Chapter 10
Re-Imagining Science Laboratory Learning for the New Normal in a Post-Pandemic World

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ABSTRACT

With the onset of the global pandemic in 2020, the education community was forced to shift from "teaching as usual" to "emergency remote instruction" (ERI). Faculty at all levels were required to quickly adapt to new teaching and learning methods that allowed students to meet course goals and demonstrate learning gains with minimal disruption. This rapid shift was seamless for some, uncomfortable for many, and groundbreaking for all. For science educators who use laboratories and hands-on approaches to engage students, it can be daunting to re-imagine ways to design such experiences. What educators learned along the way, however, is that many of the novel techniques developed to engage science students during ERI will continue to be valuable as face-to-face instruction resumes. This chapter examines lessons learned during these unprecedented times and identifies effective innovations and equitable approaches that can be integrated into post-pandemic classrooms of all modalities. This will ensure that education in the new normal will be flexible, equitable, and effective.

INTRODUCTION

According to the National Center for Education Statistics (n.d.a), 21 percent of public schools and 13 percent of private schools offered online courses during the academic year 2017-2018. Fast forward to spring 2020 through spring 2021, this number exponentially increased as schools shifted to remote and

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online instruction due to the Covid-19 pandemic. As the world recovers from the pandemic and educators build on lessons learned and look ahead to the "new normal", there will be increased opportunities to engage students in physical, hybrid and virtual classrooms. The blending of these learning environments presents unique opportunities and challenges as teachers adapt lessons to ensure learning outcomes are met.

For science educators who extensively use laboratories and hands-on approaches to engage students, it can be daunting to re-imagine ways to design such learning experiences. This chapter will explore effective instructional strategies for designing authentic science laboratory lessons for distance and blended learning environments. Additionally, concrete examples where these approaches have been effectively implemented by educators across science disciplines and grade levels will be presented.

The Science Laboratory in Education: An Overview

Hands-on, experiential learning is a key component of science education. Scientific experimentation provides students with opportunities to apply technical knowledge and skills, extend their learning of scientific concepts, strengthen critical thinking skills, engage in scientific processes, and further their interest in science (Hofstein & Lunetta, 2004; Hofstein & Mamlok-Naaman, 2007; Ma & Nickerson, 2006; Ottander & Grelsson, 2006). Furthermore, it has been shown that physically interacting with scientific phenomena and materials enhances student learning through sensorimotor modifications (Kontra et al., 2015). While such experiences are typically designed for classroom or laboratory settings, there are growing opportunities to engage in experimentation in online and remote environments with activities varying from virtual to hands-on (Faulconer & Gruss, 2018; Herzog & Mawn, 2020; Kennepohl, 2021; Mawn et al., 2011, Mawn, 2016; Rowe et al., 2017).

Domin (1999) describes four teaching approaches used in laboratory settings. The *expository approach* uses predetermined experiments and procedures to demonstrate predetermined outcomes; this is known as the "cookbook laboratory". The *inquiry* and *discovery* approaches provide students with greater control over the experimental question and design. For inquiry labs, the outcome is unknown to the instructor and student; for discovery labs, the instructor guides students to the desired outcome. Finally, for *problem-based* labs, students are presented with a problem, and they determine the experimental methods needed to find a solution. Each of these instructional approaches can impact students' engagement levels, technical and cognitive processes, and learning outcomes. Additionally, the use of technology to enhance learning and create engaged, inquiry-based experiences has proven to improve student success (de Jong, 2019).

As science educators design science laboratory experiences for varied learning environments, it is important to define clear outcomes so that assessments and activities align with these outcomes. Is the emphasis on basic technical skills such as following protocols, observation, measurement, data collection? Are students engaged in experimental design, problem solving, and data analysis? Are they being asked to analyze problems, formulate testable hypotheses, devise approaches, and conduct open-ended investigations? This represents a progression from lower- to higher-order cognitive skills as students engage in laboratory learning. Studies have shown the positive impact of implementing critical thinking within laboratory activities and formative assessments (Rodriguez et al., 2018; Weaver et al., 2016). These learning gains extend into the K-12 education sector, where allowing students to think, engage, and develop solutions for their communities improves student learning outcomes and success (Pewnim, 2011).