Science and the Courts - a Liberal Studies Module

Overview

What follows is a sketch of a module meant to illustrate how the perspectives of the Humanities and Social Sciences can be brought to bear in teaching the fundamentals of engineering and science[1]. "Fundamentals" are broadly defined, going beyond those proclaimed in a chemistry textbook, to include what is basic in making the results of laboratory tests understood and useful in contexts other than that of the laboratory itself - in this case the context of the courts and the law of the land

The module has as a focus a recent decision of the US Supreme Court in which a citizen of the State of New Mexico was arrested and charged with driving while intoxicated (DWI) on the basis of evidence obtained from the analysis, via gas chromatography, of a blood sample. The individual, a Mr. Bullcoming, petitioned the Supreme Court claiming that the way the evidence was presented in a New Mexico court violated the confrontation clause of the 6th amendment of the Constitution. The Supreme Court agreed. The module addresses the use of laboratory test data as evidence in court; how the law evaluates and weighs evidence of this kind; how it tries to ensure its veracity.

The objective is to develop students' understanding of the sources of authority in engineering and science - including the role of sophisticated instruments in establishing that respect - and to have them reflect on what's required to communicate the meaning and status of engineering and scientific work to "foreigners". At the same time, students will be assigned a laboratory task and experience what it takes to produce "good data". They will learn about the different sources of experimental error and struggle to master the craft technique required to setup and run an experiment. Development of the student's understanding of the import of amendments to the US Constitution is a further objective.

In the next few pages I briefly describe some source materials, most all available online, for student consumption, reflection, and discussion. I then describe, even more briefly, the laboratory exercise - a task a student in a traditional analytical chemistry class might encounter. The final section explores the kinds of questions and issues that might be addressed in order to bring a sense of coherence to these two learning experiences and accomplish the module's objectives.

Resource materials

Many of the resource materials relevant to the module's purpose are available online. The *Federal Evidence Review* posts a resource page on *Bullcoming v. New Mexico* providing links to key briefs and other materials of the Supreme Court case[2]. There are links to the full text of the Supreme

1. I assume the reader is familiar with the examples of modules of similar intent included in my "proposal" titled "Bachelor of Arts in Engineering".
2. http://federalevidence.com/node/1048

Court decision; and links to the Merit Briefs, i.e., the arguments made before the court by the *petitioner,* Mr. Bullcoming*,* and the *respondent*, the State of New Mexico; to Amici Curiae Briefs, i.e., essays in support of one or the other by third parties. The page also shows a link to the record of the state court that found that the presentation of the gas chromatographic data did not violate the confrontation clause of the 6th amendment. Other resources include a brief history of the development of chromatography methods[3], laboratory manuals and "how-to" videos that would help prepare students for the lab work.

The Supreme Court Decision

A good place to start is with a reading of the opinion of the US Supreme Court in the case of *Bullcoming V. New Mexico* as delivered by Justice Ginseburg, writing for the majority[4].

SUPREME COURT OF THE UNITED STATES

Syllabus

BULLCOMING *v.* NEW MEXICO

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> In the case before us, petitioner Donald Bullcoming was arrested on charges of driving while intoxicated (DWI). Principal evidence against Bullcoming was a forensic laboratory report certifying that Bullcoming's blood-alcohol concentration was well above the threshold for aggravated DWI. At trial, the prosecution did not call as a witness the analyst who signed the certification. Instead, the State called another analyst who was familiar with the laboratory's testing procedures, but had neither participated in nor observed the test on Bullcoming's blood sample. The New Mexico Supreme Court determined that, although the blood-alcohol analysis was "testimonial," the Confrontation Clause did not require the certifying analyst's in-court testimony. Instead, New Mexico's high court held, live testimony of another analyst satisfied the constitutional requirements.
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> The question presented is whether the Confrontation Clause permits the prosecution to introduce a forensic laboratory report containing a testimonial certification—made for the purpose of proving a particular fact—through the in-court testimony of a scientist who did not sign the certification or perform or observe the test reported in the certification. *We hold that surrogate testimony of that order does not meet the constitutional requirement*. [emphasis mine] The accused's right is to be confronted with the analyst who made the certification, unless that analyst is unavailable at trial, and the accused had an opportunity, pretrial, to cross-examine that particular scientist.

The arguments of the petitioner and the respondent, in the form of audio files as well as text, are also available on line.

3. For a historical overview: "Solving Crimes with Chromatography", by Joseph Fluegemann; personal communication of Prof. Prausnitz, Professor, Chemical Engineering, University of California, Berkeley.

4. http://federalevidence.com/pdf/Bullcoming/Bullcoming.v.NM.6.23.11.pdf

Amici Curiae

The authors of an *AMICI CURIAE* brief in support of the petitioner, claimed that

> Gas chromatography testing for blood alcohol involves the exercise of judgment and presents a risk of error by the analyst that can be discovered only through cross-examination of the actual analyst who ran the test.[5]

and described how the gas chromatograph can be used to determine blood alcohol content, an explanation based upon two well-known text books.

> GC is a method of separating a complex mixture into its component parts and quantifying them after separation. *See generally* Harold M. McNair & James M. Miller, *Basic Gas Chromatography* (John Wiley and Sons, 2d ed. 2009) David T. Stafford, *Chromatography, in Principles of Forensic Toxicology* 89 (Barry Levine ed., 4th ed. 2003).[6]

To enliven their explanation, the authors offer a "ball analogy". Imagine a pile of different types of balls - tennis, soccer, baseball, a bowling ball - placed at the bottom of a downward-sloping driveway.

> The balls represent each different chemical component in a mixture. You want to find the bowling ball, so you can go bowling later in the afternoon, but you are blindfolded. The bowling ball represents the ethanol in a mixture.

Imagine then a powerful leaf blower blowing the balls up the slope. The different properties of the different balls (and of the driveway) determine which balls rapidly make it to the top, which are retarded.

> Studying all of these many separate physical events that affect the speed at which various balls make it to the top of the driveway would produce a sort of "separation science."...if a person begins by measuring the speed with which a given ball has reached the top, then he or she should be able to extrapolate the ball's unique characteristics, identifying it as a tennis ball, a golf ball, or the sought-after bowling ball[7].

The authors of this brief then go on to explain ".how an analyst might make errors during the GC test that would be unknown by a surrogate analyst testifying at trial." e.g., in preparation of the sample, in loading the machine, in selecting the test parameters, and in the interpretation of the results.

Other briefs were submitted and accepted in support of the respondent - the State of New Mexico[8]. In this we read that "The gas chromatograph is, indeed, a wonderful machine...". The machinery in the State's laboratory is so advanced that it "...eliminates Confrontation Clause concerns".

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5. http://federalevidence.com/pdf/Bullcoming/Bullcoming_Amicus_NACDL.pdf filed by the National Association Of Criminal Defense Lawyers, National College For Dui Defense, and New Mexico Criminal Defense Lawyers Association in Support of Petitioner
6. Harold M. McNair & James M. Miller, *Basic Gas Chromatography* (John Wiley and Sons, 2d ed. 2009); David T. Stafford, *Chromatography, in Principles of Forensic Toxicology* 89 (Barry Levine ed., 4th ed. 2003).
7. This analogy is attributed to Dr. Harold McNair, Ph.D., professor emeritus at Virginia Tech.
8. http://federalevidence.com/pdf/Bullcoming/Bullcoming-Amicus_NM_DepartHealth.pdf

The Confrontation Clause

The Confrontation Clause of the 6th Amendment itself is also available online

> In all criminal prosecutions, the accused shall enjoy the right to a speedy and public trial, by an impartial jury of the State and district wherein the crime shall have been committed, which district shall have been previously ascertained by law, and to be informed of the nature and cause of the accusation; to be confronted with the witnesses against him; to have compulsory process for obtaining witnesses in his favor, and to have the Assistance of Counsel for his defence[9]

The Lab Exercise

The forensic laboratory test performed to determine that Donald Bullcoming's blood-alcohol concentration was "well above the threshold for aggravated DWI" was gas chromatography, one of several chromatographic methods of analytical chemistry for the separation of the components of a material through partition between two phases - one "stationary", the other "mobile". In liquid chromatography, the mobile phase is a liquid - the material in solution. In gas chromatography, the mobile phase is a gas.

A cruder method, and the one to have students engage, is Thin Layer Chromatography (TLC). It too provides a way to identify compounds and determine their purity. But in contrast with gas or liquid chromatography, TLC requires but a minimum of resources and apparatus to do an experiment. (It is also used to determine the proper solvent system for performing separations using liquid chromatography). Careful hand-work is required in preparing test samples, so too the exercise of judgement in the choice of a solvent, development time, and means for revealing the result[10].

Detection and identification of the separated components requires other than strictly chemical knowledge and craftsmenship. The use of ultraviolet light of a certain wavelength is one (non-destructive) method available in TLC for "seeing" the results. A video explaining the method is found at an MIT Open Courseware site.[11]

Discussion

The above is but a rough sketch of activities - online reading, a lab exercise - students would engage. More needs to be said concerning the scope of these activities; their prerequisites; and the kinds of questions that might be made the focus for reflection and discussion (and examination). Along the way I say a bit about who might be responsible for teaching the module.

Scope

The module is meant to bring into play two different worlds - the (object) world of the analytical

9. http://en.wikipedia.org/wiki/Sixth_Amendment_to_the_United_States_Constitution
10. http://ocw.mit.edu/courses/chemistry/5-301-chemistry-laboratory-techniques-january-iap-2004/labs/complete_manual_2004_ac.pdf
11. http://ocw.mit.edu/resources/res-5-0001-digital-lab-techniques-manual-spring-2007/videos/tlc-the-basics/

chemistry lab and the world of law and the courts. Ordinarily, when a student enters the classroom in either domain. the door is closed and walls erected to keep all that is foreign at bay, if not unseen. The advantage is clear: Each subject for learning - each way of life - has its own language, is restricted with regard to the kinds of things and agents allowed to count within the domain. There are bounds too on ways of reasoning, on what qualifies as legitimate argument and established theory. And there are traditional forms and means for testing the student. To attempt to meld two such different worlds is to invite chaos.

When one opens the door, breaks down the walls, many new foci and connections for learning become available. The web is a resource but it's also a bottomless pit. One can imagine a whole semester length course on 'Science and the Courts'[12] But it need not take a whole semester to meet the objectives. Through a judicious choice of original source materials; of the materials, methods and purpose of the laboratory exercise; and prescription of student productions - e.g., lab notebook, essay, annotated bibliography - a week would suffice.

What is clear is that the preparation in any case - whether a full course or a week's work - research will be required to frame the student's efforts. As faculty accustomed to relying on well established and respected textbooks, we generally fail to recognize the effort expended by researchers and teachers over the past few hundred years in synthesizing, summarizing and reducing the variety and numerous developments in theory and in application, within any particular engineering domain, down to the apparently unified, coherent and well ordered collection of concepts, principles and methods - as well as exemplary problems - that appear in a textbook. Any attempt to redefine and broaden what is taken as "fundamental" in engineering will necessarily require research, rethinking and redoing of educational materials. Perhaps, in this day and age, the production of a traditional textbook will not be required; but certainly the construction of an online equivalent resource will require filtering, reshaping, abstracting, and the construction of new forms of student exercise.

In setting this framework, one must be careful not to constrain the student's freedom to explore and do research themselves. We want the student's experience to be open to the extent that he or she must be active in, not only the interpretation and discussion of assigned texts, but also in the selection of texts he or she claims are important and relevant.

Prerequisites

Just as the duration and scope of the module can vary, so too the level at which the content is engaged, e.g., the contents and assignments might be geared toward the undergraduate in a Liberal Studies in Engineering Program as is the intent here. The module, then, would be designed for a student with but Advanced Placement credit in a high school chemistry course and an American History course.

12. On the spur of the moment, I went to Advanced Google and searched on "science and the courts" site:edu. At the top of the list was a link to Jennifer L. Mnookin, *The Courts, the NAS, and the Future of Forensic Science*. http://www.law.yale.edu/documents/pdf/Alumni_Affairs/Mnookin_The_Courts_The_NAS_and_the_Future.pdf Voila, another scholarly article relevant to our purpose - one questioning the reliability of forensic data. The second on the list was "L8600 Science and the Courts" an offering of the Columbia Law School; further down, a special seminar, fall 2007, Science and the Courts, at Amherst College. I went no further scanning the 243,00 results (0.08 seconds).

What prerequisites do I suggest for faculty? The way to ensure an interplay of the two worlds is to require the participation on equal terms of a faculty member of a Department of Chemistry (or Chemical Engineering) and a faculty member of a Law School. In time, it may be that the equivalent of today's graduate teaching assistants, having majored in liberal studies themselves as undergraduates, might be given major responsibility.

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Doing the lab exercise, students should gain a sense of how things can go wrong; how doing a laboratory procedure requires fine tuning ingredients to obtain "good data" - all this should be journaled in a lab notebook. Students will learn that to do an experiment, one must know a good bit about the outcome before one starts. The question of "bias" due to an experimentalist's foresight can be introduced at this point. A more general question regarding human error - as contrasted with other sources of error - might also be put on the table.

Contrasting the machinery required to do Thin Layer Chromatography with that deployed in Gas Chromatography can lead to a discussion of how the experimentalist's (and theorist's) knowledge and know-how is captured and resides in the machine itself[13] Where, then, lies the authority in science (and engineering)? Is it in the "wonderful machine" itself - so a "surrogate's" presentation of the evidence in court is allowed? Or does the authority rely upon the standing of the scientist(s) whose theoretical and craft work framed and inspired the design and production of the machine? What about the lab technician, the licensed operator of the instrument? What does he or she contribute to this picture? What if the actual person, technician, who ran the test *is* required, as the US Supreme Court ruled, to present the evidence in court? What must he or she "know" about the workings of the machinery if we are to accept the data as evidence? I am licensed to drive an automobile; but I would not claim that I could explain the cause of every knock, whine, stall or reverberation whenever such might occur.

And what about that "ball analogy"? How does that contribute to the petitioner's case? In the engineering sciences there are some strict analogies - e.g., resonance in an electrical circuit, resonance in a mass-spring system - strict in that the mathematical expression of the two phenomena is one and the same. Is that true of the ball analogy? If not, what is it's "scientific" value? Or is it like a cartoon, meant to lead the reader to believe he or she understands how GC works?[14] We might ask students to compare the rhetoric of the documents of the court and of the textbooks of the engineering and science course.

To prompt discussion of communication in science and engineering, one could ask students how they explain to their friends what they do in the lab and the significance of their work. Is explaining ones work to a lab instructor less of a challenge than presenting ones procedure, results and their significance to someone lacking any experience in analytical chemistry - say a chief justice of the US Supreme Court? Do students ever construct an analogy of the sort seen here? What does it take to make an analogy of this imaginative kind?

13. Davis Baird; *Thing Knowledge: A Philosophy Of Scientific Instruments*; Univ. of California Press
14. And why didn't McNair include this analogy in his text book?

Returning to the court room: Students might be assigned the tasks of arguing a question on behalf of a petitioner and a respondent only the question would best be set in a different context, with a different referent constitutional clause and a different, even imaginary, test procedure. (Of what might this consist?)

When I first read the 6th amendment to the US Constitution containing the "confrontation clause" my reaction was: "Is that it?" This kind of question can lead to reflection on the possibility of "strict" interpretation of the document. How do precedents matter and provide a basis for decisions when so few words need so constructive a reading? How, throughout our history, has the confrontation clause been interpreted? How does authority of the law differ from, is the same as, authority of science? How does history, precedent, matter in the education and practice of the engineer?

No doubt there are many other foci, questions, assignments that would contribute to meeting the module's objectives. My purpose is to sketch, not detail a syllabus. I hope only to show what "adopting a humanities and social science perspective on exemplary content of undergraduate engineering education" might mean.