

Chapter 1

New Questions for Chemistry Education Research

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This chapter describes the rationale for bringing together the distinguished group of contributors to this book. It also summarizes each contribution.

Online course development and the resulting effect on the classroom are important current topics for contemporary educators in diverse fields. The chapters in this book address these topics specifically for chemistry educators.

My interest in this subject stems from my own experience adapting an on-campus course to an online format. When my team began the work of re-organizing the material of our on-campus course for a new and broader audience online, e.g. by developing online media to take the place of in-person lectures and labs, I looked for research by other chemistry educators on best practices for doing this. To my surprise, I found very little of what I was hoping to find.

As a result, I began to make notes about issues I encountered, in the hopes that I would someday be able to compare my ideas and experiences with others working along the interface of on-campus and online chemistry education. My team also began collecting data from students, in order to track the effects of new materials and methods on the learning process. This equipped me to develop preliminary views about what worked and what did not.

Frustrated by the lack of available research on the topic, as well as eager to meet other chemistry educators with similar experience, I reached out across the US, in order to find others who shared my desire to exchange ideas and research in this unique niche in science education. I proposed a special session at the

American Chemical Society National Meeting in Denver in Spring 2015, and convened chemistry educators who had developed high profile online and/or on-campus chemistry courses.

The credentials of the group that assembled at the special session of the ACS speak for themselves. As a group, they include the instructors and course developers from the majority of chemistry courses that had been offered on the EdX and Coursera platforms at that time.

Following the valuable exchanges at and after the original ACS meeting, this book presents their original ideas and data, and in the process, fills an important gap in research in chemistry education.

The authors in this book address questions such as these:

- How can the online education movement advance and inform how instructors and researchers approach chemistry education in general?
- What pedagogical decisions are made in creating online courses? How do they differ from the pedagogical decisions made in on-campus teaching? Where can overlap between the two be used effectively?
- How can the construction of an online course contribute to on-campus teaching? How can online materials, such as videos, be used to flip, blend, or otherwise change how on-campus students approach course materials?
- How can a large number of students in a course, whether offered online or on-campus, be leveraged in creating a successful learning experience? How can the social dimensions of on-campus courses be recreated in online classes, thus overcoming traditional concerns about distance learning?

Answers to important questions like these help us better understand how to execute successful online courses. They can also help us better understand how to bring the fruits of online courses back to on-campus chemistry courses. Each chapter makes a unique and important contribution to this better understanding.

In Chapter 2, Hutchinson and Obenland propose that the advent of online education holds great promise for chemistry education, because it offers an exciting new opportunity for instructors to publish teaching in a way that has not previously been possible. Traditionally, instructors have published articles *about* their teaching. However, with the advent of online courses, instructors can now show how “lesson plans, innovative tools, and creative ideas are actually implemented”. The authors discuss how the online format allowed Hutchinson to publish his own unique approach to general chemistry teaching. This approach emphasizes students developing concepts through inductive, rather than deductive, reasoning. Hutchinson has been developing this method in his on-campus classroom at Rice since the early 1990’s and has received numerous inquiries about the implementation from instructors at other institutions. The

online course finally offered an opportunity to share his method more widely — both with the general public and with high school chemistry teachers wishing to enroll in the course for professional development. In addition, Hutchinson has used the videos from the online course to augment the on-campus classroom by making them available as review materials in a method he refers to as “back-flipping”.

There are several other examples in this book of instructors utilizing the online format to share their unique teaching methods with the world. One such example is presented in Chapter 3, where Evans shares a “generalized approach” for teaching intermediate organic chemistry developed by himself and colleagues. This method emphasizes early exposure to general principles and concepts, as opposed to relying on detailed structure and reactivity of specific structural groups. Evans gives two examples of this model in the chapter: the grouping of organic structures into building blocks, and a special approach to curved-arrow formalism in organic reactions. As opposed to some of the other authors in this book, Evans and colleagues *first* developed an on-campus course which utilized a flipped classroom with assigned videos and a diverse set of computational tools, and *then* translated the course to a Massive Open Online Course (MOOC). He argues that the generalized approach facilitates transfer of knowledge from one context of organic chemistry to another, and that this may make it especially beneficial for MOOC students because they tend already to have some chemistry education and experience.

In Chapter 4, Woodrum and Soult explore the great potential of online courses for addressing gaps and shortcomings in students’ education at the high school level. The authors created two online general chemistry courses at the University of Kentucky with the aim of increasing preparedness for college-level chemistry for incoming freshmen. They explain that such online courses are of special value in eastern Kentucky, where many factors, including high poverty levels and low rates of teachers having majored in chemistry, contribute to inadequate chemistry preparation in high school. In addition to presenting material in a lecture style format, the online courses emphasize videotaped problem solving. Also, a printable copy of all presentations and problems is made available so that students can follow along. The final courses are offered on Coursera and can be used in multiple ways: as supplemental material for students enrolled in high school chemistry courses, independently by students between high school and college, or by teachers for use either in their own classes or as continuing education.

In Chapter 5, Suchoki shares the perspective of an instructor who started recording video materials and using them in a flipped classroom model as early as the 1990s, long before the current online education movement. In this early version of an online class, the videos were broadcast on cable television and Suchoki used classroom time for interactive study and hands-on activities. Here Suchoki discusses the important distinction between content delivery and content facilitation, and continues by listing diverse strategies for how instructors can mediate content facilitation in the classroom. This should be valuable reading for instructors generally, but perhaps especially so for instructors hoping to incorporate more active learning in a flipped classroom model.

Further insights into the use of online materials in the on-campus classroom is presented by Canelas and co-workers in Chapter 6. The authors describe their research on how online videos, which were originally created for a series of MOOCs on Coursera, were used to web-enhance an on-campus introductory chemistry course. The chapter begins with a thorough discussion of previous research analyzing educational use of online videos that should be of great interest to anyone interested in this topic. The authors then present their research, which compares two groups of students: one which could freely access videos as supplemental information outside of class and one which could not. The authors studied students' performance and perception of materials by analyzing final exam scores, and quantitative and qualitative course evaluations. As a whole, the chapter presents a compelling example of the type of research needed if we want to understand how the new pedagogical tools afforded by online education can best be leveraged in the classroom.

Chapter 7 and Chapter 8 are both examples of non-traditional chemistry courses. Both chapters also have in common that they describe some of the give-and-take that tends to occur between online and on-campus versions of the same course.

In Chapter 7, Stevens gives a careful account of the development of a medicinal chemistry course that was originally offered at Davidson College and later developed into an online course on the Edx platform. The chapter describes in detail the approach to the developmental phase of the online course production, from team building to key pedagogical decisions. One noteworthy feature of Stevens' course is the inclusion of videos by chemistry professionals such as Novartis scientists, intellectual property attorneys, and executives at biotech companies. This is an example of how the online course format sometimes allows for incorporation of material that can be difficult to arrange in the on-campus classroom. In discussing the online and on-campus iterations of this course, Stevens reviews the successes and challenges in incorporating online materials into the on-campus classroom in a way that should interest anyone attempting to do the same.

In Chapter 8, my colleague, M. Brenner, and I provide another account of the give-and-take that can occur between online and on-campus versions of the same course. Our course is a general education course at Harvard that aims to teach chemistry and physics using food and cooking. In the chapter, we describe the course development process as it occurred over two online and two on-campus course iterations. This includes an account of some noteworthy advantages of the online format. It also includes a discussion of how we overcame certain limitations of the on-campus course by incorporating material from the online course. We back up our discussion with empirical data, collected from student evaluations and focus groups, showing which aspects of the course were deemed more or less helpful to students' learning experience. Like Chapter 6, this chapter should be of interest to other instructors hoping to use materials from online courses in the on-campus classroom.

Finally, in Chapter 9, York and colleagues report on their work developing an Academic Social Network as a way to address challenges in their large general chemistry course at Rutgers, which enrolls over 2,000 students. The Academic

Social Network integrates problem template engines and a critical skills network with a virtual classroom environment that can be used either privately between students or as formal discussion sections led by an instructor. These components are also connected to a social networking system that allows students to contact and receive help at any time of day from one of their peers who, according to the completed online assignments, are at their level of content mastery or above. As a whole, the network thus leverages large enrollments to offer “on-demand peer mentoring and delivery of custom instruction”. This type of online instructional technology has the potential of improving student learning in a wide range of large enrollment chemistry courses, whether offered online or on-campus.