Forensics as a Gateway: Promoting Undergraduate Interest in Science and Graduate Student Professional Development through a First-Year Seminar Course

Louise K. Charkoudian,* Jared J. Heymann, Marc J. Adler, Kathryn L. Haas, Kassy A. Mies, and James F. Bonk

Department of Chemistry, Duke University, Durham, NC 27708-0346; **louise.charkoudian@duke.edu*

At many colleges and universities, teaching experience ranks as one of the most important criteria in selecting faculty candidates *(1)*. Despite the clear demand for faculty candidates to possess strong training in education, most graduate programs in chemistry lack formal pedagogical instruction *(2)*. The prevalence and adequacy of programs in existence have been questioned in this *Journal (3)*, and a recent national survey reports only 43% of students in the life sciences believe their doctoral program suitably prepares them for a career in academia *(4)*. This lack of development during graduate school often leaves young faculty ill-prepared to face the challenges of the classroom. While many doctoral programs offer formal training for teaching assistantships, this position often affords little opportunity for professional development as they are performed under the constraints of predetermined course content and supervision of the lecturing professor. One of the most daunting tasks facing new faculty is the development of a new class, from conception to writing lectures and student evaluation *(5)*. With the mentorship of a professor, five graduate students created their own opportunity for pedagogical training by designing and teaching an undergraduate course on forensics and its underlying scientific principles.

The application of forensic science to the classroom, specifically within the context of chemistry, has long been recognized for its value in advanced courses and developing alternate careers in science *(6–8)*. Forensics has recently undergone a renaissance of interest based on popular media, resulting in a flurry of presentations at national meetings *(9–14)*, but has not been specifically addressed by this *Journal* outside of individual activities for nearly two decades *(7, 8, 15–17)*. Herein, we report the development and execution of a team-taught, first-year undergraduate seminar course in forensic chemistry.

Graduate Course Development

The development of the course was a two-semester project during which the graduate students met weekly with the faculty mentor (Figure 1). The team's first task was to select a course topic based primarily in science that would be exciting to both students and teachers, yet capable of being taught to students who have a limited background in chemistry. Several socially relevant and interesting topics in chemistry were evaluated before the topic of chemistry in forensics was selected. It was hoped that the pop-cultural appeal of forensics would spark

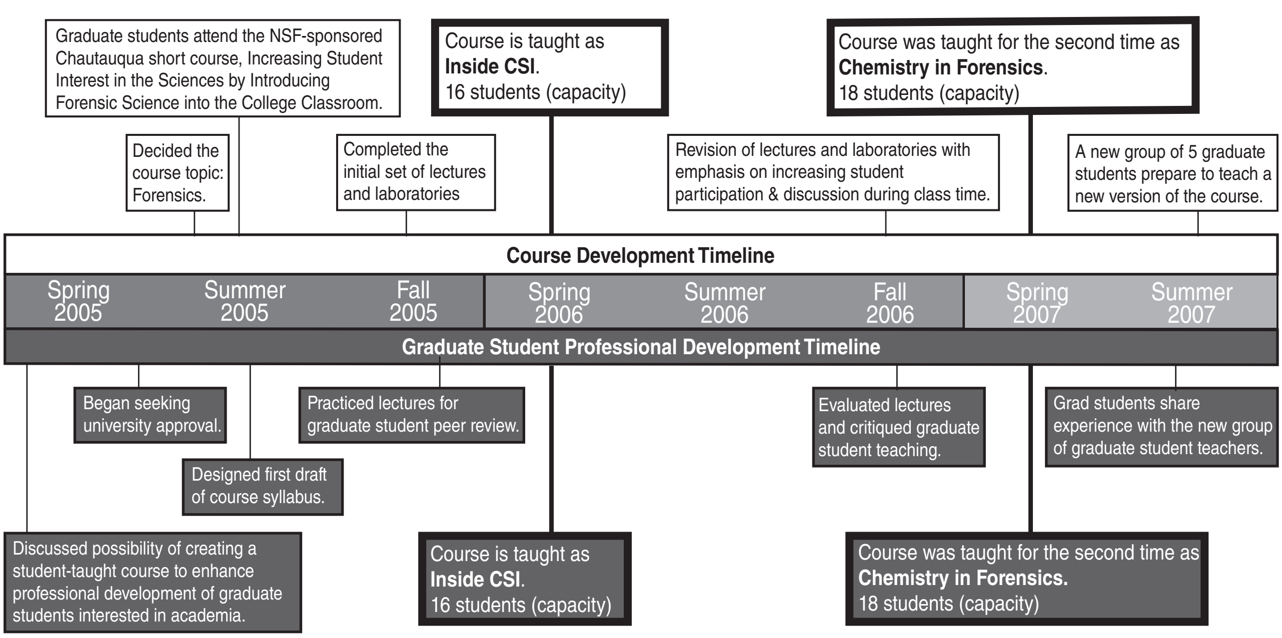

Figure 1. Timeline for the development and execution of Chemistry in Forensics.

List 1. Course Development Outline

First Semester Goals and Assignments
Break course topic into subtopics
Begin development of individual lectures and laboratory
Create a course outline
Develop course syllabus
Define student presentation component
Develop final project
Second Semester Goals and Assignments
Peer review lectures and laboratory experiments
Finalize final project content and assignment
Create mid-semester and end-of-semester evaluation forms

interest, making this course an effective vehicle to introduce the scientific method to a greater number of college students and increase undergraduate enrollment in the sciences.

After selecting the course topic, the graduate students attended the NSF sponsored Chautauqua short course, Increasing Student Interest in the Sciences by Introducing Forensic Science into the College Classroom *(18),* for an introduction to the topic and the opportunity to discuss with other educators how forensics is being taught in the college classroom. In addition to discussions with peer educators, this short course allowed opportunity for communication with experts in the field, providing a foundation and realistic insight into the topic of forensics.

In the first semester of course development the graduate students began designing the undergraduate course, Chemistry in Forensics, using this time to establish the content and structure. To increase the appeal of this new course for undergraduates, it was designed to fulfill a series of student course requirements within the university curriculum: natural science (NS), freshmen seminar (FS), and science, technology, and society (STS).[1] The scientific content of the course inherently qualified it for NS classification. To fulfill the FS requirement, the course was designed to ensure active participation of students by including class discussions, student presentations, and a hands-on mock criminal investigation. The lecture portion of the course integrated the fundamental scientific principles governing forensics (science) with the techniques used in crime scene analysis (technology), while observing the dynamic relationship between forensics and society (society).

The remainder of this first semester of course development was dedicated to establishing detailed course content (List 1). The core concepts of forensic science were divided into five subtopics: criminalistics, physical evaluation of evidence, inorganic chemistry, organic chemistry, and biochemistry. Each graduate student was responsible for developing detailed lectures and in-class activities for one specific section. Two forensics texts and one corresponding laboratory manual were valuable resources during lecture preparation *(19–21).* After the course content of each subtopic was determined, the team finalized the course outline and syllabus. The mock criminal investigation was based on material from an interactive forensic Web site *(22).*

The second semester of course development was dedicated primarily to peer revision of course content. Each graduate student presented a lecture to the other four graduate students and the faculty mentor for evaluation of the content, format, organization, and delivery. Informal feedback from the five-member audience was used to improve the lectures and laboratories. The team-teaching approach allowed for a unique opportunity in which the graduate students received a wealth of constructive criticism on their own lectures and were able to observe and critically evaluate their peers.

With regard to the formalization of this program, the time dedicated to course development was performed under the label of graduate course, Introduction to Professional Development: Teaching College Chemistry. Therefore, the students were not compensated financially for course development, but rather received transcript recognition. The actual teaching of the course was departmentally funded through two teaching assistantships, which were divided across the five graduate students. This compensation was provided primarily to support the advisors of each graduate student for their time spent outside of the laboratory and was supplemented with additional teaching or research appointments. Within the context of continuing high productivity in laboratory research during the semester in which the undergraduate course was taught, all graduate students were not required to attend each lecture. Despite the division of course instruction, the graduate students voluntarily attended each lecture to offer direct classroom feedback of individual lectures, while maintaining a united front and enhanced involvement with the undergraduates. The research advisors of the graduate students unanimously approved of this professional development program and continue to enthusiastically endorse the current and future involvement of their graduate students in this pedagogical training series.

Undergraduate Course Implementation

Outline

Chemistry in Forensics was offered in the spring semesters of 2006 and 2007 as a first-year seminar fulfilling the FS, NS, and STS requirements of this university. Prerequisites for the course were one semester of college chemistry, one year of high school chemistry, or the equivalent. Enrollment was limited to 16 and 18 students in 2006 and 2007, respectively, to promote active participation. Course goals were for students to be able to

- Define, explain, and correctly use common terms and concepts to describe crime scene analysis and forensic chemistry techniques
- Recognize fundamental chemical concepts and terminologies
- Locate primary literature on forensic chemistry
- Present a topic in forensic science addressing science, technology, and society components
- Collect evidence from a crime scene, use basic chemical techniques to examine the evidence in the laboratory and write a logical and coherent report on his or her analysis of the crime scene

To meet these objectives, a variety of teaching techniques were employed including lectures, demonstrations, discussions,

Table 1. Chemistry in Forensics Outline

Topic/Activity	Content of Each Class Period
Criminalistics	1. Evaluating the crime scene 2. Inside the crime laboratory 3. CSI effect 4. Lab: Searching Forensic Literature
Physical Evaluation of Evidence	5. Fingerprints and impressions 6. Comparison of physical evidence 7. Blood stain pattern analysis and firearms 8. Case study: Evidence and Deductive Reasoning
Inorganic Chemistry in Forensic Science	9. Periodic table 10. Spectroscopy and radiation 11. Chemical reactions 12. Lab: Metal Residue Testing
Organic Chemistry in Forensic Science	13. Introduction to organic chemistry 14. Analytical techniques 15. Drugs and toxicology 16. Lab: Identification of an Unknown White Powder
Biochemistry in Forensic Science	17. Hair and forensic entomology 18. Forensic serology 19. DNA 20. Case study: Biological Evidence and the O. J. Simpson Trial
Student Presentations	21–25. Student-selected presentation topics
Mock Criminal Investigation	26. Background of case and request evidence 27. Laboratory analysis of evidence 28. Final investigation and analysis

Note: The course was divided into 28 75-minute periods. The course and detailed information about course content, in-class activities, and homework assignments can be found in the online supplement.

student presentations, laboratories, visiting speakers, and case studies.

The course was organized in a progressive manner (Table 1). Students gained an understanding of the fundamentals of forensic science through lectures and then applied that knowledge to create a presentation on a novel topic in forensics. The course concluded with a mock criminal investigation, which allowed the students to apply the knowledge they obtained throughout the semester.

Graduate Student Lectures

The first four classes introduced criminalistics, Locard's exchange principle, proper practices in evidence collection, forensic laboratory techniques, and forensic evidence analysis. These lectures also focused on the importance of probability determination in analysis of forensic evidence and the difference between individual and class characteristics *(20)*. After the fundamental principles of criminalistics were presented, the jury foreman of a local murder trial shared his experience in working with a team of jurors to analyze forensic evidence to determine a first-degree versus second-degree murder verdict. This was followed by an in-class debate on the CSI effect, which provided the students with an opportunity to discuss and critically evaluate the influence of forensic television on the criminal justice system *(23, 24)*. In the final criminalistics lecture, students were introduced to methods of searching primary literature for scientific and legal information pertaining to criminalistics.

The next portion of the course covered the physical evaluation of evidence including analysis of firearms, gunshot residue, blood spatter, fingerprints, hair, and fibers. While not obviously chemical in nature, these topics form the foundation of stereotypical forensic investigation in popular culture and were therefore addressed with an emphasis on the scientific basis of these techniques. Blood spatter was studied through an in-class demonstration that illustrated the effect of velocity and angle on stain patterns. The forensic analysis of hair and fibers was presented in-depth such that the relationship between chemical composition and structure was introduced. Students learned fingerprint analysis by lifting latent prints for comparison and identification. The physical evaluation lectures concluded with a document-based interactive case study where students learned to discriminate deductive reasoning from speculation. In this activity, inconclusive evidence was provided to force students to confront uncertainty, a concept that many are uncomfortable with, yet is frequently encountered in criminal investigations *(25)*. This class ended with a discussion on the danger of speculation in forensic science and the importance of maintaining objectivity in the analysis of scientific data.

Objectivity in the analysis of evidence requires an understanding of the additional scientific principles and techniques utilized in forensics. Thus, during the remaining lectures, a large amount of time was dedicated to teaching the basics of inorganic, organic, and biological chemistry, with an emphasis on forensic applications. Although many of the key scientific concepts were presented to the students in lecture form, frequent in-class activities and demonstrations[2] were employed to appeal to different learning styles, initiate scientific inquiry, and spark student enthusiasm.

The inorganic chemistry subsection focused on the topics of elemental analysis and spectroscopy as applied to forensics. The initial lecture provided a foundation of the chemical concepts of atomic structure, differentiating elements, the periodic table, and electromagnetic radiation. Atomic absorption and emission spectroscopy were introduced through an interactive demonstration on the concepts of absorbance and transmission. Nuclear decay and radiation were also presented, including a case study involving the Litvinenko assassination *(26, 27)*. Lastly, metals were introduced with a lecture on crystallography, redox behavior, and chemical reactivity. These topics carried into the laboratory, where students performed an experiment on metal residue testing *(21)*.

The fourth subsection covered the role of organic chemistry in forensics. After defining the field as the study of carbon-containing compounds and establishing their biological importance, the first lecture period was spent explaining shorthand drawing rules, presenting the concept of stereochemistry, and demonstrating the principle of solubility. The second lecture began with a class discussion on several recent, socially relevant articles highlighting the importance of using analytical techniques for identification of organic molecules in a forensic setting *(28–32)*. The theories and applications of specific analytical techniques were then presented including chromatography, mass spec-

List 2. Elected Student Presentation Topics

- Biological fluids (DNA, paternity testing)
- Disputed Documents and Image Enhancement
- Forensic Anthropology and Odontology
- Forensic Entomology
- Forensic Psychiatry (Profiling)
- Polygraph and Voice Print Analysis
- Poisons
- Steroids
- Terrorism–Anti-terrorism

Table 2. Evidence Requested and Laboratory Experiments Performed

Evidence	Laboratory Experiment
Stain on rug	Kastle–Meyer test and FTIR analysis
White powder found in bag	Thin-layer chromatography and gas chromatography
Trace evidence (hair)	Comparison of hair fibers found at crime scene to standard hair samples of pertinent individuals
Fingerprints at crime scene	Comparison of latent prints at crime scene to the standard prints of pertinent individuals
Deceased state at time of death	Determination of blood alcohol content by UV–vis spectrophotometry

Table 3. Data from End-of-Semester Evaluations

Questions	Average	
	2006	2007
Quality of this course	4.63 (0.62)	4.67 (0.49)
Quality of the instruction	4.54 (0.64)	4.64 (0.51)
Intellectual stimulation	3.93 (0.96)	4.17 (0.71)
Participation in class discussion was encouraged.	4.06 (1.12)	4.56 (0.79)
Gaining factual knowledge	4.25 (0.77)	4.76 (0.46)
Understanding fundamental concepts and principles	4.07 (0.89)	4.41 (0.62)
Learning to apply knowledge, concepts, principles, or theories to a specific situation or problem	4.67 (0.62)	4.47 (0.51)
Learning to analyze ideas, arguments, and points of view	4.46 (0.78)	4.53 (0.63)
Learning to synthesize and integrate knowledge	4.06 (1.06)	4.44 (0.51)
Learning to conduct inquiry through methods of the field	4.69 (0.60)	4.75 (0.45)
Learning to evaluate the merits of ideas and comparing claims	4.08 (0.86)	4.63 (0.62)
Developing skills in oral expression	3.60 (1.12)	4.41 (0.81)
Developing writing skills	3.31 (0.85)	4.06 (1.00)

NOTE: Students ranked each question on a scale to 1–5, where 1 is poor and 5 is excellent. Sample size was n = 16 and 18 in 2006 and 2007, respectively. Standard deviations for each value are indicated in parentheses.

trometry, nuclear magnetic resonance, and spectrophotometry. Pharmacology and toxicology were the subjects of the third class period, which covered basic pharmacokinetics, structures of many common drugs, blood alcohol level calculation, and drug testing. In the final meeting of the organic chemistry subsection, students used thin-layer chromatography to determine the component(s) of an unknown white powder by comparison to known samples.

The final series of lectures introduced the concepts and techniques critical to the analysis of biological evidence. Students learned to identify various biological fluids based on serological properties. An in-class activity allowed students to visualize trace quantities of blood using the iron-induced fluorescence of luminol. In addition, the principles of heredity and genetics were presented to demonstrate how a biological sample can be associated with an individual or group of individuals. This section of the course concluded with the exploration of a case study in which the class examined forensic evidence and expert testimony from the 1995 O. J. Simpson trial. This activity illustrated how the same physical evidence may be presented differently to support opposing perspectives and influence a jury.

Student Presentations

Students selected group presentation topics based on a list generated from an in-class discussion (List 2). Groups, each composed of three students, were responsible for preparing and presenting a 45-minute lecture covering the science, technology, and societal impact of their selected topic. Each group was mentored by one of the graduate student instructors who guided the students in content selection and provided suggestions on organization, format, and delivery of the presentation. This structure allowed for increased personal attention as the students acquired the necessary skills of reading, understanding, and communicating scientific information.

Mock Criminal Investigation

In the final section of Chemistry in Forensics, students applied the ideas and techniques learned throughout the semester to a final case study. During these three class periods, students investigated a mock crime, taking on the roles of detectives, laboratory technicians, and finally competent prosecuting attorneys.

On the first day, students were divided into groups, briefed on the crime, and provided with interview transcripts and inventory of evidence derived from a previously published fictional case study *(22).* The students then assumed the role of detectives by requesting additional interviews and developing a list of evidence to be evaluated. In the second class period, the students served as forensic technicians, working in the laboratory to analyze evidence discovered earlier in the investigation (Table 2). The students spent the final day completing their investigation and developing a prosecution based on the interview transcripts and their experimental results. As their final, each student presented the case analysis independently in the form of an 8–10 page paper.[2]

Assessment

Assessments of the graduate students were provided by the faculty mentor.[3] He or she attended all meetings of the graduate students throughout the development of the course and all class meetings throughout course execution and offered informal assessments continuously throughout the entire process. The course supervisor also provided formal assessments that appear on the official transcripts of the graduate students as CHEM 379, Special Topics in Professional Development: Teaching College Chemistry.

The undergraduate students provided additional assessment of the graduate students. On the last day of class, students filled out anonymous course evaluations (Table 3).[4] Overall, students found the class to be informative and enjoyable. One student stated that, "I never really enjoyed science, but I really loved coming to class and applying what I learned to real situations." Another student, currently enrolled in organic chemistry, commented, "The introduction to chemical topics received in Chemistry in Forensics has helped [me] grasp challenging concepts in chemistry more effectively than [my] peers who were seeing the material for the first time." This remark suggests that the conscious decision of the graduate students to cover a breadth of chemical topics in their lectures was useful to students pursuing advanced studies in chemistry.

Through the course evaluations, students also provided enthusiastic feedback on the variety of teaching techniques. Students commented that "[it was] a good idea for the class to be taught by multiple graduate students—it kept the class refreshing and dynamic", "the demonstrations, presentations and crime scene effectively increased class participation", and "the final project brought together everything we learned". It is noteworthy that 14 of the 16 students from the 2006 class continued to study physical and applied sciences in their second-year. Although is difficult to determine the precise influence that Chemistry in Forensics had on the students' decision to continue in the sciences, we believe that presenting chemistry to first-year students in a course designed for students of all academic inclinations encouraged students to enroll in more science courses throughout their education at this university. In fact, unsolicited communications with former students (one science major and one non-science major, respectively) revealed that the course "confirmed [her] interest to pursue science", and that "if another course like Chemistry in Forensics was offered again, [she] would definitively enroll." The continued enrollment, along with the fact that 100% of the 2006 and 2007 students said that they would recommend the course to their peers, suggests that this seminar course shows promise for increasing student interest in the sciences.

The graduate student instructors found the design and execution of Chemistry in Forensics to be invaluable to their professional development. By creating a course from scratch, these students were able to have a complete teaching experience, that prepared them for challenges they may encounter as young faculty. Teaching the course for a second semester allowed them to experience the challenging and educational process of course revision. The team aspect of the course development was particularly useful, as they received a wealth of feedback from multiple evaluators, gained peer assessment experience, and learned to compromise. The sharing of teaching responsibilities was also efficient, as it gave the graduate students time to work on their research. This experience has already benefited four of the five graduate students, with one receiving an endowed assistant professorship at a small liberal arts college, two students accepting post-doctoral positions, and one receiving several offers of tenure track faculty positions at small liberal arts institutions. The final graduate student expects to pursue faculty opportunities upon graduating. The course development and classroom experiences of this program have been extremely valuable in these job searches, and have been discussed extensively during interviews, demonstrating the interests of this program to undergraduate-focused colleges. As a result of this program, all five students continue their pursuit of careers in academia, and feel that this program was invaluable for their preparation for the responsibilities of a young faculty member.

The success of this project has resulted in the addition of CHEM 379, Special Topics in Professional Development: Teaching College Chemistry to this university's graduate school curriculum. This class, now offered every two years, provides each new team of graduate student instructors an opportunity to design and teach a novel course of their choosing. The next group of students selected The Chemistry of Art and Archaeology for their development topic and plans to offer this new course during the spring semester of 2008. The forensics seminar has been transferred to an instructional faculty member who plans to further utilize the lectures and activities developed here in future offerings.

Conclusions

Chemistry in Forensics was a valuable experience for the graduate student instructors, the first-year undergraduates, and the Department of Chemistry. Student evaluations suggested that the content and instruction were of high quality and that the pedagogical techniques employed were successful in achieving the stated learning objectives. Graduate students found the course development and execution to be an invaluable teaching experience based on their opportunities generated for further pursuit of academic careers and their preparedness to perform in their positions. This approach is recommended to other universities looking to expand the breadth of pedagogical training for graduate students while simultaneously increasing undergraduate course offerings and enrollment in the sciences.

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Notes

1. Natural science (NS) is assigned to any course in the area of biological, physical, and environmental science; Freshmen seminar (FS) is assigned to any course that provides a discussion-based classroom experience to undergraduate freshmen, limiting class size to typically 15 students to ensure active participation; Science, technology, and society (STS) is assigned to courses that allow students to confront scientific and technological issues, providing a topical basis to not only explore how science and technology have affected societal development, but also how the needs of society have influenced scientific and technological development.

2. Details about the in-class activities, demonstrations, and laboratory experiments, along with grading rubrics developed for evaluating group presentations and final projects, can be found in supporting information.

3. For Chemistry in Forensics, Professor James Bonk, a member of the Duke chemistry faculty for 47 years, a teacher of general chemistry for 42 years, and the Director of Undergraduate Studies in Chemistry for 25 years, was the faculty mentor.

4. The assessments used here were prepared by the Duke University Assessment Office.

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