novel experiences, innovative courses, willing to engage, and wanting to learn. The last eighteen months have given us a window into the kind of challenges the future generations will face – food and water shortages, climate change, new pathogens, etc. and highlighted the importance of scientific literacy. Thoughtfully designed and pedagogically sound courses can help foster scientifically literate citizens, able to research, evaluate, and synthesize scientific information to make informed decisions. To create future interdisciplinary problem solvers, we have a responsibility to reinvigorate and innovate our college courses at all levels to engage students and facilitate learning in context, encourage them to make connections within and between disciplines, and polish their critical thinking and communication skills throughout their college careers.