Team Teaching a Mass Spectrometry Course; an Industry-University Collaboration

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Abstract

An advanced mass spectrometry course for upper-level chemistry students is described. This course was a team-teaching collaboration between a full-time faculty member and a full-time industrial chemist. The course included traditional lecture, review of papers from the literature, and a field trip to an industry site. This model for an industry-university collaboration provides an opportunity for both scientists to introduce problems common to both academia and the business world in a classroom setting.

Introduction

Team teaching can be an excellent opportunity for faculty members to learn from one another, build upon each others' strengths, and enliven the classroom all to the benefit of students who enroll in the course. When that team teaching involves a non-faculty member, in this case an expert from industry, both the faculty member and the industrial chemist can engage with challenges that face the scientific community as a whole, and this prospect brings a different dynamic to the dialog. Herein, we describe an upper-level (juniors and seniors) course in mass spectrometry offered through the Chemistry Department at Butler University in the fall of 2010.

Background

Butler University is located in Indianapolis, IN five miles from downtown. Butler is a Master's comprehensive university enrolling just over 4000 undergraduate students across our six academic colleges. The ACS certified Chemistry Department offers only undergraduate degrees to approximately 45-50 graduates per year. The fifteen full-time faculty members engage in undergraduate research with students, and a spirit of inquiry is infused throughout the curriculum. Faculty members collaborate extensively in research and teaching efforts, resulting in a department where teamwork is the norm for problem-solving in the laboratory and the classroom.

The location of the University in an urban area allows for students to engage in internship opportunities, especially in science-rich Indianapolis. Butler students are routinely employed by local industry including Roche Diagnostics, AIT Laboratories, Eli Lilly & Co. and Dow AgroSciences. This has fostered strong relationships and partnerships with these industrial contacts, especially with Dow AgroSciences. Students are able to secure academic year and summer internships with these industrial partners, and demand for Butler students has grown.

Dow AgroSciences, a wholly owned subsidiary of The Dow Chemical Company, began in 1989 as DowElanco, a joint venture between the plant sciences businesses of The Dow Chemical Company and Eli Lilly and Company. In 1997, DowElanco was renamed Dow AgroSciences (DAS) when Dow acquired 100 percent ownership of the business from Lilly. The products and services that DAS designs solve customers' pressing crop production problems, and boost agricultural productivity to maximum sustainable levels to keep pace with the growing needs of the world's rapidly expanding population. The research focus of DAS is on game changing technologies to provide better crops, better plant nutrition and better control of destructive crop and non-crop weed and insect pests. DAS has hired no less than ten Butler graduates in the past ten years.

In the late 1990's, an industrial chemist (Gilbert) inquired about evening, adjunct opportunities at Butler, as he had previous positive teaching experiences elsewhere. Butler students had expressed an interest a special topics course on spectroscopy. A new faculty member (Wilson) trained as an organic chemist agreed to teach an advanced course so long as it was not a solo preparation. So, in 1997, an upper-level organic spectroscopy course was offered at Butler team taught by Wilson and Gilbert. Wilson covered the spectroscopy topics of infrared and nuclear magnetic resonance and Gilbert covered mass spectrometry. This course was compartmentalized where each instructor taught his or her expertise, and while there was collaboration, it was limited in scope. A few years later, Gilbert was the solo instructor for a course that focused exclusively on mass spectrometry. While Wilson and Gilbert continued professional contact, it took more than a decade for the two to return to the classroom together.

Rationale for the Course

In the intervening years, the curriculum at Butler University had undergone a significant transformation. Upper level laboratories in the curriculum became almost exclusively project driven.[1-3] Classrooms from the first year through the fourth year involved a variety of pedagogical styles all aimed at engaging the students with the material.[5-7] The "special topics" course offerings for upper-level chemistry had become very organic chemistry and medicinal chemistry oriented and there was a desire to offer more diversity to this portion of our curriculum. These three-hour topics courses vary in delivery from three 50 minute sessions per week, to two hour and 25 minute sessions per week, to a two and half hour session once a week usually taught in the evening.

Mass spectrometry is taught in both lecture and laboratory in the organic chemistry series. Students utilize GC/MS data routinely in the organic laboratories in both semesters for compound identification as well as analysis of reaction mixtures. In the spring semester, a more detailed examination of mass spectrometry takes place in the organic lecture where molecular ion peak cluster characteristics, fragmentation patterns, and stable ions are discussed. The introductory analytical chemistry series utilizes GC/MS and LC/MS for both introductory instructor-designed laboratories and project-based laboratories designed by students. Detailed discussion of the components of mass spectrometers is only offered in an advanced instrumental lecture course which is offered once annually, and the mass spectrometry portion of this course is a week or two long.

Given the recent advancements in mass spectrometry,[8-11] as well as the ease of finding current topics involving mass spectrometry in the popular and scientific press,[12-17] an upper-level course devoted to mass spectrometry was a logical addition to the curriculum. Wilson approached Gilbert about team-teaching a course entirely devoted to his area of expertise with a focus on application. While not trained as an analytical chemist, Wilson would contribute knowledge of current student preparation and her genuine interest in the area. Gilbert would bring his expertise to the fore, as well has his enthusiasm for the subject matter at hand. The course was slated for the fall of 2010, and seven students enrolled with one additional student auditing the course.

Structure of the Course

The thirteen-week course was structured similarly to other upper-level courses in the Butler Chemistry curriculum. This included traditional lectures, discussion and response to literature readings,[13-17] video demonstrations and animations of the instruments,[18] examination of instrument parts on both working instruments in the department and components provided by Gilbert, as well as problem solving at the board. The video demonstrations of instruments were part of promotional materials provided by instrument vendors often available on the vendors' websites. These were an especially popular element of the course.

All of the lecture materials (presentation slides, links to websites, literature articles, etc.) were posted on our course website. Prior to lectures, both Gilbert and Wilson posted slides, literature papers, and other links on the website. As the lecture material evolved over the semester, students found it was helpful to have access to previous presentations in order to prepare for quizzes and exams as well as in the preparation of their final projects. Approximately half of the course was dedicated to each portion of the instrumentation such as pumps, sample introduction, ionization techniques, detectors, etc. The application of each piece of the instrument to various laboratory circumstances was highlighted. Gilbert was primarily responsible for leading discussion on instrumentation details including examples of how MS is used in the agrochemical industry (testing for metabolites, mapping chemical contamination, etc.). Applications of mass spectrometry in the popular literature (the Contador clenbuterol case was in the news at the time as was the Gulf of Mexico oil spill), evaluation of fragmentation patterns of organic molecules, guidance for in-class presentations, and day-to-day matters of the course were the responsibility of Wilson.

As an example of one of the topics, low resolution ESI/MS, MALDI/MS and high resolution (Orbitrap) ESI/MS were specifically compared in the area of protein analysis. Our lecture materials were adapted from the presentation found at the following link: http://biomed.umit.at/upload/introduction_to_proteomics_part_1x.pdf. Our class discussion was toward the middle of the semester after most of the instrumentation had been described. The lecture material includes a discussion of identification by the intact protein, protein fragments, and protein digests. The use of web-based search engines for protein identification from fragment sequences determined by these MS techniques was presented but not demonstrated.

Students were evaluated in the course through frequent quizzes, exams (a mid-term and a final), a paper and presentation on the paper topic. The weekly quizzes kept the students on-task and up-to-date on the material presented in the course. The exams were both short answer testing on specific instrument components and based on real problems presented from the literature. Students were asked to make decisions about best component choices as well as evaluate questions such as "is this the best configuration to gather the data needed to address this problem?" The exams and quizzes were prepared and graded by both faculty members with final grades assigned by consensus between the two instructors.

Lastly, the research paper and presentation allowed the student to look at an area of mass spectrometry more deeply and share that knowledge with the class. The research paper either focused on a literature article or an instrumental component. All of the papers required multiple original literature references (no Wikipedia citations). The in-class presentation was 20-25 minutes. Each student either described the new component and the data that could be obtained with this component in an instrument or described question that was posed and answered in the literature article and how MS instrumentation was used to obtain the data. For example, one of the students chose to evaluate a few recent papers using atmospheric ionization from R. Graham Cooks' research efforts. Both instructors evaluated the papers and the in-class presentation of those papers.

A final structural element of the course was a field trip to DAS. There, Gilbert enlisted the assistance of two colleagues in order to provide three "instrument stations" where students collected data. As part of the field trip, students were presented with hypothetical problems that could be solved using modern mass spectrometry approaches, and the students performed hands-on analysis to answer the questions posed. For example, a combination of LC/MS and MALDI-TOF analysis was utilized to identify a protein. In a second station, surface desorption techniques, including 'paperspray',[19] were used to study the source of a hypothetical chemical contamination.

Student Response

Student response to this course was overwhelmingly positive. The in-class videos (especially videos detailing MS-MS and Orbitrap) and the field trip to DAS were clear class favorites. In addition, students enjoyed working on their literature research project. Many of them were able to explore areas focused on his or her interest (we had engineers as well as chemistry majors in the course). Students also enjoyed hearing about the topics that others had chosen during the in-class presentations and generally asked good questions of one another.

Students would have preferred to cover fewer "lecture" topics and engage in more literature-based analysis. Several of the students found the text too intellectually dense (*Fundamentals of Contemporary Mass Spectrometry* by Chhabil Dass[20]), but they did acknowledge that it was an excellent resource. Lastly, while the quizzes were not a popular item for the students, they grudgingly admitted that the quizzes served their intended purpose. Students rarely got behind in the course and were more prepared to participate in class discussion.

In addition, this course appears to have been helpful for those students going on to graduate school. A portion or most of the material covered in our course was also covered in graduate courses taken by several of the students in the course. This is especially noteworthy as none of the students are in graduate programs to study analytical chemistry or mass spectrometry, yet the utility of this course reaches across several other sub-disciplines of chemistry.

Faculty Reflection

Without hesitation, Wilson and Gilbert would teach this course again, schedules permitting. Most of the elements of the course would be maintained, including the quizzes and exams, the papers and presentations, and the field trip to DAS. In addition, the videos and animations of the instruments will also be retained, updating them to models currently available on the market. The suggestion by the students to include more literature-based examples, especially from the popular press, is a good one. Additional real world examples could provide the platform to discuss specific instrument components in the context of an actual scientific challenge, although this will require more work and preparation on the part of the instructors.

Several key components were required in order to have this collaboration be successful. First, it was helpful that the two instructors had a previous professional relationship with one another. There was no awkwardness as the instructors "got to know each other" in the classroom. The previous experience of teaching a more compartmentalized course allowed each instructor to know the other well enough to play to each person's strengths. It also allowed for a fair division of labor at the outset with each of the instructors understanding his and her duties and responsibilities.

Second, it was crucial that each of faculty member felt comfortable saying “we don’t need to include that” or “this topic is not right for this group of students” and “I didn’t do a very good job with that topic” to each other. This is true for exam and quiz writing, a sensitive area for many faculty members, and especially true for the grading of those quizzes and exams. Team teaching a course exposes the co-instructors to each others’ teaching weaknesses, and it is important to enter the team-teaching relationship without judgment.

Third, absolute trust in the other faculty member was essential. Several (three) occasions arose where one or the other faculty member took sole responsibility for the delivery of material in the course for that week. Most of the other in-class experiences were far more collaborative between the two instructors. However, the knowledge that the co-instructor could step in at any time, and do an excellent job, gave each faculty member the peace of mind to be elsewhere when required.

Finally, by combining the experience and resources provided through this academic/industry collaboration, the students gained access to a breath of real-world applications and technologies that would normally unavailable in an undergraduate setting. As the students were introduced to the types and applications of each of the mass spectrometers presented, the lectures included examples from the actual development of novel chemistries. For example, in the LC/MS section, several ionization techniques were introduced including both electrospray (ESI) and atmospheric pressure ionization (APCI). The design of each source was covered in detail, along with the mechanism of ionization, and the advantages/disadvantages of each. To bring these differences to light, Gilbert presented examples including the identification of metabolites of the natural insecticide Spinosad. In one example, the glutathione conjugate of spinosad, ESI produced a molecular ion, whereas no molecular ion was observed using APCI due thermal degradation. The ability of the industry contributor to provide these types of real world industrial examples, in addition to facility tours and in-class handling of actual instrument components, served to strengthen the overall quality of the course.

Conclusions

A team-taught mass spectrometry course with full-time faculty member and industrial chemist instructors has been described. This model of collaborative instruction works well for an upper-level topic course. Leveraging the current instrument knowledge of the industrial partner and the curiosity of the faculty member, a unique academic experience for a small group of students was created.

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