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Editorial

Looking to the Future of Analytical Chemistry Education: A New Resource to Help Instructors

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When faced with the task of constructing a syllabus for an analytical chemistry course, we suspect that most instructors begin by identifying a list of content areas they intend to cover. A content-coverage model characterizes the courses we ourselves took in college and is the format of textbooks that are usually the primary supporting resource for most courses. While we do not intend to dismiss the relevancy of content areas, there are issues with an approach that is primarily focused on content areas in analytical chemistry. Modern analytical chemistry is an interdisciplinary effort in molecular measurements that is continually inventing new techniques, refining established ones, and seeking out new applications. As a result, it is impossible to cover all the topics that might be considered relevant in the typical number of courses required for an undergraduate or even a graduate degree. One of us (M.L.K.) recently coordinated a survey of the analytical chemistry curriculum for the Analytical Division of the American Chemical Society (ACS). In their responses, many analytical chemistry instructors indicated that they struggle to decide what topics to include in their courses, due to the limited time available for a large number of topics and the ever-changing landscape of measurement science as techniques develop. Indeed, we can personally relate to this challenge. Fused silica capillary columns and liquid chromatographic bonded phases are just two examples of developments that have occurred since the oldest one of us (T.J.W.) completed an undergraduate degree in the mid-1970s. Numerous advances in bioanalytical methods and nanoscience have occurred since the youngest of us (M.L.K.) completed her degrees in the mid-2000s. Thus, scientists who rely on analytical chemistry and measurement science must stay abreast of continuing advances in the field, and instructors must make thoughtful choices about what content to prioritize in their courses.

An alternative to the broad content-coverage model is to design analytical courses that provide depth in selected areas while at the same time developing the skills students need to be successful in undertaking analytical science. The ACS Guidelines for the certified undergraduate degree provide a useful list of process skills that students need in chemistry careers.[1] These include competence in use of the chemical literature, written and oral communication, teamwork, ethical decision-making, and problem-solving. Competence in problem-solving is further defined as having the following abilities: clearly define problems, develop testable hypotheses, design and execute experiments, analyze data using appropriate statistical methods, understand uncertainties in experimental methods, and draw appropriate conclusions. Mastery of these skills ensures that students are equipped to learn independently about new techniques, and even propose their own advances, regardless of the specific course content covered during their formal education. However, courses that include meaningful development of these skills will have a different structure from conventional analytical chemistry classroom and laboratory experiences. Classroom lectures are reduced significantly and replaced with small-group or other activities that engage students in the material being covered. Students are given more decision-making authority in the design and execution of laboratory experiments, which typically involve multiweek projects completed by small teams. In addition to promoting skills development, these evidence-based or active learning approaches have also been shown to enhance student achievement on the content areas that are still key to the course.[2−12] Finally, if well facilitated, active learning has the potential to create a more inclusive course environment where all students feel valued.[13−21]

The success of active learning is dependent on the quality of the exercises as well as the effectiveness of facilitation by the instructor. The need for suitable exercises and knowledge of how to effectively facilitate them have been barriers to the implementation of active learning in many fields.[22,23] Within analytical chemistry, there has been a sustained effort to remove these barriers through a 20+ year, NSF-supported collaboration of faculty. We recently edited a book titled *Active Learning in the Analytical Chemistry Curriculum* that collects the expertise and curricular innovations of many of these faculty.[24] Composed of 16 chapters with 39 different coauthors, this book will be a helpful resource for instructors wishing to incorporate more skill development and active learning into their courses. Authors represent Ph.D.-granting, 4-year public and private, community college, historically Black, and Hispanic-serving institutions. While all but one of the authors are from institutions in the United States, descriptions of the activities, their facilitation and assessment are applicable worldwide. Many of the exercises described in the book are

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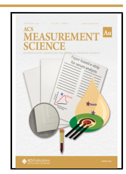

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freely available for instructors and students on the Active Learning site of the Analytical Sciences Digital Library.[25]

The first two chapters discuss prior research that justifies why instructors should use active learning in their courses and provide strategies for getting started in the effective use of active learning. Subsequent chapters describe different strategies for using active learning in the classroom and the laboratory that will be of interest even to faculty experienced in active learning. One chapter focuses on the use of simulations to expand student's facility with analysis methods. Another focuses on the use of active learning in graduate courses. Examples of assessment strategies are presented throughout the book, and analytical chemistry instructors are encouraged to contact authors of the chapters for additional insights into the use and facilitation of their exercises.

We and the other chapter authors value our use of active learning. We get to know students better with this approach, and we are better able to adapt instruction to students' specific needs. Being freed from concerns about whether our courses cover a sufficient breadth of content and seeing our students develop skills that we know will be useful in their future careers makes teaching a more rewarding experience. We hope that members of the measurement science community will find this resource helpful in the education of future generations of analytical scientists.

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Notes

Views expressed in this editorial are those of the authors and not necessarily the views of the ACS.

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