DEVELOPING A ONE-SEMESTER COURSE IN FORENSIC CHEMICAL SCIENCE FOR UNIVERSITY UNDERGRADUATES

by

ROBERTA SUE SALEM

B.S., BAKER UNIVERSITY, 1970
M.S., IOWA STATE UNIVERSITY, 1973

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Curriculum and Instruction
College of Education

KANSAS STATE UNIVERSITY
Manhattan, Kansas

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Abstract

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Information was gathered and analyzed through review of literature and proof of concept interviews, laying the foundation for the framework of the course outline.

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CHAPTER 1 - Introduction

Three threads are woven together in this dissertation research: the university liberal arts curriculum; the place of the natural sciences in this curriculum; and the ability of forensic science to motivate general education students to achieve in chemistry.

The place of the liberal arts, or general education, in the university has been disputed as long as there have been universities in America (Sale, 1989). Liberal arts as the term suggests, means liberation from an uneducated state, the freedom to think and creatively conceive on a higher plane. The original arts liberals were designed for the "liberal education" of free citizens who had the leisure to study. From at least the Middle Ages, seven liberal arts were recognized: grammar, rhetoric, logic, arithmetic, geometry, music, and astronomy (Kimball, 1986). Although in the past the liberal arts did not include the natural sciences, at the present time liberal arts courses, commonly referred to as general education courses (Costner, 1989; McGrath, 1948), include three areas: natural sciences; social sciences; and the humanities (National Association of Scholars [NAS], 1996).

Confusion has sometimes existed about the value of general education as well as its differentiation from professional education (Sale, 1989). In the late 1800's the American high school was seen to serve two different purposes: preparation for college and preparation for the world of work (Tyler, 1949). The National Education Association, in 1892, appointed the Committee of Ten, chaired by Charles Eliot, president of Harvard University, to establish a standard curriculum for all high school students (Ornstein, 1993). The Committee chose subject specialists to define learning objectives for the high school students (Tyler, 1949). Because the proposed objectives were too technical and too specialized for most high school students, subject specialists were seen as too esoteric to suggest relevant course material for all except those pursuing in-depth specialization. According to Tyler (1949) the Committee of Ten had simply asked the wrong question of the specialists. Instead of asking, "What should be the elementary instruction for students who are later to carry on much more advanced work in the field?" (Tyler, p. 26), a more suitable question would have been, "What can your subject contribute to the layman, the garden variety of citizen?" (p. 26). Schwab (1978) put it more bluntly, "Scholars, as such, are incompetent to translate scholarly material into curriculum" (p. 36).

After World War II sent thousands of returning service men to the universities, curriculum development for general education courses became more organized. Tyler (1949) suggests four fundamental questions must be asked and answered as curriculum is developed.

1. What educational purposes should the school seek to attain?
2. What educational experiences can be provided that are likely to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained? (p. 1)

Tyler (1949) pointed out that educational curriculum development is highly individual. Curriculum must be designed both for the level of students as well as uniquely planned for the needs of each individual institution. Schwab (1978) suggested that five areas of expertise are required to develop rigorous curriculum: the subject matter, learning, a community person, teaching, and curriculum development.

Even in today's highly technical and technological academic environment, workplace, and daily life, support continues for general education (Nussbaum, 2004). Kimball (1986) suggested that chemistry might form the foundational subject matter for general education, as this subject teaches and encourages the kind of thinking that can transfer to other academic areas. A report published by the National Association of Scholars (NAS, 1996) states that lip service is still given to general education; however, most general education courses are becoming less rigorous as time goes on – except for science and math courses. This may indicate that there is a specific "core" of knowledge in the sciences and math that cannot be changed.

The NAS (1996) study reports that post-secondary schools are not stressing literacy in mathematics and science. It has been suggested that there are in fact two cultures in academia today: the scientists and those whose academic area is the humanities (Snow, 1959). It has also been suggested that a third culture is emerging and taking the place of the traditional humanistic intellectual culture. This third culture is composed of scientists who are writing to the intelligent reading public, making the adventure of science available to all who will read (Brockman, 1995). Therefore, general education is needed more now than ever before (Nussbaum, 2004) in order to produce an intelligent reading public: persons who can participate in a world where "Science has become a big story" (Brockman, p. 18) and "the only news" (Brockman, p.18) available in the beginning of the 21st century. Chemistry can lead the way in post-secondary general education courses by providing rigorous curricula (NAS, 1996) and encouraging the kind of thinking that can transfer to other academic areas (Kimball, 1986). But chemists, course developers, and instructors must make the study of chemistry attractive to undergraduates, especially those who do not intend to major in a science.

Evidence suggests that forensic studies attract students. Academic programs across the country have experienced greatly increased enrollments since the addition of forensics to traditional science courses. The chemistry department of one moderately sized Midwestern liberal arts university recorded 1,408 lower division and 313 upper division credit hours in the 2004-05 academic year. This occurred after a general education course in forensic chemistry and a Forensic Chemical Science degree program were added to the department curriculum. This was a 21.2% increase over the 1,420 credit hours of chemistry courses for the previous academic year, the largest increase in the College of Arts and Sciences. In the academic year 2004-05 the general education forensic chemistry course in this university contributed approximately 450 hours to the total of 1,721, over 26% of the overall chemistry department enrollment (Office of Institutional Research, 2005). A large Midwestern university initiated a forensic science program in October 1999. Thirty-five students signed up the first day the program was available, and the first year saw 179 students enroll. The second year 275 students were in the program, the third year 350, and after five years 495 students were enrolled in the forensic science program at this university (Office of Institutional Research, Washburn University, Topeka, KS, 2006).

As Tyler (1949) and Schwab (1978) indicated, it requires more than one individual to build a curriculum. It also takes an instructional design. Willis (1995) set forth a constructivist instructional design, C-ID. Constructivism can be defined as a theory of knowledge wherein knowledge is actively constructed by the knowledge seeker (Staver, 1998). Willis sees the constructivist design process as a team effort, wherein the students are an integral part of the team. The constructivist design model stresses subjective data, qualitative interview techniques, and formative evaluation. Dick, Carey and Carey (2001) in *The Systematic Design of Instruction* outlined the dominant curricular design process in the late 1900s: Instructional Systems Design (ISD).

While acknowledging that constructivists encourage learning to be transferred to performance, Dick contends that the ISD model can, in fact, be used to create instruction that can promote transfer of learning and also be motivating to the learner if "created by the designer through extensive use of learner analysis" (Dick, 1995, p.7). Furthermore, the ISD model has long been dominant in the field because it traditionally delivers educational products with effectiveness and efficiency. Therefore, the ISD model is used in this dissertation research.

Statement of the Problem

Although several university level forensic science textbooks have appeared in the past few years e.g., Bell, 2006; Jackson & Jackson, 2004; Johll, 2006), there is no available general education curriculum to teach forensic chemical science at the university general education level. Therefore, this study is ground-breaking in that it is designed to research and develop the components necessary to teach forensic chemistry at the general education level at a four-year university. These components were researched by questioning experts in the field of forensic science, instructors of university natural science general education courses, and university students having taken at least one general education course in the natural sciences.

Goals of the Study

The questions posed for the research herein described are as follows: Is there a need for a multiple delivery course for a Forensic Chemical Science (FCS) course in the general education arsenal of small universities and community colleges, and if so, can a course be developed that that will allow university students in general education FCS classes to construct a solid knowledge of basic chemistry and to apply that knowledge to forensic problems? The goal of this research is to research, develop and validate a course for a general education-level forensic chemical science course at the university level.

This course can be used by instructors of general education college or university chemistry courses. The specific research question is: Is there a need for a multiple delivery Forensic Chemical Science (FCS) course in the general education arsenal of small universities and community colleges, and if so, can a forensic chemical science course be developed and validated by a Research and Development methodology for use as a general education course in four-year universities?

Scope and Limitations of the Study

This study produced a course to be used in a particular type of curriculum: general education at the four-year university level. The course focuses on a specific discipline, chemistry, and also an explicit subcategory – forensics within that discipline. The course is not designed for chemistry majors. Therefore students majoring in any subject except chemistry could benefit from this course. However, students in chemistry courses outside the four-year universities will benefit from the application of this course or parts thereof. These students are those in community colleges and possibly high schools. This course includes forensic applications which may or may not generalize to other liberal arts chemistry courses.

Definitions

Committee of Ten – the committee appointed by the National Education Association in 1892 to establish a standard curriculum for both high school as university preparatory and also high school as a terminal educational institution (Ornstein, 1993) The ten members of the committee were Charles W. Eliot, William T. Harris, James B. Angell, John Tetlow, James M. Taylor, Oscar D. Robinson, James H. Baker, Richard H. Jesse, James C. Mackenzie, and Henry C. King (The Committee of Ten: Main Report, 1892).

Constructivism – a theory of knowledge resting on two main principles: 1) knowledge is actively constructed by the knowledge seeker and 2) the function of cognition is not to discover reality, but to organize the world as it is experienced (Matthews, 2000).

Forensic chemistry – specializing in or having to do with the application of scientific, especially (chemical) knowledge to legal matters, as in the investigation of crime (Guralnik, 1984)

Forensic science – the application of science to law (Saferstein, 2004)

Needs Assessment – a systematic set of procedures undertaken for the purpose of setting priorities and making decisions about programs or organizational improvement and allocation of resources (Altschuld & Witkin, 2000)

Research and Development – an industry-based development model in which the findings of research are used to design new products and procedures, which then are systematically field-tested, evaluated, and refined until they meet specified criteria of effectiveness, quality, or similar standards (Gall, Gall, & Borg, 2003)

Student interest – a combination of characteristics of the learner, including his/her knowledge of the subject, characteristics of the text and the interaction of the two (Bernstein, 1955; Garner et al, 1991)

Student motivation – can be differentiated into extrinsic, wherein a task is viewed as a means to obtain a reward or intrinsic, wherein the reward is the pleasure of the task itself (Newby & Alter, 1989) or that feeling created by conditions designed to stimulate the student's desire to be interested and to achieve his/her best (Keller, 1987)

Third culture – phrase coined by John Brockman to indicate "those scientists and other thinkers in the empirical world who, through their work and expository writing, are taking the place of the traditional intellectual in rendering visible the deeper meanings of our lives, redefining who and what we are" (Brockman, 1995, p. 5).

University general education course – a course which provides intellectual skills or knowledge in certain areas: history, the arts, literature, philosophy, religion, the social sciences, or the natural sciences (Catalog, 2005 – 2006)

University liberal arts program – the necessary information for an educated person (Kimball, 1986)

Summary

The need for a scientifically literate populace capable of thinking critically creates the need for effective liberal arts curricula at the post-secondary level of education (Taylor, 1998). The sciences, chemistry in particular, have been designated as the foundation courses by which critical thinking can most effectively be learned (Kimball, 1986). This research is designed to produce a multi-delivery course that will capture the overwhelming student interest in forensic science in order to develop critical thinking skills and habits of mind via university liberal arts chemistry.

CHAPTER 2 - Review of the Literature

The fabric of this study is woven from three threads: The university liberal arts education - general education – curriculum; the place of the natural sciences in this curriculum; and the ability of forensic science to motivate general education students to achieve in the natural sciences, specifically in chemistry. Naturalistic research methodology based on constructivist epistemology will be used to determine specific tools to assist general education students in learning chemistry and forensic applications.

Liberal Arts Education

Stone (2004) argues that educators "don't really know what a liberal art is", although "faculty members know it when (they) see it, even if (they) can't quite define it" (p. 5). The origins of liberal arts curricula can be traced to the ancient Greeks. The Athenians originated the concept of liberal education during the fifth and fourth centuries B.C.E. The cultural ideal was to educate citizens who had leisure to study. In the Middle Ages seven fields of study comprised the liberal arts: grammar; rhetoric; logic; arithmetic; geometry; music; and astronomy (Kimball, 1986). More recently Lovlie and Standish (2002) declared, "the principal aim of *Bildung* (defined loosely as education for humanity) . . . is to strengthen the student's innate powers and character development" (p. 318). Education for humanity is roughly equivalent to liberal arts or general education (Lovlie & Standish, 2002). During the Renaissance a liberal education embraced studies during which students learned and practiced wisdom (Kimball, 1986). "With the rise of experimental science and the dawning of the Enlightenment" (Kimball, 1986, p. 115), liberal education continued alive and well. During eighteenth century England, "chemistry . . . was said to accomplish . . . the same ends of liberal instruction as classical languages" (Kimball, 1986, p. 187).

In the late 1800s and early 1900s, John Dewey emerged as the leading scholar and advocate for liberal education. Dewey's vision of liberal arts education included the natural and experimental sciences and vocational training (Lovlie & Standish, 2002). This concept has been resurrected recently. Stone (2004) suggests that the purpose of liberal education is to foster passion and critical thinking, and that vocational subjects can do both for some students. In fact, "chemistry and biology – also have vocational inclinations" (Stone, 2004, p. 5).

The Sciences in Liberal Arts Education

Joseph J. Schwab, a disciple of Dewey, carried the torch of liberal arts education into the latter half of the 20th century and emphasized the importance of science. Schwab, like Dewey, taught at the University of Chicago. Schwab's written endorsements of liberal education are important because he was a scientist, with his doctorate in genetics not in the humanities. Whereas he viewed the humanities as an integral part of a general education program, he also felt strongly that all students were capable of learning and should be taught some of the thought processes of science (Westbury & Wilkof, 1978). "The integration of science into a scheme for general education had always been a fundamental goal of the general education movement, but it had proved to be a quite elusive end because of the lack of interest of scientists in the issue" (Westbury & Wilkof, 1978, p. 9). The value of Schwab's contribution to the advancement of the liberal arts curriculum stemmed in large part from his training as a geneticist. Kimball (1986) tells us that recommendations for continuing and expanding general education gained strength after World War II, but Westbury and Wilkof (1978) contend that "by the fifties and sixties, when Schwab was writing most prolifically, and for his largest audiences, the concern for the kind of general education which is at the core of all of Schwab's work had faded" (p. 2).

In 1996 the National Association of Scholars (NAS) published a massive report on studies of liberal arts education in the top fifty undergraduate institutions. These institutions were sampled for the academic years that began in 1914, 1939, 1964, and 1993. The title of the work, *The Dissolution of General Education: 1914-1993*, gives the general outline of the findings in three broad categories: the dissolution of structure; the evaporation of content; and the decline of rigor. The overall finding is that U.S. undergraduate institutions continue to pay lip service to the ideal of liberal arts education, but reality shows that the passion and the critical thinking are no longer present. Moreover, the most massive changes in all areas came after 1964.

The NAS (1996) study confirms that humanities, social sciences, natural science and mathematics all show increases in the average number of courses per institution from 1914 – 1993. The greatest of these increases came from the humanities and social sciences. The number of humanities courses expanded by over five times, and social science course offerings increased by over eight times. In the same time period, natural science and mathematics courses increased by less than three times. It is possible that the sciences and mathematics contain a core of knowledge that cannot be readily altered as fashion changes and that this knowledge core could be the authentic basis of a liberal arts course.

"Nothing has shaped the modern world more than the natural sciences and the protean technologies they have generated . . . their mastery is critical to an understanding of innumerable issues of public policy and intellectual dispute. This requires . . . a comprehension of science as method and process, and not merely as a body of knowledge or as an oracular source of theoretical authority" (NAS, p. 19). Or as Schwab phrases it, "by the time graduates of the traditional survey courses reached the point in their careers when they most needed their scientific knowledge, much of that knowledge was out of date . . . It is here that enquiry, with an emphasis on the organizing, conceptual principles of investigation, finds its place in the liberal curriculum." (Schwab, 1978, p. 141).

Considering the foregoing, one would expect to find most undergraduate universities stressing the natural sciences. The NAS report (1996) substantiates that expectation – for the years 1914, 1939, and 1964, when natural science requirements were found in an average of 83% of the schools studied, with the greatest percentage (90%) coming in 1964. By 1993, however, the number of undergraduate universities requiring natural science for graduation had plummeted to 34%.

Following its own suggestion that science be comprehended as a method and a process (NAS, 1996), the NAS report defines rigor in science liberal arts courses as those that have a laboratory component – rigor becomes merely "hands on". This definition bastardizes Schwab's concept of "enquiry". Schwab's students did not perform laboratory work, but instead, with "minds on", critiqued the scientific literature of their time. However, counting courses with laboratory components is easier than determining whether the students are actually thinking.

In 1914, 1939, and 1964 an average of 79% of the schools studied by the NAS required at least one science course with a laboratory, with the highest percentage (84%) occurring in 1964. In 1993 only 30% of the schools studied required a science course with a laboratory in the general education curriculum. These data show that liberal arts education in this country is, if not dead, at least in dire need of resuscitation, and this researcher argues that the sciences can not only lead the way, but that science-led general education is now more needed than at any time in the past. According to Nussbaum (2004), liberal education is, in practice, an American idea and an American ideal. Only liberal education can produce people who can think critically. Moreover, "The idea of liberal education is more important than ever in our interdependent world" (p.42).

Forensic Chemistry and the Liberal Arts Curriculum

It would perhaps be ironic if crime and punishment were to lead U.S. education out of the science-avoidance that has characterized it for so long (NAS, 1996). Some of our most valued national treasures are the bullet fragments collected from the scene of the assassination of one of our most beloved presidents (Guinn, 1979).

In the popular press there is no doubt that forensic science has provided the interest and motivation to pull students into the sciences. Alexander LeMaine, writing for the Scripps Howard News Service (2004) and Sid Perkins, writing in *Science News* (2004) both discuss several academic programs – undergraduate and graduate - across the country, which have increased enrollment by adding or expanding forensic science programs. The largest professional society of science teachers, the National Science Teachers Association (NSTA, 2003) reports that some experts worry that using forensic science to stimulate interest in crime will promote violence in schools. However, the NSTA also teamed up with Court TV to develop units to bring forensic science into middle and high school classrooms in order to motivate students to study biology, chemistry, and physics (Collins, 2003; Court TV, 2003). Parents are getting on the bandwagon (Yost, 2003), and school boards are buying into the value of forensic science in the high school classrooms (Colgan, 2002).

Motivation and Interest

The popular press uses the terms "interest" and "motivation" interchangeably. Educational psychologists define these terms more rigorously, and study each in depth. The published research into interest and motivation offers much valuable information for course development.

In today's world where no child is to be left behind, each child must be motivated to give schoolwork his/her best effort and, " . . . issues of cognitive competence are intertwined with issues of motivation to perform" (National Research Council [NRC], 2002, p. 280). The NRC continues, "Although cognitive psychologists have long posited a relationship between learning and motivation, they have paid little attention to the latter . . . Research has been done on motivation, but there is no commonly accepted unifying theory, nor a systematic application of what is known to educational practice" (p. 280). The NRC recommends research involving case studies of small numbers of students. Writing specifically for the teaching professor, Cavallo, Rozman, Blickenstaff, and Walker (2003) declare that achievement motivation is in dire need of further study.

Achievement motivation can be classified as extrinsic or intrinsic. Extrinsic motivation is toward performance goals such as higher grades and gold stars. Intrinsic motivation is toward learning goals such as personal satisfaction (Lepper, 1988; Newby & Alter, 1989). Miller and Hom (1990) prefer the term "continuing motivation" to intrinsic motivation. Mitchell (1992) found that "although intrinsic motivation seems to come closest to what motivation means in the minds of . . . people in general, it is extrinsic motivation that is the stronger predictor of GPA" (p. 153).

In the early 1990s, Chance and Kohn initiated a lively discussion concerning the value of intrinsic versus extrinsic motivation. Chance defended extrinsic motivation, after first declaring that "the distinction between intrinsic and extrinsic rewards is somewhat artificial" (1992, p. 203). Chance declared that extrinsic rewards, as such, were not to blame but rather rewards given for the wrong reasons: completing a task rather than completing a task competently. Kohn responded by chastising Chance for ignoring "the entire constructivist tradition (in which teaching takes its cue from the way each child actively constructs meaning and makes sense of the world rather than treating students as passive responders to environmental stimuli" (1993, p. 786). Chance (1993) had the last word by invoking the conundrum of which came first: the teaching (extrinsic rewards) or the learning (intrinsic rewards)?

In a cross-cultural study, Lin, McKeachie, and Kim (2003) found that extrinsic and intrinsic motivation are "separate continua rather than a dichotomy" (p. 252). Using final course grades, these researchers showed that a medium level of extrinsic motivation coupled with high intrinsic motivation produced higher grades in all three U. S. samples and the one Korean sample studied.

Whereas some educational psychologists distinguish between interest and motivation, others go further, distinguishing between different varieties of interest. Kintsch (1980) differentiated between cognitive interest and emotional interest. Iran-Nejad (1987) differentiated between interest and liking. In a review of the literature on interest, Hidi (1990) distinguished between situational interest and individual interest, and this has become the common differentiation (Askell-Williams & Lawson, 2001).

Mitchell (1993) and Schraw, Bruning, and Svoboda (1995) analyzed situational interest in more detail. Schraw, et. al. "identified six potential sources of situational interest" (p. 11): text cohesion; ease of comprehension; vividness; emotiveness; personal prior knowledge; and engagement. Three of these sources, ease of comprehension, vividness, and engagement were found to be most important. Mitchell (1993) defined situational interest as "an interest directly tied to the content of instruction" (p. 425). He states that "Classroom boredom . . . may really be an indication of a bigger schooling problem, namely the lack of motivation to learn" and that "taking steps toward understanding how to enhance interest in the . . . classroom may prove to be one of the most direct ways to approach the problem of effective . . . instruction" (p. 424). Examining the multifaceted structure of situational interest in the secondary school mathematics classroom, Mitchell found that the factors of "meaningfulness" and "involvement" are most directly correlated with situational interest. But Mitchell also drew in another thread - that interest and motivation could be opposite sides of the same coin – or perhaps even the same side.

Interest in Forensic Science

Forensic science provides interest and motivation to get more students into science programs at the undergraduate and graduate levels (LeMaine, 2004). However, long before Crime Scene Investigations (CSI) became standard television fare – indeed, before television became a force to be reckoned with in the U.S. – Bernstein (1955) studied the relationship between the reader's interest and his or her comprehension of the text. Bernstein defined interest as a complex feeling or attitude derived from:

1) characteristics of the reader, including physical and emotional well-being at the time of reading, background of experience, favorite occupations and hobbies, and ability to understand the material;

2) factors inherent in the text itself, including the form and style of writing, its logical organization, and 'human interest'; and

3) interaction of the reader and the material, including the extent to which the material stimulates the reader's imagination, facilitates his identification with the characters in the text, fulfills his needs, or arouses his emotions. (p. 283)

Bernstein gave a group of one hundred ninth graders two short stories, one highly interesting, and the other low in interest. The students were given comprehension tests on both stories. The highly interesting story was read more rapidly and with greater comprehension than the uninteresting story. Bernstein's summary was, ". . . school programs which encourage pupils to work in the areas of their interests create situations conducive to effective reading" (p.288). In 1949, R. W. Tyler wrote in *Basic Principles of Curriculum and Instruction* that "If the school situations deal with matters of interest to the learner he will actively participate in them and thus learn to deal effectively with these situations" (p. 11). In the waning years of the 20th century, Schraw, et al declared, "Several studies have found that increasing . . . interest improves text recall" (1995, p. 2).

Garner, Alexander, Gillingham, Kulikowich, and Brown, (1991) suggest in their literature review that readers understand and remember information better when they read about a topic in which they are interested. In a separate review of the literature, Schiefele (1991) concurs that interest level is related to comprehension level. Lepper and

Cordova (1992) conclude from yet another literature review that there is a "powerful correlation" (p. 188) between interest value of a selection and the ease of learning and retention. Anderson, Shirey, Wilson, and Fielding, (1987) report that, in four experiments, rated interest accounted for thirty times as much variance in sentence recall as readability, and also that interest accounted for about the same amount of variance as reading comprehension. Schraw and Lehman (2001) maintain that "interest in a text is related positively to learning" (p. 42) and that "interest is related to more and often deeper text processing" (p. 43). In a review of the literature preceding their investigation of student perceptions of interesting lessons, Askell-Williams and Lawson (2002) noted that there is "higher reading comprehension for high-interest subject matter" and that "interest is a considerably more powerful variable in determining readability than the assigned readability level of school texts" (p. 130). Moreover, research linking interest and performance suggests that encouraging interest might be the same as encouraging learning (Askell-Williams & Lawson (2002).

There is one exception to the link between interest and comprehension: seductive details. Seductive details can be defined as "segments that are highly interesting, but unimportant to the text's main themes" (Schraw & Lehman, 2001, p. 32). In their review of the literature, Schraw and Lehman (2001), report that the research regarding the applicability of seductive details to enhancement of learning is far from clear. Lepper and Cordova (1992) and Garner, Gillingham, and White (1989) both found that seductive details, while interesting, distracted the reader from the important information in a passage. This finding held both for adults and children.

Researchers have documented a strong positive relation between interest and reading comprehension. But viewers' interest in forensic science television programs stands apart from reading. Thompson and Thornton (2002) found that adult learners are motivated by relevance and the meeting of immediate interests. Schiefele (1991) reports that "Interest is . . . always related to specific topics" (p. 301). And "Subject-matter-specific interest is probably more amenable to instructional influence than are general motives or motivational orientations" (p.302). Hollis (1996) used popular fiction such as *The Mysterious Affair at Styles*, by Agatha Christie; *The Documents in the Case*, by Dorothy Sayers and *Jurassic Park*, by Michael Crichton to invigorate summer seminars for high school students. Therefore, there is some basis to suggest that an interest in forensic science could provide a motivation for studying chemistry.

Constructivism and Pedagogy

Course development is the heart of this research, and constructivist theory is the driving force behind the beating of the heart. Schwab (1978) declares that a person's experience has both an inner and an outer dimension and that without the inner dimension, "the outer dimension simply does not exist – as experience" (p. 272). Schwab (1978) also says that our past experience combines with present events to determine our experience in the present. "What we are, what we know, how we have been bent, and what we remember, determine what we experience in the present" (p. 272). Although not generally recognized as a constructivist, Schwab's writings lend themselves somewhat to constructivist interpretation.

According to Ernest (1995) there are as many definitions of constructivism as there are constructivists writing today. Matthews (2000) identifies three varieties of constructivism: the personal constructivism of Piaget and von Glasersfeld, social constructivism coming from the works of Vygotsky, Driver, and Ernest, and philosophical constructivism as represented by Kuhn and van Fraasen. Phillips (1995) suggests six constructivists as espousing differing views of constructivism: Ernst von Glasersfeld speaking to science and mathematics; Immanuel Kant as the quintessential constructivist; Linda Alcoff and Elizabeth Potter dealing with the sociopolitical processes by which knowledge is constructed; Thomas S. Kuhn working with scientific revolutions and paradigms; Jean Piaget, generally regarded as a foundational figure; and John Dewey. All of these constructivists hold views that "(a) understandings are constructed by using prior knowledge to go beyond the information given and (b) the prior knowledge that is brought to bear is constructed, rather than received intact from memory" (Ernest, 1995, p. 470). Staver (1998) restricts himself to what he defines as "the two best-known types (of constructivism), radical and social" (p. 503). Phillips (1995) uses the terms "individual" and "sociopolitical" instead of "radical" and "social", and Cobb (1994) and Driver, Asoka, Leach, Mortimer, and Scott (1994) use "personal" and “social”, but this researcher will use the constructivist terminology as defined by Staver.

Constructivism is an epistemology, a theory of knowing and knowledge. von Glasersfeld’s (1984) writing will be used to explicate radical constructivism. By speaking to the academic areas of math and science, von Glasersfeld is fundamental to our quest for the epistemological basis of university chemistry instruction. He defines radical constructivism as follows:

> Radical constructivism, thus, is radical because it breaks with convention and develops a theory of knowledge in which knowledge does not reflect an “objective” ontological reality, but exclusively an ordering and organization of a world constituted by our experience. The radical constructivist has relinquished “metaphysical realism” once and for all (1984, p. 24).

von Glasersfeld (1984) points out that, because constructivism is, at first glance, incompatible with common sense, there is the risk that it will be discarded. However, upon further reflection, constructivist thought inevitably leads one to realize that each person is responsible for his thinking (constructions) and therefore also for his actions.

In general, our knowledge (construction) is useful if it stands up to experience and allows us to make predictions. The main question radical constructivism deals with is, “ if our experience can teach us nothing about the nature of things in themselves, how ... can we explain that we nevertheless experience a world that is in many respects quite stable and reliable?” (von Glasersfeld, 1984, p. 27) The answer, derived by von Glasersfeld is, “human truth is what man comes to know as he builds (constructs) it. Therefore science is the knowledge of origins, of the ways and the manner (of) how things are made.” (p. 27) Radical constructivists focus on individuals making sense of their own world within their own minds. Hence, in some respects the designations of “personal” or “individual” are more defining than the designation of “radical”.

For input about societal constructions, we turn to a definition from Staver (1998): “in social constructivism, collective meaning making is achieved through language-based social interaction” (p. 508). Social construction of knowledge is carried out by groups or communities, not individuals (Nelson, 1993). This social knowledge construction involves rules held by a sociocultural group (Phillips, 1995). McCarty and Schwandt (2000) declare that true social constructivism does not begin in the mind of an individual, but with language, that social knowledge construction takes place within public dialogue, and that it can be used to build a theory of learning (Richardson, 2003).

Constructivist epistemology "provides a sound theoretical foundation for" (Staver, 1998, 517) building science pedagogy. Even critics of constructivism acknowledge its value in designing curriculum (Staver, 1998). And it is social constructivism and the need to go beyond purely personal constructivism that is viewed as a part of the process of enculturation into the practices of intellectual communities, of which the community of science is one (Cobb, 1994). It is important to science education to note that scientific knowledge is socially negotiated. "The objects of science are not the phenomena of nature but constructs . . . advanced by the scientific community to interpret nature" (Driver et al., 1994, p. 5). Learning science, therefore, requires initiation of the student into the ways of knowing science (Driver, et al., 1994). Social constructivist epistemology requires changing today's mainly teacher-centered classrooms (Taylor, Gilmer, & Tobin, 2002) into student-centered classrooms where students actively explore scientific phenomena via instruction that builds on students' prior knowledge and experience. Learning comes about when a previous knowledge scheme is modified after exposure to experiences that induce cognitive conflict (Driver, et al., 1994). Practices designed to be student-centered with cognitive conflict include, but are not limited to, group dialogue, introduction of formal domain knowledge, and opportunities for students to challenge existing understandings (Richardson, 2003). Also, emphasis may be on doing as well as knowing (Bredo, 2000). However, it is essential that the educator practicing constructivist pedagogy be thoroughly grounded in a field of expertise (Elkind, 2004; Richardson, 2003) and that the educator understand that learning science requires that the student enter into a "different way of thinking about and explaining the natural world" (Driver, et al., 1994, p.8).

To summarize, Staver's (1998) four components of radical constructivism: knowledge is actively built up from within each member of a community; social interactions are central to the building of knowledge; cognition and language are functional and adaptive; and the purpose of cognition and language is to bring coherence to an individual's world of experience and a community's knowledge base.

Pedagogy is also experiencing change as a consequence of advances in technology at the university level. Teaching with technology needs to be based on a sound philosophy of education, and this may well be constructivism (Elkind, 2004). More college-level instructors are considering constructivist pedagogy (Abbas, Goldsby, & Gilmer, 2002). Ernest says that pedagogy is "a theory of teaching – the means to facilitate learning" (p. 466) and this theory must be based on an appropriate epistemology. A methodology is the "theory of which methods and techniques are appropriate and valid to use to generate and justify knowledge" (p. 465) within the epistemology.

Research Methodology

If the scientific method is no longer sacred (Harwood, 2004), perhaps the demise of the linear model of systematic design of instruction (Dick, Carey & Carey, 2001) is close behind. (See Figure 2.1)

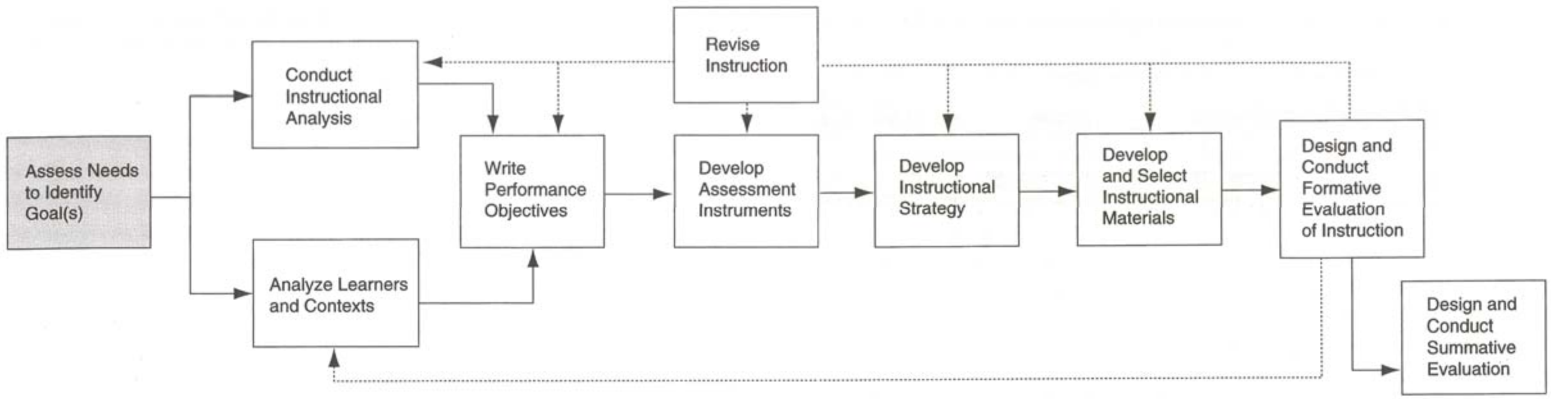

Figure 2.1 The Dick and Carey Systems Model For Designing Instruction
From Dick, W., Carey, L. & Carey, J. O. (2001). The Systematic Design of Instruction, 5th ed., New York: Addison-Wesley, pp. 16-17. Reprinted with permission of the author.

Constructivist theory is appealing, and theoretical power emanates from its capacity to explain, guide research, and predict. Rowland argues that, "criticizing designs created from a constructivist view in terms of criteria derived from an objectivist view . . . is fruitless" (1995, p.19). If evidence exists, it will be found in the discussions of Walter Dick (1995, 1995a, 1997) and Jerry Willis (1995, 1998, 2000). Examination of the literature of the paradigm wars reveals fascinating conceptual debate but no empirical data indicating success or failure for either the older instructional systems design (ISD) model or the newer constructivist instructional design (C-ID) models (See Figure 2). In fact, Willis (1995) echoes Rowland (1995) that it can be argued "there is no way of testing the validity of different theories that members of different theoretical camps will agree is a satisfactory test" (p. 10).

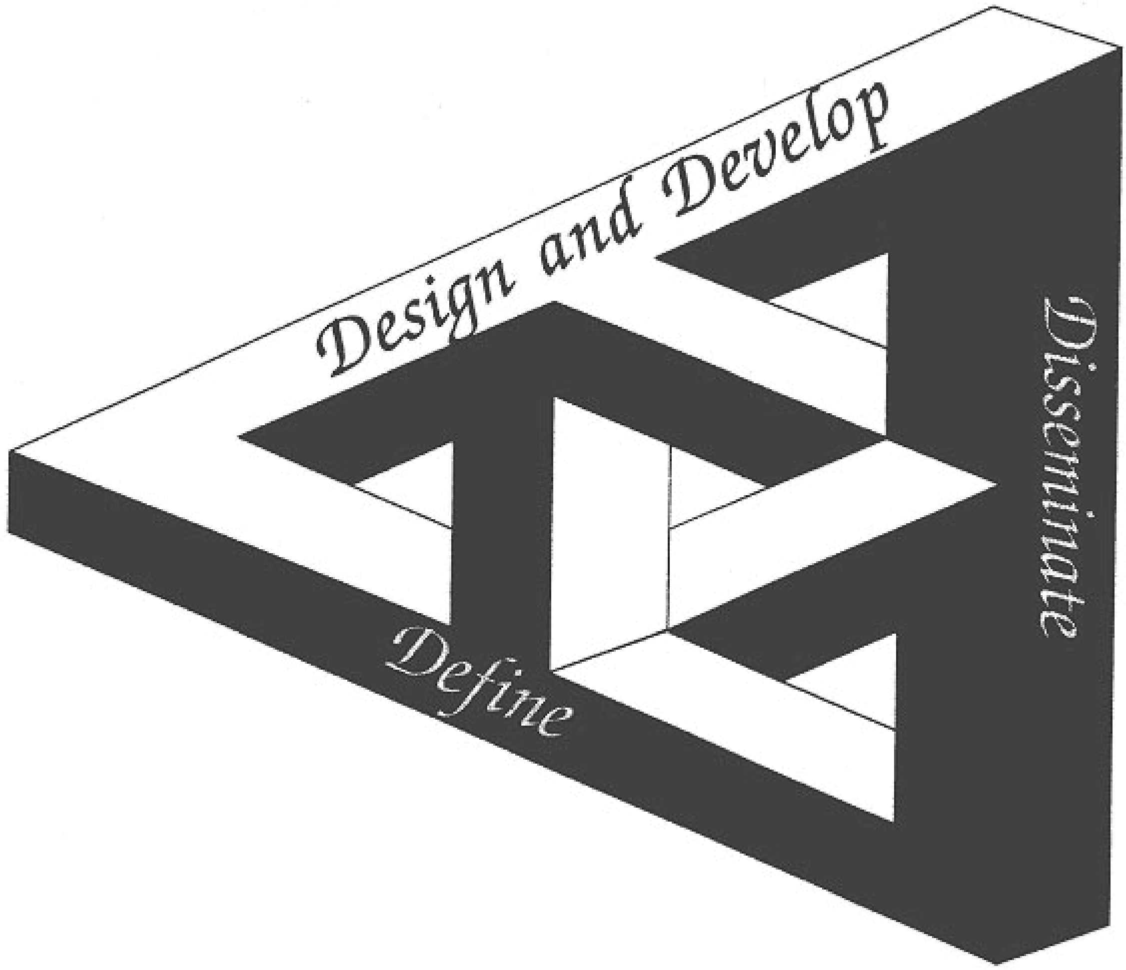

Figure 2.2 A graphical representation of the R2D2 Instructional Design (ID) Model.

The model has three focal points (Define, Design and Develop, and Disseminate). The nature of the graphic which has no obvious beginning or ending and constructs an "impossible world" perspective, represents the two Rs of the R2D2 model: Recursion and Reflection. Willis, J. (1995). A recursive, reflective instructional design model based on constructivist-interpretivist theory. Educational Technology 35(6), p. 15. Reprinted with permission of the author.

Nevertheless, a brief analysis of the two types of models will help set the stage for the methodology used in this study. The ISD model of Dick and Carey (See Figure 1) has long been the dominant model for developing educational materials. Even though published well after the initiation of the Paradigm Wars, the highly regarded educational research text by Gall, Gall & Borg (2003) mentions only the ISD model. The ISD model was first developed in the 1960s and was influenced by the Skinnerian behavioral psychology prevalent in education at that time (Willis, 1998). While acknowledging that constructivists encourage learning to be transferred to performance, Dick contends that the ISD model can, in fact, be used to create instruction that can promote transfer of learning and also be motivating to the learner if "created by the designer through extensive use of learner analysis" (Dick, 1995, p. 7). Furthermore, the ISD model has long been dominant in the field because it traditionally delivers educational products with effectiveness and efficiency.

Willis (2000) sees the C-ID process as a team effort as did Schwab (1978) wherein the students are an integral part of the team. In order to give students substantial ownership, he even suggests making them coauthors of any material produced (Willis, 1995). Askell-Williams and Lawson (2001) hold the view that "an essential source of information about interest in learning situations is from learners themselves" (p. 132). This ties in with the C-ID model, which stresses subjective data, qualitative interview techniques, and formative evaluation. Summative evaluation is viewed as unnecessary as the whole process is circular rather than linear (See Figure 2). As Ernest (1995) relates, the process is recursive: in constructivism, a structure is always built on a foundation, and then that structure becomes the foundation for the next structure, *ad infinitum*.

Willis (1995) states that traditional ISD models are based on the assumption that objective (quantitative) analysis is better than subjective (qualitative) analysis. The models of C-ID, however are based on the assumption that subjective analysis – with both instructor/designer and students involved in an ethnographic study - will result in a design which is both more usable and more used by the students and instructors who are involved in the production. As in all qualitative studies, the theories - or in this case the workable product - arise as the study progresses. The study defines the product; the product does not define the study. However, "formative evaluation is critical" (Willis, 1995, p. 12) because it is this evaluative process that improves the product. Summative evaluation does nothing to improve the product. The process of development is "active, authentic, social, and collaborative" (Willis, 1995, p. 16). Similar to action research, "most of the activity is in the context of creating the instructional material" (Willis, 1995, p. 16).

An ethnographic study of villagers in the rural United States will differ in scope and focus from a similar study of inner city inhabitants of a large metropolitan area in the United States. So, too, a learning product produced by and for students in the Midwest may or may not be suitable for students in New York or Los Angeles. In the learning product produced by C-ID, "there are too many local, context-based variables . . . to make valid generalizations to other settings" (Willis, 2000, p. 16). If a summative evaluation is necessary, C-ID can only produce "the story of what happens when the material is used in a particular context in a particular way with a particular group of learners" (Willis, 2000, p. 16).

Dick (1995) suggests that the ISD model was, in fact "never intended to reflect how instruction is designed in the 'real world'" (p. 9). Most designers skip steps or circle back to repeat steps instead of insisting on the model's lockstep linearity. Dick sees the greatest value of the ISD model in its insistence on effectiveness. And, he suggests that "designers who augment ISD fundamentals with judicious use of selected constructivist principles will make design decisions that result in instruction that engages learners and produces learning outcomes that are required by the client" (Dick, 1995, p. 10).

Perhaps it is possible to weld the two design systems into one harmonious whole. Rowland (1995) suggests that "ISD methods do not in and of themselves provide the core creative elements of the best designs. . . (but) that carried out expertly . . . ISD can be helpful and can ... result in 'creative instruction'" (p. 20-21) because the power of the design comes from "the experience, expertise and creativity of the designer" (Rowland, 1995, p.22). For example, Herrington and Standen (2000) were able to fit a "constructivist shell" with real-life learning over an existing program designed from ISD methodology.

Lebow (1993) carries the argument one step further, suggesting that learning and motivation can both be designed into education and that the student learns when the learning has personal relevance. To this end educational tools can be designed to augment each student's ability to transform knowledge, but this does not necessarily mean the rejection of performance objectives. Both the instructor and the student can have input during the design process. Working together, the team of instructor and student can construct a product, which will incorporate knowledge transfer, personal relevance and motivation in a form that is efficient and effective. How this will be brought about is the topic of the next chapter.

CHAPTER 3 - Methodology

"What are you doing now?" Rimbaud said.

"Collecting data," Hawk said.

"That's all?"

"Un-huh."

"What you going to do when you get enough data?" Rimbaud said.

"Depend on what the data tell us," Hawk said. "Tha's why we gathers it."

From *Cold Service* by Robert Parker

Introduction

The design of this study follows the educational research and development (R&D) methodology as outlined by Dick, Carey and Carey (2001), Gall, Gall and Borg (1999) and Gall, Gall and Borg (2003). This chapter outlines use of the seven steps of the development cycle of the R&D process. Findings will be evaluated after each step to determine how (or whether) to continue the process. But, the process will not follow the lockstep, behavioral linearity of Dick, Carey and Carey's Instructional System Design (ISD). Dick himself suggests that constructivist theory can easily fit into the ISD product and that most developers modify the ISD product to suit their particular needs (Dick, 1995).

Design Overview

The questions posed for the research and development described herein are as follows: Is there a need for a multiple delivery (King & Fricker, 2002; Pond, 2002) Forensic Chemical Science (FCS) course in the general education arsenal of small universities and community colleges, and if so, can a course be developed that will allow university students in general education FCS classes to construct a solid knowledge of basic chemistry and to apply that knowledge to forensic problems? This research will be partially based on Tyler's (1949) four fundamental questions for curriculum development.

1. What educational purposes need to be attained?
2. What educational experiences can be provided that are likely to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained? (p. 1)

Any course building will be based on Dick, Carey and Carey's (2001) eight step design process.

1. Assessment of needs
2. Analysis of learners, contexts, and instructional goals
3. Development of performance objectives
4. Development of assessment instruments
5. Development of instructional strategy
6. Development and selection of instructional materials
7. Formative evaluation(s)
8. Summative evaluation

The steps of the R & D process for developing a multiple delivery course for a general education forensic chemical science course include the following: (1) needs assessment; (2) planning the product and small scale validation (1st field test); 3) product revision and 2nd field test. These steps are outlined below in Table 3.1 – Sources of Data.

Table 3.1 Sources of Data

Phase description	Phase one instrument	Phase two instruments	Phase three instruments	Timeline
Needs assessment	Questionnaire to 30 forensic scientists			March – May 2007
Validation of product (1st field test)		Prototype (1st field test) course and questionnaire to 9 peers of the researcher: university or community college forensic science instructors		September 2007 – January 2008
Usefulness of product (2nd field test)			2nd field test course and questionnaire to 7 students in university forensic science courses	February – May 2008
Review of results	Peer review	Peer review	Peer review	

Phase One – Needs Assessment

Needs assessment (NA) is the most important aspect of instructional design. Dick, et al. (2001) say that trying to decide exactly what one wants to accomplish is the most difficult task. This is especially complicated when dealing with university students in a general education context (Alalou, 1999).

Before any research can take place, the problem should be specified and the objectives outlined (Malhotra, 1993). In the case of the present study, the problem is to determine, first, whether there is a need for a multiple delivery university general education course in forensic chemical science. If a need is found, the next step would be to determine how students can successfully construct scientifically accepted chemical concepts and apply them to forensic problems.

The needs assessment was conducted via open-ended questionnaires sent, by email or surface mail, to forensic scientists currently working in the area. (See Subject Selection Procedures) The questionnaire inquired, using open-ended questions, about the need for a university/community college-level general education Forensic Chemical Science (FCS) course. Respondents were encouraged to consider that university general education courses attract a large variety of students, including, but not restricted to potential business people, lawyers, those who will work in the criminal justice field, media persons, and, of course, potential jurors. If the respondent saw a need for such a course, she/he was then asked to suggest specific topics that should be covered.

The answers to the questionnaires were coded and individually analyzed by at least two persons skilled in qualitative analysis. The coding was compared and conclusions drawn as to the need for the forensic chemical science course and topics that should be included in this course. Triangulation is recommended (Gall, Gall & Borg, 2003), and triangulation, validation measures, and interview procedures are discussed in more detail below.

Qualitative or quantitative: that is the question. Malhotra (1993), working in the area of business marketing defends the choice of qualitative methods. "The objective of qualitative research is to gain an understanding of the underlying reasons and motivations for people's attitudes, preferences, or behavior." (p. 156). Also qualitative research can provide insights and understandings not necessarily bought out with quantitative research. Qualitative research is more flexible in that new insights and possibilities can emerge (Altschuld & Witkin, 2000). Therefore, a qualitative approach was chosen for this research and development study.

Two major direct approaches are used in qualitative marketing research: focus groups and in-depth interviews. A focus group allows a large amount of data to be created and will produce a wider range of information than individual interviews. However, focus group data are messy, and the group itself is difficult to moderate. Results are more easily misjudged than the results of other data-collection techniques (Malhotra, 1993). In-depth interviews are relatively unstructured personal interviews. This method can uncover greater insights than focus groups and thus is used for exploratory research (Malhotra, 1993).

There is a third alternative: questionnaires. Questionnaires have two advantages over interviews and focus groups: cost and time. Although questionnaires are more commonly used in quantitative research, they have been used successfully in qualitative research (Gall, et al, 2003). Therefore questionnaires are the tools of choice for this dissertation research.

Phase Two – First Field Test

Following the needs assessment (NA), questionnaires were sent to 15 - 20 university and community college instructors who teach forensic science courses. (See Subject Selection Procedures) These instructors were also sent a preliminary multiple delivery product of the proposed course. The questionnaire included with the product solicited suggestions for specific chemical concepts, in addition to those sketched in the product, which correlated with the forensic topics deemed important by the forensic scientists. The questionnaires also solicited teaching methods, in addition to those in the product, that could be used to teach these chemical concepts. The questionnaire also queried the sequence of the product and the proposed length (one 16-week semester). The responses were coded and individually analyzed by at least two persons skilled in qualitative analysis. The coding was compared and conclusions drawn as to the topics and teaching techniques that should be utilized in this course. These comparisons produced a triangulation for the first field test of the product.

Comparing topics from the forensic scientists and the university/community college instructors formed a triangulation for topic selection and teaching techniques. At this point a preliminary product was produced using the topics and teaching techniques extracted from the questionnaires of Phases One and Two. Part of the instructional design product of Dick, et al (2001), was used to produce the preliminary product. Performance objectives (step 3) and instructional strategies (step 5) were then developed. Instructional materials were then developed and/or selected (step 6).

Phase Three – Final Field Test

This initial product was tested with eight students (See Subject Selection Procedures) in a university general education forensic science course. According to Altschuld and Witkin (2000), students are the primary level (Level 1), the direct recipients of services. The students are the reasons for the existence of service deliverers, i.e. instructors, Level 2 and program delivery systems, classrooms, and salaries for Level

2, (Level 3). Most research is conducted with Levels 2 and 3 predominating. The needs and concerns of the students can become lost. "Needs assessors should remember . . . whose needs are being assessed" (Altschuld & Witkin, 2000, p. 10). Therefore, students constitute the final field testers of the product.

Questionnaires were included with the product. These questionnaires queried the students about additional concepts which were valuable to them to learn in a general education FCS course and what concepts should be deleted. They were asked about effective and ineffective information delivery methods. Students were asked to critique the parts of the initial course they used. These questionnaires were evaluated as before: the responses were coded and individually analyzed by one person skilled in qualitative analysis. The coding was compared and conclusions drawn as to the topics and delivery methods that should be employed in this course. These comparisons produced a triangulation for the evaluation of the preliminary product.

Triangulation involves using different sources for data collection, but in naturalistic research methodology the researcher remains the primary data collection tool. In qualitative analysis of data scientific neutrality is not possible (Krathwohl, 1998). Triangulation is one method of dealing with researcher bias. In this study triangulation is achieved by examining the problem from three different perspectives, students, instructors of general education forensic science courses, and professional people practicing in the area of forensics.

One additional method of checking for validity was used in this study: peer checking. A peer was asked to inspect the coding of samples of data. This provided evidence of "interrater reliability of coding as well as of analysis" (Krathwohl, 1998, p. 340).

Subject Selection Procedures

The questionnaires of Phase One, the needs assessment (NA), were sent to forensic scientists working in the field. The first tier of these scientists were those on the accreditation advisory board for the Forensic Chemical Science (FCS) program at Washburn University. In addition to receiving questionnaires, these people were asked to suggest other forensic scientists in the United States with whom they are acquainted and who would provide good input into the needs assessment for the multiple delivery course for a general education forensic chemical science course at the university level.

The Phase Two questionnaires were sent to university and community college instructors who teach forensic science courses. These instructors were selected from two sources. Questionnaires and a product was sent to all members of the editorial advisory board of the new journal, The Forensic Teacher. Instructors were also selected from the database of forensic instructors hosted by the Midwest Forensics Resource Center (MFRC) at AmesLab, Ames, Iowa. Todd Zdorkowski, associate director of the Center, volunteered to assist with the selection. These instructors were sent a product of the multiple delivery course in Forensic Chemical Science and a questionnaire with which to critique the product.

Students who field tested the product and completed a questionnaire outlining the strengths and weaknesses of the product came from the Introductory Forensic Chemistry course taught by the researcher. Each of the students signed a "Form of Consent – Research Involving Human Subjects" (Appendix F – Kansas State University Form of Consent) indicating that his/her participation was voluntary and not coerced by the researcher.

Summary

The purpose of this research and development study is to design a course suitable for a university liberal arts Forensic Chemistry Course. The need for such a course was determined by querying professionals in the field of forensic science. Using the (ISD) design process, the course was constructed by querying the experience and needs of college and/or university general education forensic science instructors and also the input of university and/or community college students. Data were gathered through questionnaires with subjects purposefully selected by the snowball method (Creswell, 1998). In addition to using the three different sources of data, the researcher will continued to triangulate the study by use of peer checking.

CHAPTER 4 - Development of the Product

Introduction

The development of the Forensic Chemical Science Course (hereafter referred to as “the FCS Course” or “the Product”) followed the educational research and development (R&D) methodology as outlined by Dick, Carey and Carey (2001), Gall, Gall and Borg (1999), and Gall, Gall and Borg (2003). This chapter describes the use of three phases of the development cycle of the R&D process. Findings were evaluated after each step to determine how, or whether, to continue the process. The process did not, however, follow the lockstep, behavioral linearity of Dick, Carey and Carey’s Instructional System Design (ISD). Dick (1995) himself suggests that constructivist theory can easily fit into the Instructional System Design and that most developers modify the ISD product to suit their particular needs.

Design Overview

This study was partially based on Tyler’s (1949) four fundamental questions for course development.

1. What educational purposes need to be attained?
2. What educational experiences can be provided to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained? (p. 1)

Course development was based on a modification of the eight step design process of Dick, Carey and Carey (2001).

1. Assessment of needs
2. Analysis of learners, contexts, and instructional goals
3. Development of performance objectives
4. Development of assessment instruments
5. Development of instructional strategy
6. Development and selection of instructional materials
7. Formative evaluation(s)
8. Summative evaluation

The questions posed for the research described herein are as follows: Is there a need for a multiple delivery Forensic Chemical Science (FCS) course (King & Fricker, 2002; Pond, 2002) for a course in the general education arsenal of small universities and community colleges? If so, can a course be developed that will allow university students in general education FCS classes to construct a sound knowledge of basic chemistry and to apply that knowledge to forensic problems?

The steps of the R & D process for developing the multiple delivery course for the general education forensic chemical science course included: 1) needs assessment; 2) planning the product and small scale validation (1st field test); and 3) product revision and 2nd field test. These steps and the time required for each step are outlined below in Table 4.1 – Data Collection.

Table 4.1 Data Collection

Phase description	Phase one instrument	Phase two instruments	Phase three instruments	Timeline
Needs assessment	Questionnaire to 30 forensic scientists[1]			March – May 2007
Validation of product (1st field test)		Prototype (1st field test) course[2] and questionnaire[3] to 9 peers of the researcher: university or community college forensic science instructors		September 2007 – January 2008
Usefulness of product (2nd field test)			2nd field test course[4] and questionnaire[5] to 7 students in university forensic science courses	February – May 2008
Review of results	Peer review[6]	Peer review[6]	Peer review[6]	

[1] See Appendix A (questionnaire sent to the forensic scientists)

[2]See Appendix H (prototype course sent to the instructors of general education natural science courses – developed after analysis of questionnaires from forensic scientists)

[3]See Appendix C (questionnaire sent to instructors of general education natural science courses)

[4]See Appendix D (course given to university forensic students – developed by including suggestions made by forensic scientists and instructors of general education natural science courses)

[5]See Appendix E (questionnaire given to university forensic students)

[6]Peer reviewer Prof. S. Tutwiler, PhD

The steps in this research and development process repeat a cycle of development of product, testing by different cohorts, qualitative evaluation of test results, and revision of product. This cycle was repeated three times and is diagramed in Figure l. The figure illustrates the entire process from needs assessment to final product.

The foundation of the process is the needs assessment, which forms the base of the pyramidal figure.   The size of the base represents the number of forensic scientists contributing to the assessment of needs, a number larger than the numbers of participants of the two field tests.

The cohort of the first field test of the product was nine university professors. The students who tested and evaluated the modified prototype of the second field test numbered eight. Between the second field test and the product was a short period of time during which the modified prototype was revamped to align with the comments of the university students.

The apex of the pyramid represents the final product: The Introductory Forensic Chemistry Course for University General Education.

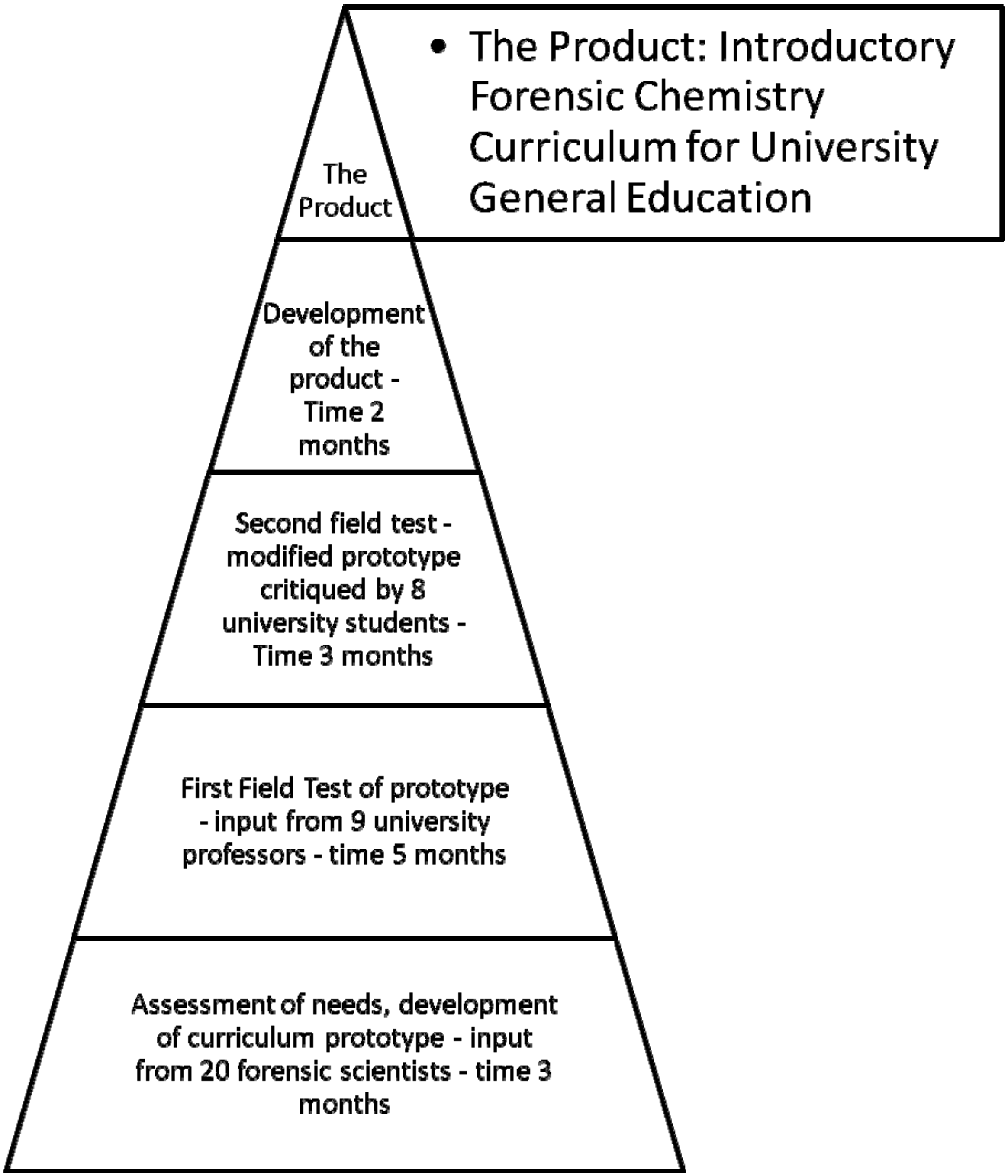

Figure 4.1 Research and development sequence of the study.

Needs Assessment

In March 2007, questionnaires (See Appendix A) targeting the need for a general education forensic chemical science course were mailed by surface and electronic mail to thirty forensic scientists, most of them active in the field, although some were recently retired. Twenty questionnaires (67%) were returned. The participants are represented numerically in Table 4.2 (next page). Anonymous responses are not a requirement of the R & D process, but the identities of these persons are protected for their security. For this study, numerical coding was used for the participants to keep the reporting tables free of clutter and to keep the reader focused on the comments, rather than the identity of the respondents.

Table 4.2 Experts Participating in the Needs Assessment

	Position	Organization	State
1.	Forensic Scientist	Kansas Bureau of Investigation	KS
2.	Forensic Pathologist (Coroner)	Shawnee County Coroner's Office	KS
3.	Forensic Scientist (Chemistry)	Kansas Bureau of Investigation	KS
4.	Special Agent (retired)	Kansas Bureau of Investigation	KS
5.	Forensic Scientist III (Chemistry)	Kansas Bureau of Investigation	KS
6.	Forensic Scientist	Kansas Bureau of Investigation	KS
7.	Special Investigator (retired)	Kansas Bureau of Investigation	KS
8.	Forensic Scientist	Kansas Bureau of Investigation	KS
9.	Forensic Scientist IV	Kansas Bureau of Investigation	KS
10.	Latent Print Chief	Kansas Bureau of Investigation	KS
11.	Forensic Scientist	Kansas Bureau of Investigation	KS
12.	Forensic Scientist	Kansas Bureau of Investigation	KS
13.	Forensic Scientist	Kansas Bureau of Investigation	KS
14.	Supervisor III	Kansas City Police Crime Lab	MO
15.	Forensic Scientist	Kansas Bureau of Investigation	KS
16.	Forensic Scientist (Biology)	Kansas Bureau of Investigation	KS
17.	Forensic Scientist III	Kansas Bureau of Investigation	KS
18.	Forensic Scientist III (Chemistry)	Kansas Bureau of Investigation	KS
19.	Chief Medical Investigator	Shawnee County Coroner's Office	KS
20.	Photographer (retired)	Kansas Bureau of Investigation	KS

The first item of the questionnaire asked, "Is there a need for persons outside the forensics area (jurors, lawyers, those working in the criminal justice field) to have a better understanding of forensic chemical science?" These forensic scientists saw an overwhelming need in this area: 15 (75%) said "Yes"; 4 (20%) said "No; and 1 (5%) responded "Both".

The priorities of the various needs reported by the respondents were coded 1, 2, or 3 – First, second, or third priority, respectively. Priorities, when identified by the forensic scientists were coded on the original questionnaires as follows: 1st priority, orange; 2nd priority, yellow; 3rd priority, green. The prioritized list of needs was instructive; however, several respondents commented on needs, but neglected to prioritize them. These were coded “C”. Introductory non-prioritized comments from forensic scientists were coded pink; final comments were coded blue. Table 4.3 shows the coded return from all forensic scientist questionnaires, both prioritized returns and the returns containing only comments.

The first category was mentioned by eight respondents. The second category was mentioned by more respondents (ten), but fewer chose to prioritize their comments of the “CSI effect”. Therefore, the “CSI effect” is listed second in importance in Table 4.3. The remainder of the Table 4.3 is organized similarly.

Table 4.3 Prioritized Needs for a University General Education Forensic Chemical Science Course

Priorities Enumerated by Forensic Scientists*	Categories
1, 1, 2, 2, 3, 3, C, C	Science: basics and limitations: (what can and cannot be analyzed; it can't be analyzed if it's not there)
1, 3,C, C, C, C, C, C, C, C	Counteract the "CSI effect" in jurors
1, C, C	Common sense
1, C	Statistics
1, C, C	Forensic scientists and police together complete the investigation
1	Time for analysis
1	Chemistry of the human body
1	Time of death
1	Logic of Results: margin of error: qualitative analysis
2	Expense of analyses and salaries (Understand necessary vs. unnecessary)
2 , C	DNA: How analyzed
2	Tests available
C	Lawyers need better knowledge of FCS to make better use of expert witness

*1 = First Priority

2 = Second Priority

3 = Third Priority

C = a non-prioritized comment by a forensic scientist

Full comments from the forensic scientists illuminate the coding. Fleshing out category 1, "the basics and limitations of the science", four scientists commented:

- First Priority: Lay people should be given "an introduction to the basics behind the sciences and the limitations of them".
- First Priority: They should know "what the results really mean both statistically and logically.

- First Priority: Lay people should understand "the chemical composition of human body fluids and which chemicals, common to a household, react with body fluids".

- Comment: Lay persons "should understand the limits of the forensics".

Categories 2, "counteracting the CSI effect" and 3, "common sense" were addressed by several scientists.

- Comment: One problem is that "we are letting the TV doing [sic] the teaching".

- Comment: "There are popular TV programs which plant seeds of misunderstanding in the minds of viewers."

- Comment: There are "huge misunderstandings about what forensic testing can really do, what it should do, how long it takes the testing to be complete, and how expensive excessive and unnecessary testing can be".

- Comment: "Any training should not only inform, but address misconceptions and be weighted on practicality."

- First Priority: Lay people should understand "what is involved (steps/process and length of time) in the testing processes"

- Second Priority: Lay people should understand "what type of testing is necessary/appropriate for a particular case" and "why some types of testing are NOT necessary for a particular sample/case"

- Third Priority: Lay people should understand "what type of testing is available in the field of forensic science".

- First Priority: "There is a need for people to have plain common sense."

- Comment: "There are huge misunderstandings about what forensic testing can really do, what it should do, how long it takes the testing to be complete and how expensive excessive and unnecessary testing can be."

- Comment: "Any training should not only inform, but address misconceptions and be weighted on practicality."

- First Priority: Lay people should understand "what is involved (steps/process and length of time) in the testing processes"

- Second Priority: Lay people should understand "what type of testing is necessary/appropriate for a particular case" and "why some types of testing are NOT necessary for a particular sample/case"

- Third Priority: Lay people should understand "what type of testing is available in the field of forensic science".

- First Priority: "There is a need for people to have plain common sense."

- Comment: "There are huge misunderstandings about what forensic testing can really do, what it should do, how long it takes the testing to be complete and how expensive excessive and unnecessary testing can be."

Four scientists addressed Category 5, The need for forensic scientists and the police to be involved:

- Comment: "The majority of the programs out there are not being instructed by forensic scientists with experience. Working in the field creates an appreciation and understanding for how science and math works together to create the field of forensic science. Having a degree in chemistry or biology alone does not make a person able to adequately teach forensics."

- Comment: "Any training should not only inform, but address misconceptions and be weighted on practicality."

- Comment: "An understanding of the chemistry is not as important as an understanding of what departments of the law enforcement community do and how they come to their conclusions."

- Comment: "Unfortunately, many schools throughout the country are adding to the problem by starting forensic science programs in which instructors with no practical forensic science experience teach about forensic science."

Based on the results of the Needs Assessment and the experience of the researcher, who has taught general education forensic chemistry for ten years, a Forensic Chemical Science course was developed. (See Appendix H – the complete course for the first field test – sent to instructors of general education natural science courses)

First Field Test – Analysis of Questionnaire

Subsequently, the Product was offered to thirty-six professors of forensic science courses in universities in the midwest. This listing was provided by Todd Zdorkowski, director of the Midwest Forensics Resource Center, Ames Lab, Iowa State University, Ames, IA. Five professors responded. The Product was then offered to thirteen university faculty members who attended a National Science Foundation sponsored Forensic Science workshop at Williams College in Williamstown, MA, in the summer of 2007. Three professors responded. One, a personal friend of the researcher, agreed to help with the course construction. These nine professors completed and returned questionnaires, and also analyzed the Product for the first field test.

Questionnaires were mailed by surface and electronic mail to nine professors associated with instruction in forensic science at the university level. (See Appendix C for names and institutions of the nine professors who completed questionnaires for this study.) These nine faculty members had expressed interest in helping with the project of developing a general education forensic chemistry course for university teaching. All are currently active in their universities, with appointments ranging from senior lecturer to department chair. All are or have been involved in the teaching of forensic sciences at the university level. Some have experience as expert witnesses. Individuals' demographics are presented in Table 4; persons in this group varied from 4 to 47 years experience in the area.

Table 4.4 Experts Participating in the First Field Test of the General Education Forensic Chemical Science Course

Participant	Position	# Years	State	Expert Witness*
Questionnaire & Product Analysis	Assist. Professor, Anal. Chemistry	4	CO	No
Questionnaire & Product Analysis	Chair, Chemistry & Engineering Physics	12	WI	Yes
Questionnaire only	Assoc. Professor, Molecular Biology	13	SD	Yes
Questionnaire only	University Forensic Lab Director	32	IN	Yes
Questionnaire & Product Analysis	Assist. Professor, Chemistry	6	MO	No
Questionnaire & Product Analysis	Community College Forensic Lab Director	47	KS	Yes
Questionnaire only	University Forensic and Investigative Sciences Program Director	31	IN	Yes
Questionnaire & Product Analysis	Senior Lecturer, Chemistry	9	TN	No
Product Analysis only	Associate Professor, Chemistry	?	IN	?

*A person who has training, education or experience on a particular subject and who is formally found to be qualified as an expert by a judge. (Office of the Attorney General, State of California)

First Field Test – Questionnaire Analysis

Over sixty items of interest were gleaned from analysis of the nine questionnaires. During the first coding, four categories arose from these sixty-plus items: Subject Areas, Science; Subject Areas, Non-science; Presentation of Content, Teaching Techniques, Delivery Systems; and Processes of Science, Analysis. Almost immediately it became obvious that the Subject Area, Science category contained items more properly categorized in two categories: Subject Area – Science, and Subject Area – Science

Applied to Forensics. Renamed, these categories became Pure Science and Applied Science – Forensics.

At this point, the items of interest were typed on separate pieces of paper, and each item was placed in one of the five categories and presented in random order in Table 4.5.

Table 4.5 First Categories from First Field Test Questionnaires

Pure Science	Applied Science Forensics	Subject Areas Non-Science	Presentation of Content Teaching Techniques Delivery Systems	Processes of Science Analysis
Measurements- Units & math	Crime scene investigation	Statistics and probability	Group work	Substance ID: chromatography, spectroscopy
Scientific method applied to forensics	Forensic entomology	Emphasis on Frye court case	Individual work	Inorganic analysis (spectroscopy)
Physical and chemical properties	Forensic odontology	Quality assurance/control	Seeing the material as relevant engages students	
Properties of matter	Forensic anthropology	Ethics	Mix it up every 20 minutes or so-maintain interest and attention	
Structure of matter (atoms & molecules)	Forensic pathology	Management and organization of the forensic laboratory	Process-oriented guided inquiry is difficult to plan and execute but is very effective if done correctly	
Organic analysis (bonding and intermolecular forces)	How to process a crime scene (cross-contamination)	Role of the expert witness	Incorporate as many methods as possible	
Basic nuclear chemistry	Fingerprints	Forensic computer science	Guided inquiry	
Energy (physics)	Questioned documents	Forensic science and the law	Smaller class size is better in general education	
Cell structure	Drug testing	Impression evidence	Individual work – best learning experience	
DNA	Blood spatter reconstruction	Firearms and toolmarks	Large classes (100): lecture, textbook, and some online sources are the only methods that work	
Genetics	Chemical development of blood patterns	Forensic engineering	Group work needs to be in a controlled setting	
	Body decomposition	Legality: Frye & Daubert	Lecture: efficient way to transfer information: doesn't work for some students	
	Hair and fiber analysis		Not effective: lecture, textbook, student papers	
			Group work – only small groups (2 or 3)	
			Lecture – convey lots of information	
			Lecture	
			Lab work – essential reality check	

Pure Science	Applied Science Forensics	Subject Areas Non-Science	Presentation of Content Teaching Techniques Delivery Systems	Processes of Science Analysis
			Laboratory work	
			Recitation	
			On-line – easier to grade	
			Lab work and presentations are most effective	
			Research papers don't work	
			Lab experiences	
			On-line work	
			Hands-on works	
			Paper and presentation – emphasize communication with peers	
			Lab work emphasizes concepts, maintains involvement and interest	
			Presentations more valuable than papers because of the peer review aspect	
			Student-researched presentations	
			Presentations can consume a lot of time	
			Student-researched papers	
			Textbook	

The items within Pure Science remained constant during the analysis, but Pure Science became Science Concepts, as that seemed to more clearly characterize the items within the category. The items are: measurements – units and math; properties of matter, physical and chemical properties; structure of matter (atoms & molecules); basic nuclear chemistry; energy; cell structure, DNA, and genetics; scientific method applied to forensics. These items will be discussed in more depth during the construction of the course for the second field test.

The category Presentation of Content, Teaching Techniques, and Delivery Systems was the most cumbersome, both in title and in number of items; therefore, the coding changes began with this category. First, the name of the category was changed to Learning Strategies because what is being designed is a student-centered, not teacher-centered, course: a course which will encourage creative learning on the part of the students, not necessarily creative teaching on the part of the instructor.

Next the items within Learning Strategies were arranged into two large subcategories: Individual Work and Group Work. Individual Work contained the items of on-line work, the textbook, and recitation. Group Work contained lab work and student presentations.

Several comments were made about lecture, which is conspicuous by its absence in the grouping. One reviewer stated that lecture, the textbook, and student papers are not effective. Two reviewers stated that lecture conveys lots of information, and that lecture is an efficient way to transfer information. Bottom line: provided by one reviewer – lecture is not a learning strategy, and is not effective as a teaching strategy. Because of the ability of a lecturer to deliver large amounts of information in a short period, lecture can be an efficient method of instruction, but when student learning is entered into the equation, the lack of effectiveness of lecture is exposed.

Within the subcategory Individual Work, five reviewers out of eight said they do not use on-line work in their courses or did not mention on-line work in their reviews. The textbook appears in the Individual Work sub-category because seven of eight reviewers recommended it, indicating that the textbook has a place in the student's arsenal of learning tools.

Recitation, which can be defined as "a student's oral reply to questions and a class period especially in association with and for review of a lecture" (Merriam-Webster Online Dictionary, 2008) will be discussed in more detail during development of the Second Field Test course. For now, it remains one of three techniques in the Individual Work subcategory.

Several reviewers commented on the value of small group work. One professor observed that smaller class size is better in general education classes. Two professors commented that it is best to mix up techniques every twenty minutes or so to maintain interest and attention and that one should incorporate as many methods as possible. Guided inquiry is a learning technique that can be used most effectively in small (defined as 2 or 3 students by one reviewer) group work. This technique is most effective with product production, such as that resulting from student-researched presentations and laboratory work; therefore, inquiry is embedded within the two areas of group work: laboratory work and student-researched presentations.

One reviewer stated that laboratory work and presentations are most effective. In addition to this reviewer, five other professors recommended laboratory work. One commented that lab work emphasizes concepts and maintains involvement and interest. Another pointed out that lab work is the essential reality check. A third reviewer commented that "hands-on works". The hands-on/inquiry dichotomy will be discussed more in the section dealing with the development of the course for the Second Field Test.

The final item in the subcategory of group work is student-researched presentations. Overall, the reviewers felt that papers do not promote learning, and that presentations are more valuable because of the peer review aspect. One reviewer pointed out that presentations can consume a lot of time, but they also emphasize communication with peers. Reviewers said that laboratory work and presentations were the group work techniques from which students gain the most, and they are self-assessing.

This analysis is tabulated in Table 4.6.

Table 4.6 Category: Learning Techniques Stressing Inquiry

Individual Work	Group Work
On-line	Laboratory work
Textbook	Student-researched presentations
Recitation	

Once the Learning Techniques category was outlined, four categories remained: Pure Science, Applied Science Forensics, Subject Areas Non-Science, and Processes of Science Analysis. As items migrated back and forth among these four categories, designations of the categories evolved: Pure Science became Science Concepts, Applied Science Forensics became Direct Scientific Analysis of Forensic Samples, and Processes of Science Analysis became Instrumental Analysis of Forensic Samples.

The science concepts suggested by the professors in their questionnaire answers remained constant. However, the concepts were rearranged into an improved sequence with which to design the course for the second field test. Also, eleven items were regrouped into seven items by combining concepts that were similar or would be taught in close proximity. Measurements – Units & Math remained; the Scientific Method Applied to Forensics remained unchanged. Properties of Matter was incorporated into Physical and Chemical Properties of Matter. Structure of Matter (atoms & molecules) remained as did Basic Nuclear Chemistry. Organic analysis (bonding and intermolecular forces) also remained in the listing. Within the genetics category, structure of DNA and function of DNA were added to more tightly define genetics in the science category. DNA analysis then belongs in either the analytical or forensic category, the application of science categories. Finally, the designation that one physics professor had appended to the concept of energy was removed. Energy underlies all the concepts, so the category became Science Concepts, with an underlying emphasis on energy.

The Science Concepts from the analysis of professor questionnaires is outlined in Table 4.7.

Table 4.7 Learning Techniques Stressing Inquiry and Science Concepts

Science Concepts Stressing Energy	Learning Techniques Stressing Inquiry	
Measurements – units and math	Individual Work	Group Work
Scientific method applied to forensics	On-line	Laboratory work
Physical and chemical properties of matter	Textbook	Student-researched presentations
Structure of matter (atoms & molecules)	Recitation	
Basic nuclear chemistry		
Organic analysis (bonding and intermolecular forces)		
Cell structure; DNA structure and function; genetics		

The items in the category Instrumental Analysis of Forensic Samples arise directly from items in the Science Concepts category. Inorganic analysis – spectroscopy - is based on the atomic structure of atoms. Substance identification – chromatography - is based on organic bonding and intermolecular forces. The term "spectroscopy" was deleted from this item, as it was already in an item of its own. The item "drug testing" is included within the item "chromatography". Whereas no professor mentioned it, DNA analysis by polymerase chain reaction – short tandem repeats (PCR-STR) was added based on its frequency of use in forensic laboratories. According to Saferstein (2007), all forensic science curricula should include the DNA analysis (PCR-STR) most used in forensic laboratories today. This analytical technique arises directly from the discussion of DNA structure and function.

Three categories are now organized and outlined in teaching order in Table 4.8.

Table 4.8 Science Concepts and Instrumental Analysis of Forensic Samples

Science Concepts Stressing Energy	**Instrumental Analysis of Forensic Samples**
Measurements – units and math	
Scientific method applied to forensics	
Physical and chemical properties of matter	
Structure of matter (atoms & molecules)	Inorganic analysis (spectroscopy)
Basic nuclear chemistry	
Organic analysis (bonding and intermolecular forces)	Substance identification: chromatography
Cell structure; DNA structure and function; genetics	DNA analysis by PCR-STRs

Table 4.9 Learning Techniques Stressing Inquiry

Individual Work	**Group Work**
On-line	Laboratory work
Textbook	Student-researched presentations
Recitation	

Two categories remained to be analyzed: Applied Science Forensics and Subject Areas Non-Science. At this point in the analysis, Applied Science Forensics was renamed Science Applied Directly to Forensic Samples, so as to distinguish it from the category Instrumental Analysis of Forensic Samples.

In the category Science Applied Directly to Forensic Samples were the items: crime scene investigation, forensic entomology, forensic odontology, forensic anthropology, forensic pathology, how to process a crime scene (cross-contamination), fingerprints, questioned documents, drug testing, blood spatter reconstruction, chemical development of blood patterns, body decomposition, and hair and fiber analysis.

The category Subject Areas Non-Science contained the items Statistics and probability, Emphasis on Frye court case, Quality assurance/control, Ethics, Management and organization of the forensic laboratory, Role of the expert witness, Forensic computer science, Forensic science and the law, Impression evidence, Firearms and toolmarks, Forensic engineering, and Legality: Frye & Daubert. It was almost immediately obvious that Forensic computer science, Impression evidence, Firearms and toolmarks, and Forensic engineering were four items that belonged not with Non-Science, but in the category Science Applied Directly to Forensic Samples. Firearms and toolmarks are subsets within Impression evidence, the more inclusive term (Saferstein, 2007). How to process a crime scene (cross-contamination) was condensed under the more general Crime Scene Investigation.

This left the Subject Areas Non-Science containing only those items of legality and items which, while important, do not require a deep scientific background to understand. The three items which were totally devoted to the legal aspects of forensics (Emphasis on Frye court case, Legality: Frye & Daubert, and Forensic Science and the Law) were condensed into one item called Forensic Science and the Law. At this point all items mentioned by all professors were categorized.

Table 4.9 displays the final categories and items from the analysis of the questionnaires. The Instrumental Analysis of Forensic Samples category was moved so that it would be next to the Science Concepts Stressing Energy category, as understanding of some science concepts is required for understanding of some instrumental analyses. For example, it is necessary for students to understand the structure of matter, specifically as applied to the structure of atoms and molecules in order to understand spectroscopy. Inorganic analysis of forensic samples relies on several types of spectroscopy. Also, knowledge of organic analysis, including bonding and intermolecular forces, is necessary for understanding chromatography, one of the main analytical techniques for analyzing and identifying various substances in the forensic lab. Likewise, DNA structure and function are basic to analyzing DNA in the forensic lab.

Table 4.10 Categories from First Field Test Questionnaires

Science Concepts Stressing Energy	Instrumental Analysis of Forensic Samples	Science Applied Directly to Forensic Samples	Subject Areas Non-Science	Learning Techniques Stressing Inquiry	
Measurements – units and math	Inorganic analysis (spectroscopy)	Crime scene investigation	Quality Assurance/Control	Individual Work • Online • Textbook • Recitation	Group Work • Laboratory work • Student-researched presentations
Scientific method applied to forensics	Substance identification: chromatography	Forensic entomology	Statistics and probability		
Physical and chemical properties of matter	DNA analysis by PCR-STRs	Forensic odontology	Ethics		
Structure of matter (atoms & molecules)		Forensic anthropology	Role of Expert Witness		
Basic nuclear chemistry		Forensic pathology	Management and organization of the forensic lab		
Organic analysis (bonding and intermolecular forces)		Fingerprints	Forensic science and the law		
Cell structure; DNA structure and function; genetics		Questioned documents			
		Drug testing			
		Blood spatter reconstruction			
		Chemical development of blood patterns			
		Body decomposition			
		Hair and fiber analysis			
		Impression evidence			
		Forensic computer science			
		Forensic engineering			

First Field Test – Analysis of Course

The same professors who answered the First Field Test questionnaire also critiqued the First Field Test course. Their comments are summarized in Table 4.11.

Table 4.11 Comments by Professors on First Field Test Course

Unit I Comments
• Conversions: Known conversions, dozen eggs, etc. Important to emphasize that a unit does not change the "amount" • Physical properties glass/soil: emphasize intensive vs extensive; what advantage/disadvantage a consideration of each type gives the investigator • pH: Log units? Any discussion of acid/base chemistry? Buffers? • Exp glass density limited in detail, same other labs • Understand scientific method and applications • Understand adversarial system • Compare / contrast adversarial system and scientific method as to determining truth • Admissibility of evidence and expert testimony • Measurement, precision, accuracy • Color as a physical property
Unit II Comments
• Ppm and ppb should be taught as mass functions; Diffraction might fit in better directly with atomic structure/molecular structure; Diffraction of more of a scattering even than an absorption or emission event. Atomic structure is certainly the key starting point for both radioactive decay kinetics and basic spectroscopy . . . there is a potential for the students to see them as vastly different. How much kinetics? AA lab: AA of simulated samples; might be fun to cover sample prep: oxidation/reduction of metals and acids if time allows • Revisit bullet analysis lab. Discuss recent events related to this field. • Qualitative vs quantitative analysis • Classification and individualization (classical analytical chem. Vs forensic chem.) • Pure substances vs mixtures (relationship between mixture composition and its physical properties) • Atomic theory discussed before electronic structure and bonding • Students should understand that the samples given to them were prepared by dissolving metal fragments; Bring in the FBI bullet ID problem • Eliminate AA lab: FBI unreliable method for bullets (soil?)
Unit III Comments
• Add polar and non-polar bonds and dipole moments; chromatography is based on intermolecular forces (magnet analogy) • Likes that the chromatography lab requires cooperation of the whole class! • Use thin layer for ink chromatography

Unit IV Comments
• IR and Raman analysis are now useful for quick identification of drugs • Relationship between biochemistry and drug classification? • Emphasize sample prep for drugs & DNA; also sample preservation from crime scene; physical inspection (by police) of drugs confiscated by police; microscopy of vegetation; color and texture for solids; Prescription pills can be identifies using the "Drug Identification Bible" and confirmed by GC/MS
Comments on Appendices
• Great discussion topics! • CSI Paper: Very nice idea • Discussions: Very nice; We spent 4 hrs discussing #1.
General Comments
• Recommend adding fingerprinting and die and tool impressions, if resources allow • Course short on content - flesh it out • Specific course objectives, tie in how each topic and each experiment contributes to the goals and objectives • Types of forensic evidence and analyses
Comments on Speakers and Videos
• Think these out better
Comments on Subjects to be Covered
• Chemical properties and qualitative testing for drugs, blood and semen • Chemical and physical properties of latent fingerprints that allow us to visualize them • Trace evidence/ Locard's exchange principle – relate to atomic/molecular nature of matter • Evidence collection and preservation – chain of custody • Evidence admissibility standards
Comments on Delivery Methods
• Experiments that illustrate the relevance of the subject matter are a key delivery method • Group learning is effective for both lab & classroom work • Guided inquiry is best for helping a student internalize knowledge – all labs Permission for labs "Used with permission from" • Labs – include all materials & instructions for preparation • Mock trials if time allows

Development of Product for Second Field Test

The Product Course for the Second Field Test (Appendix D – course provided for analysis by the university students) was developed using all available data collected to date: the Needs Assessment and prioritized comments from forensic scientists, the analysis of the questionnaires (Appendix B- questionnaire to instructors of general education natural science courses) provided by professors teaching in the field of forensic science, and the critiques of the Product Course for the First Field Test (Appendix I-course prototype provided for analysis by the university professors) provided by some of the same professors who answered the questionnaires (see Table 1 – Data Collection). The structure remains similar to that of the Product Course for the First Field Test, but additions, deletions, and changes were made with reference to the research mentioned above.

The Course for the Second Field Test (see Appendix D – course provided for comment to university students) was developed from the Course (Appendix I-course provided for comment to the university instructors) from the First Field Test by addition and/or expansion of the topics covered. The revisions were based on the analysis (see Appendix B – forensic scientist questionnaire comments) of the questionnaires returned by forensic scientists as well as the analysis (see Appendix C – questionnaire sent to instructors of general education natural science courses and Table 10) of questionnaires returned by the professors and the comments (Table 11) by the professors on First Field Test Course. For example, crime scene investigation including measurement, accuracy, precision and scientific method were among the topics added to Unit I of the Second Field Test Course.

The Second Field Test Course was offered for critique to all forty-seven students in the researcher's general education Introductory Forensic Chemistry courses in the Spring semester 2008. Eight students responded. Each of the students signed a "Form of Consent – Research Involving Human Subjects" (Appendix F – Kansas State University Form of Consent) indicating that his/her participation was voluntary and not coerced by the researcher. For their part in this research, some of these students elected to complete the questionnaire (Appendix E – questionnaire provided to university students) and/or analyze the Product: the Second Field Test Course (Appendix D-course designed for student analysis).

Of the six students who completed the questionnaire, one was a freshman, two were sophomores, two were seniors, and one did not give a year in school. Three students were business majors (2 accounting and 1 finance major), one a communications major with a minor in psychology, one a criminal justice major, and one a forensic chemical science major. For three of these students Introductory Forensic Chemistry was the first general education science course they had taken. The other three students had taken a general education environmental chemistry course or biology course before taking the introductory forensic chemistry course. Table 11 summarizes the comments of the students on the science they learned in the introductory forensic chemistry course and how they learn best overall.

Table 4.12 Selected Student Responses for Science Concepts Learned and Best Learning Techniques From Second Field Test Questionnaire

Science Concepts Learned and Instructional Techniques Used Most Successfully	Best Learning Techniques Overall
• Chromatography – lecture, text, group work, lab • DNA – Lecture, text, group work, online discussion • Electron dot structures – lecture, peer tutoring, online resources • Organic compounds – lecture, individual work • Periodic table – lecture, quizzes, online work • Science – based math-lecture, group work • Spectroscopy – lecture, lab, group work • Qualitative/quantitative measurements – lecture • Density – lecture, lab, group work • Atomic structure – lecture, group work • All science – lecture, lab, recitation, peer tutoring once a week • All science – lecture, lab, recitation, non-lab group work, individual work • All science – textbook • All science – lecture, student presentations	• Controlled group work – all members of group engaged • Homework problems • Hands-on practice • Individual work • Laboratory work • Lecture • On-line resources • Socratic teaching • Real life examples • Visually from power point presentations or drawings

Some students commented about their personal learning styles:

- "Individual work (it's) best to read and figure it out myself."
- "I learn best from lectures. Sometimes students can read an entire chapter and have no idea what they just read (me!). Listening to a lecture is so much more interesting and educational. The teacher can put spins on

things that you would never have thought about. They can also use examples and presentations that help me to better understand certain concepts. It is much easier to think critically when taking tests after you have listened to the teacher talk about a specific subject and made it interesting."

- "One avenue that I routinely use is the textbook's web site that utilizes an interactive guide and quiz."
- "Socratic teaching (allows me to) learn most – each student (should) speak at least once per class period."

Summary

The three distinct parts of the methodology (the needs assessment, the first field test, and second field test) and their respective participants (forensic scientists, faculty who teach forensic science, and university students) gave clear direction to the progress of this research and the development of this product. The forensic scientists validated the need for this product; the faculty instructors suggested topics and learning techniques; the students shared their own valued learning techniques to round out the research. The product (Chapter 5) incorporates suggestions from all three groups of participants.

CHAPTER 5 - The Product

The Product, a course for a one-semester forensic chemistry course designed for the general education of university undergraduates, was developed with input from three groups of persons: the needs assessment by questionnaire from forensic scientists, the evaluation of the First Field Test (FFT) course and questionnaires from university professors teaching forensic science, and university students in a forensic chemistry course who evaluated the Second Field Test (SFT) course and answered a questionnaire about their personal learning techniques.

The forensic scientists declared the need for this product. Following Tyler's (1949) fundamental questions for course development, the professors suggested both educational purposes needed to be attained and also educational experiences likely to attain these purposes. The educational experiences were organized during the qualitative analysis of the data from the professors' answers to the questionnaires and also their analysis of the FFT course. The students who participated in the Second Field Test by answering the questionnaire and/or analyzing the SFT course determined whether the educational experiences were attained.

The Product is a version of the SFT course, revised to make it more congruent with the needs of the students and more consistent with some suggestions of the professors, suggestions that were overlooked in the period between the FFT course and the development of the SFT course.

Development of the Product

One student commented that the textbook and accompanying website were valuable study aids; therefore, the publishing information of two forensic science or criminalistics textbooks associated with web sites was added to the cover page of the Product.

Unit I underwent minor changes based on the students' review. Overlooked during the development of the SFT course, color as an important intensive physical property of materials was added to the Topics Covered in Unit I.

One change was made in Unit II. Several professors commented on the substantial changes in the analyses of bullets over the past forty years, specifically since the John F. Kennedy assassination. Since one of the laboratory exercises for this unit is based on the older method and the JFK assassination case, one professor suggested the lab be eliminated, but two professors suggested discussion of the FBI bullet identification problem and recent events related to this field. The researcher added discussion of the problem to Unit II.

Unit III – Organic Analysis Emphasizing Chromatography - remained unchanged From the SFT course to the final Product. Regarding Unit IV, the single change was the addition of infrared (IR) analysis to Topics Covered, A. Drugs. This was done following the suggestion of one of the professors.

This study was partially based on three of Tyler's (1949) four fundamental questions for course development.

1. What educational purposes need to be attained?
2. What educational experiences can be provided to attain these purposes?
3. How can these educational experiences be effectively organized?

Educational needs were defined by the forensic scientists who returned the first questionnaire. Their thoughtful answers to the questions provided the base upon which the rest of the course was built: a pragmatic base in that these people grapple daily with the concepts professors and students only study from afar.

The educational experiences were provided by the professors who answered the questionnaire designed for them. These people, who work daily teaching forensic science, provided high quality responses to the questions they were asked. The organization of these topics by the researcher formed the outline for the Product (below).

Students are those for whom a course is ultimately designed. Students who answered the questionnaire generally added to the knowledge gained from this project by sharing techniques which benefit them in study of forensic science topics. These learning techniques are summarized in Chapter 6 – Conclusions.

Introductory Forensic Chemistry: On the Cutting Edge

A one-semester course designed for the general education of university undergraduates

Suggested Textbooks

Saferstein, R. (2007) *Criminalistics: An Introduction to Forensic Science.* Upper Saddle River, NJ: Prentice Hall

Girard, J.E. (2009) *Criminalistics: Science and Crime.* Boston: Jones & Bartlett

Unit I – Physical Properties of Materials
Emphasis on Glass and Soil

Laboratory: Inquiry into analysis of glass fragments (see next page)

Guest Speaker: Practicing or retired forensic scientist discussing:

1. Science: its basics and limitations (what can and cannot be analyzed; it can't be analyzed if it's not there)
2. How the "CSI" effect in jurors can be counteracted
3. Common sense applied to forensic analyses

(See Appendix 4 for additional topics for discussion by forensic scientists.)

Topics Covered

A. Crime scene investigation
   1. Measurement – accuracy and precision
   2. Scientific method applied to investigation

B. Mathematics
   1. Metric / metric conversions
   2. Metric / English conversions
   3. Significant digits

C. Physical properties of materials
   1. Intensive – forensic value (advantage / disadvantage)
      a. Temperature
      b. Density
      c. Refractive index
      d. Gross appearance
      e. pH
      f. color

   2. Extensive – forensic value (advantage / disadvantage)
      a. Weight / mass
      b. Volume

   3. Glass fractures

Introductory Forensic Chemistry Laboratory Exercise I
Inquiry into Crime Scene Glass Analysis
To be done after discussion of density in lecture
Group work: 2 – 3 students

Set the stage:

Your task, if you accept it, is to analyze the four samples of glass given to you: one questioned sample (from the crime scene) and three known samples (from three different suspects). In order to analyze these samples, you will have access to the following equipment and supplies:

Goggles
Nitrile gloves
Magnifying glass
Ruler
Electronic balance
Graduated cylinder
Deionized, distilled, or tap water

You may ask for any other item you want / need, and if it is available, your lab instructor will get it for you or explain why you may not use it. **However:** density analysis is required.

Your laboratory report:

1) Describe everything you do and the results of your experimentation. When using measurements, record to the precision of the instrument / equipment you are using. When doing calculations, show all work, and report the answer(s) to the correct number of significant digits.
2) You are to determine, if possible, whether any of the known samples can be eliminated as being different from the questioned sample. If you think a known sample might be the same as the questioned sample, discuss / list (in detail and specifically) all the similarities you found.
3) Discuss your testimony as an expert witness. In other words, what you can testify to in regards to your analysis in the lab. **Be specific and concise. Testify to only what you did and saw with your own eyes. Remember that elimination of suspects is more reliable with class evidence than is identification.**

Unit II – General Inorganic Analysis by Spectroscopy

Laboratory: Choice of two or, if time allows, both. (See following pages.)

1. Bullet Fragment Analysis by Atomic Absorption Spectrophotometry
   This laboratory exercise is a nice example of the analysis of the bullet fragments in the Kennedy assassination case. The results are designed to be similar, although the analysis techniques are different. This laboratory experiment can lead into two areas of discussion: 1) Why was Neutron Activation Analysis used on the real bullet fragments? And 2) What led to the decision of the FBI to stop using this method for bullet fragment analysis?
2. Inquiry into glass fragments

Guest Speaker: Practicing or retired forensic scientist discussing:

1. How forensic scientists and police together complete the investigation
2. How long analyses take
3. Logic of results, margin of error, and the value of qualitative analysis
4. Role of the expert witness

(See Appendix 4 for additional topics for discussion by forensic scientists.)

Topics Covered

A. Mathematics concepts
   1. Percentage
   2. Parts per million (ppm)
   3. Parts per billion (ppb)
   4. Interconversion of above

B. Atomic Structure
   1. Electron energy levels and sublevels
   2. Electron configuration and dot diagrams
   3. Isotopes

C. Nuclear decay reactions and neutron activation analysis

D. Basic spectroscopy
   1. Qualitative / quantitative analyses
   2. Basic spectroscopy
      a. Inductively coupled plasma - Optical Emission Spectrophotometry (ICP-OES)
      b. Atomic absorption spectroscopy (AAS)
      c. X-ray analyses
         i. X-ray diffraction (XRD)
         ii. X-ray fluorescence or microfluorescence (XRF)

Simulated Analysis of Trace Amounts of Silver in Bullet Fragments
Introductory Forensic Chemistry Laboratory Exercise II

(To be done immediately before or after discussion of the FBI's revision of its stand on trace element analysis of bullets.)

loosely patterned after V.P. Guinn's neutron activation analysis of trace silver amounts (Guinn, 1979) in the bullet fragments from the John F. Kennedy assassination

Analysis of silver by flame atomic absorption spectroscopy

Introduction

Over the past thirty-seven years, much controversy has arisen concerning the assassination of John F. Kennedy. (Lifton, 1980) Complete lifetimes have been spent analyzing evidence and predicting convincing scenarios different from that outlined the Warren Commission report. (Menninger, 1992)

Prior to the analysis of the actual bullet fragments from the assassination, Guinn "analyzed a number of samples of WCC/MC 6.5-mm bullet lead, from all four of the production lots made by WCC." (Guinn, p 486A) This study showed that bullet lots were heterogeneous, especially in the trace amounts of silver and antimony, but individual bullets were particularly homogeneous in regards to these elements. Therefore, an analysis of the trace amounts of silver or antimony should give a good indication of the total number of bullets from which the six "fragments" came.

Silver is our trace metal of choice, as it is detected at low ppm levels on our instrument.

Procedure

After the instrument has warmed up, a calibration curve will be calculated using a blank and three standards of 2.0 ppm Ag, 6.0 ppm Ag, and 12.0 ppm Ag. Four unknowns, W1 through W4, will be analyzed. (The bullet fragments to be analyzed have already been dissolved in acid in order to facilitate the time in lab.) The number of bullets represented by the four samples (fragments) will be determined.

A. Calibration curve determination:
   1. With the tubing in the blank press the appropriate button to analyze.
   2. Record the absorbance value and the standard deviation on your data sheet.
   3. Place the tubing into the deionized (DI) water to rinse.
   4. Place the plastic tubing into the low standard (2.0 ppm Ag).
   5. Press the appropriate button to analyze.
   6. Place the tubing into the DI water to rinse.
   7. Repeat #4,5, and 6 with the mid standard (6.0 ppm Ag) and the high standard (12.0 ppm Ag).
   8. Record standard concentrations and all absorbance readings on your data sheet.

B. Analyzing samples: Analyze samples by placing the plastic tubing into each sample container and pressing the appropriate button to analyze. Rinse between samples as before with DI water.

DATA SHEET

Solution	Concentration	Absorbance
Blank		
Low Standard		
Mid Standard		
High Standard		
W1		
W2		
W3		
W4		

C. Graph the calibration curve using the data from the blank and the three standards using Microsoft Excel. If the linear regression line misses any points by a large amount, see your instructor.

D. Using the mean ppm (mg/L) values and standard deviations for the bullet fragment solutions, determine how many bullets are represented by the four solutions.

NOTE: Use [Ag] unknown values close to the values in Guinn (1979) so the students not only get a learning experience, but feel that they are recreating a piece of history.

Bibliography

Guinn, V.P. "JFK Assassination: Bullet Analyses", Analytical Chemistry, 51 (1979), 484A. Copyright 1979, American Chemical Society.

Lifton, David S. Best Evidence. New York: Macmillan, 1980.

Menninger, Bonar. Mortal Error: The Shot That Killed JFK. New York: St. Martin's Press, 1992.

Introductory Forensic Chemistry Laboratory Exercise III

Inquiry into Crime Scene Soil Analysis

Group work: 2 – 3 students

(To be done after discussion/demonstration of heat-activated emission of elements)

Set the stage:

Your task, if you accept it, is to analyze the four samples of soil given to you: one questioned sample (from the crime scene) and three known samples (from three different suspects). In order to analyze these samples, you will have access to the following equipment and supplies:

Goggles
Nitrile gloves
Magnifying glass
Ruler
Electronic balance
Nichrome wire
Solution of hydrochloric acid
Bunsen burner
Spot plates
Cobalt glass

You may ask for any other item you want / need, and if it is available, your lab instructor will get it for you or explain why you may not use it. **However:** Emission analysis is required.

Your laboratory report:

1) Describe everything you do and the results of your experimentation. When using measurements, record to the precision of the instrument / equipment you are using. When doing calculations, show all work, and report the answer(s) to the correct number of significant digits.
2) You are to determine, if possible, whether any of the known samples can be eliminated as being different from the questioned sample. If you think a known sample might be the same as the questioned sample, discuss / list (in detail and specifically) all the similarities you found.
3) Discuss your testimony as an expert witness. In other words, what you will suggest that the prosecuting attorney ask and what you can testify to in regards to your analysis in the lab. **Be specific and concise. Testify to only what you did and saw with your own eyes. Remember that elimination of suspects is more reliable with class evidence than is identification.**

Unit III – Organic Analysis Emphasizing Chromatography

Laboratory: Thin Layer Chromatography of Inks (See next page.)

Guest Speaker: Practicing or retired coroner or medical examiner discussing

1. Determination of time of death
2. Chemistry of the human body

(See Appendix 4 for additional topics for discussion by forensic scientists.)

Topics Covered:

A. Organic compounds (good for recitation)
   1. Lewis electron dot structures
   2. Molecular mass
   3. Molecular shapes
   4. Polar and nonpolar bonds

B. Oxidation/Combustion Reactions
   1. Balancing chemical equations
   2. Covalent bond energy

C. Introduction to chromatography and mass spectrometry

Analysis of Ink by Thin Layer Chromatography
Introductory Forensic Chemistry Laboratory Exercise IV

Modified with permission from: Meloan, Clifton E., Richard E. James, and Richard Saferstein.
Lab Manual: Criminalistics: An Introduction to Forensic Science, 6th ed.
Upper Saddle River, NJ: Prentice Hall, 1998.

The thin layer technique is based on the fact that silica gel contains a thin film of water, called a **stationary phase**. A mixture of the compounds to be separated is placed in a small spot at one end of the gel-covered plate, and an organic solvent (**mobile phase**) is passed over the spot and across the paper. Since each compound present has a different size, shape, and distribution of electrical field, each compound will dissolve in water and the organic solvent to a different extent.

The net result is that if two compounds are started at the same place and solvent passed over them, one compound will move along the paper faster than the other. After a period of time, the flow of the mobile phase is stopped. The plate is dried and then sprayed with a reagent that will produce colored spots, if the compounds are not colored. The materials used in our experiment - inks - are already colored, so the latter step is not required.

Some years ago the color in inks was made of a single component substance. Therefore, when this ink was chromatographed, only one colored spot was evident. Inks manufactured in more recent times are more often multi-component materials, with the ink color due to a mixture of dyes. These inks, then, show a variety of colored spots when chromatographic separation is performed.

In this analysis we determine which type of ink pen was used to write a certain document.

CRIME SCENE

A document has been submitted to the document examination section of a forensic laboratory with the following explanation and request:

A ransom note was left at the scene of the kidnapping of Jack E. Lapping, beloved Labrador retriever of the Prince and Princess of Wellington. The note was hand-written in blue ink. After investigation, proper search warrants were issued, and pens were seized from four suspects. Using thin layer chromatography, you are to determine which pen might possibly have written the ransom note. Your plate will be given to you spotted with ink from the ransom note.

Preparation for chromatographing the ink samples involves the determination of a proper developing solvent. This will be done during the course of the laboratory.

EQUIPMENT
600 or 800 mL beakers
150 mm watch glasses
Silica gel thin layer plates
pencils

REAGENTS
Deionized water
Ethanol (denatured)
Hydrochloric acid, 0.1 M
Methanol
Water-methanol, 50:50 (v/v)
Water-ethanol, 50:50 (v/v)

METHOD

1. Make up a developing chamber for one of the reagents above. (Each solvent system will be chosen by one or two groups in order for all of us to determine which system works best.) Pour a small amount of your reagent (should be below the pencil line on the chromatography plate) into a 600 mL beaker and cover with a watch glass. This will allow the solvent to saturate the atmosphere inside the beaker before you are ready to start the chromatogram.

2. Spot the four suspect pens on the **pencil** line on which the crime scene ink is spotted. Spot and dry once. Try to make each spot as small as possible. Try not to get fingerprints on the paper.

3. Lower the paper into the solvent, with the pencil line toward the bottom of the beaker, but do not immerse the spots. Replace the watch glass, dome side up. Let the solvent come up the plate over the spots by capillary action.

4.Observe the developing chromatograms of your classmates, and note differences and similarities.

5. Allow the solvent to rise up the plate until it reaches a point approximately 4 cm from the top of the paper or until the rise slows perceptibly.

6. Remove the plate, mark the solvent front and allow the strip to dry on a clean sheet of paper.

7. Look at the chromatograms of your classmates to determine which solvent system gave the best separation

8. Determine, if you can, which pen most likely was used to write the ransom note. If, from your experiment, you cannot determine a difference, use a different solvent system and try again, if time allows.

DATA SHEET

1. What solvent did you use?

2. Which component was most soluble in this solvent? How can you tell?

3. Is the order of colors on the papers the same in every case of solvent used? Explain.

4. What is the maximum number of different colors that you see on a chromatogram? What are these colors?

5. In your opinion, which pen wrote the ransom note? Why?

6. Attach plate(s) here.

Unit IV - Analysis of Drugs and DNA

Laboratory: Paper DNA analysis: "A Case of Abduction – Mitochondrial DNA Identity Testing" by William H. Humphries and Diane L. Baker, copy write 2002, Flinn Scientific, Inc.

Introductory Forensic Chemistry Laboratory Exercise V

Guest Speaker: Practicing or recently retired forensic scientist discussing:

1. How DNA is analyzed
2. Statistics applied to DNA analysis
3. Expense of analyses and salaries (Discuss necessary vs. unnecessary analyses and analysts)

(See Appendix 4 for additional topics for discussion by forensic scientists.)

Topics Covered

A. Drugs
   1. Formulas, structures, and molecular weight calculations
   2. Analysis of gas chromatograms and mass spectra
   3. Infrared (IR) analysis

B. DNA
   1. Structure
   2. Function
   3. Forensic applications
      i. PCR using STR
      ii. RFLP
      iii. Statistical analysis

APPENDICES

These learning techniques can all be used with the same class, or different techniques can be used as time and student interest/abilities allow.

APPENDIX 1 - ONE PAPER

The paper will analyze one episode from the first six seasons of the original CSI (available in DVD format). Each person will have his/her own episode to work with, in other words, two people **cannot** use the same episode, and first come, first served.

The author will choose 10 instances in the episode where forensic science was used and will analyze each. To analyze means to discuss in appropriate detail and explain – in writing – whether collection, processing, and/or analysis was correct or incorrect and document each instance with at least one reference. (If using internet references, please choose .gov, .org, or .edu) Use APA style when reporting references at the end of the paper.

The papers will be posted (anonymously or not – by author's choice) on a web site where all of us can view them.

APPENDIX 2 – STUDENT PRESENTATIONS

Each group of 2 or 3 students will choose a topic from the list below. The rubric by which these presentations are to be graded is on the next page.

Forensic entomology
Forensic odontology
Forensic anthropology
Fingerprinting
Questioned documents
Blood spatter reconstruction
Chemical development of blood patterns
Hair and fiber analysis
Impression evidence
Forensic computer science
Forensic engineering
It's the Law: Frye and Daubert

PRESENTATION RUBRIC

Areas	**Excellent** 10 points	**Good** 8 points	**Fair** 6 points	**Minimal Effort** 4 points
Content	Information presented with introduction, body, conclusion and much supporting data	Information presented in logical order with some supporting data	Information presented in logical order	Irrelevant material and few details
Answers to Questions ***Indicates depth of research***	Indicate in-depth knowledge	Indicate some knowledge	Shows understanding only of topics covered in speech	Major lack of understanding of topic
Visual Aid ***Power Point***	Very creative: enhances presentation – does not dominate it	Too wordy – too few pictures and diagrams but relatively creative	Disorganized, little relation to topic, shows little creativity	No visual aid
Style	Equal participation of all group members; outstanding eye contact, posture, enthusiasm and appearance; voices loud enough and at correct pace	Good eye contact, posture and appearance; voice clear and loud enough to be heard by all	Eye contact and appearance are acceptable; need more group practice	No eye contact; voice low and indistinct; does not flow; non-participation by some members
Printed Outline and Bibliography (APA style) Provide to instructor before presentation ***(PPT) printout*** (email to class and instructor 2 days before) presentation)	Well-defined introduction, body and summary or conclusion 10 solid references	Ill-defined outline parts or PP printout; or emailed late 8 solid references	Incomplete outline 6 solid references	No outline 5 or fewer references

APPENDIX 3 – ON-LINE DISCUSSIONS

The instructor may choose to use any or all of these discussion topics – or choose a topic that arises naturally in class. The grading rubric for on-line discussions is on the following page.

1. Discuss the proper collection and packaging of three common types of physical evidence. Speculate on why collection and packaging these specific protocols are used for these types of evidence. (Must be types of evidence not chosen by anyone else in other words, the early student gets the choice.) Reply to at least one post.

2. Outline the forensic use of one of the following instruments or analytical techniques listed below. Find an actual case study in which one of these instruments was used to analyze evidence that was crucial to solving the case. (Atomic absorption spectrophotometry, Inductively Coupled Plasma (ICP), ICP-Mass Spectrometry (ICP-MS), Laser Ablation-ICP (LA-ICP), LA-ICP-MS, Neutron Activation Analysis (NAA), X-ray diffraction, X-ray fluorescence, X-ray microfluorescence). (Must be a case different from all other postings, thus, post early!) Reply to at least one post.

4. Discuss a case wherein fibers, paint and/or arson debris were crucial to solving the case. (Must be a case different from all other postings, ie: post early!) Reply to at least one post.

5. Discuss a case wherein analysis of drugs and/or DNA was crucial to solving the case. (Must be a case different from all other postings, thus, post early!) Reply to at least one post.

6. Whom should be included in the national DNA database: convicted felons, those arrested for felonies, all people arrested for any felony or misdemeanor, those over the age of eighteen, all babies at birth. Support your opinion. Reply to at least one post.

7. What is the most important tool/test forensic scientists have? Support your opinion. Reply to at least one post.

8. Would it be ethical to legislate implantation of an RFID-tag in every individual's tooth for easier identification after terrorist acts or natural disasters? Support your opinion. Reply to at least one post.

9. How far are we as taxpayers willing to go to fund the different training or technology that may be necessary to get more accurate findings, faster processing, more databases, etc. Support your opinion. Reply to at least one post.

10. Which is more important: personal freedom or personal safety? Support your opinion. Reply to at least one post.

DISCUSSION BOARD POSTINGS WILL BE GRADED BY USE OF THE RUBRIC BELOW. Each posting must include at least one acceptable reference* in APA style.

Points Assigned	5 points	4 points	2 - 3 points	0 - 1 point
Quality of Information	Information clearly relates to the main topic **and adds new concepts and/or information.** It includes **several** supporting details and/or examples.	Information clearly relates to the main topic. It **provides at least 1 supporting detail or example.**	Information relates to the main topic. No details and/or examples are given.	Information has little or nothing to do with the main topic or simply restates the main concept.
Critical Thinking	Enhances the critical thinking process consistently through **reflection and difference**, thereby **questioning self and others.**	Critical thinking and **reflection** is demonstrated in discussion **by the individual only**.	Responds to questions but does not engage in reflection.	Does not respond to questions and problems posed by the facilitator.
Participation	**Encourages and facilitates interaction** among members of the online community.	Responds to other members of the online community.	Rarely interacts or responds to other members of the online community.	Responds to the discussion facilitator only.
Professional Language	Both professional vocabulary and writing style are used **consistently** throughout the discussion.	Both professional vocabulary and writing style are used **frequently** throughout the discussion.	Both professional vocabulary and writing style are used **occasionally** throughout the discussion.	Professional vocabulary and writing style are not used.
*Reference(s)	All references are from scholarly journals	Scholarly journals, professional trade journals or .edu or .gov	.edu or .gov only	.com only

Adapted (thanks) from Anna Page, Instructor, Life Science at Johnson County Community College.

REPLIES WILL BE GRADED on a 10 - point scale: 5 points for **adding new information** to the discussion, and 5 points for a reference from a scholarly journal, professional trade journal, .edu or .gov.

APPENDIX 4 – ADDITIONAL TOPICS FOR DISCUSSION BY FORENSIC SCIENTISTS

Management and organization of the forensic laboratory
Quality assurance and quality control in the laboratory
Ethics
Tests available in a modern forensic laboratory, dependence on funds available
How can lawyers make better use of expert witnesses
Sample preparation for drugs and DNA
Sample preservation from the crime scene
Physical inspection (by police) of drugs confiscated by them
Microscopy of vegetation
Identification of prescription pills (IR/Raman)/confirmation by GC/MS
Qualitative testing for drugs, blood and semen
Chemical/physical properties of latent fingerprints that allow us to visualize them

CHAPTER 6 - Conclusions

Introduction

Chapter 6 summarizes the research and development of a course guide, Introductory Forensic Chemistry: On the Cutting Edge. The guide is intended for university instructors of general education forensic chemical science. This chapter also presents conclusions and implications of the study, as well as suggestions for dissemination. As this study straddles the interface between the natural and social sciences, the bias of the researcher is discussed, as well as the ability to provide anonymity to most persons contributing to this study. Finally, future study topics will be recommended.

Summary of Activities

The goal of this study was to develop a guide for a university general education forensic chemical science course. The design of the study followed the educational research and development (R&D) methodology as outlined by Dick, Carey and Carey (2001), Gall, Gall and Borg (1999) and Gall, Gall and Borg (2003). The R&D methodology consisted of a five-step development cycle (see Chapter 4: Figure 1 and Table 1).

The first step in the cycle, the assessment of need and development of the course prototype, took approximately six months, beginning in April 2007. Need was assessed by qualitative analysis of questionnaire input from twenty forensic scientists. The prototype was developed by October 2007, and the first field test of the prototype was conducted during the fall of 2007 by nine university professors self-selected for their expertise as both forensic scientists and forensic science educators. The second field test of the modified prototype was conducted by eight university students in a general education forensic science course during the spring of 2008. The final product, Introductory Forensic Chemistry: On the Cutting Edge, was developed during the summer of 2008.

Product Development

This study was partially based on Tyler's (1949) four fundamental questions for course development.

1. What educational purposes need to be attained?
2. What educational experiences can be provided to attain these purposes?
3. How can these educational experiences be effectively organized?
4. How can we determine whether these purposes are being attained? (p. 1)

Product development was based on a modification of the eight step design process of Dick, Carey and Carey (2001).

1. Assessment of needs
2. Analysis of learners, contexts, and instructional goals
3. Development of performance objectives
4. Development of assessment instruments
5. Development of instructional strategy
6. Development and selection of instructional materials
7. Formative evaluation(s)
8. Summative evaluation

Dissemination

The field of forensic science is changing and growing rapidly (Mayo, 2009). The "CSI effect" has resulted in much interest in the field of forensic science among college and university students (Wilson, 2009).

In 1999 The National Institute of Justice released this statement:

> the educational and training needs of the forensic community are immense. Training of newcomers to the field . . . is vital to ensuring that crime laboratories deliver the best possible service to the criminal justice system . . . While training programs exist in a variety of forms, there is a need to broaden their scope and build on existing resources. In recent years the demand for forensic scientists has increased for many reasons . . . The increased demand places a greater responsibility on educational institutions . . . to meet this challenge.
>
> Technical Working Group for Education and Training in Forensic Science, TWGED, 2004

Dissemination of the results of this research would be most appropriate in areas of teaching science and specifically, the areas of university education and chemical education. To that end, the researcher intends to submit papers to the *Journal of College Science Teaching* (*JCST*), a peer-reviewed journal published by the National Science Teachers Association. The *Journal of College Science Teaching* encourages submissions from all areas of university science teaching, but this forensic chemical science research would fit well in the "Research and Teaching" column which features reports of systematic research in teaching and learning science at the university level. This column of *JCST* requests research which is interdisciplinary or applicable to more than one area of science.

The report of this R&D study is also applicable for submission to the American Chemical Society – both through presentation and journal submission. The Biennial Conference on Chemical Education (BCCE), held biennially during the summer of even-numbered years, is an excellent venue for forensic chemical science education symposia. The American Chemical Society's *Journal of Chemical Education* (*JCE*) is also a good place to submit forensic chemical science papers. This peer-reviewed journal accepts submissions concerning chemistry techniques and new laboratory exercises and has accepted forensic chemistry articles in the past.

Researcher Bias – The Researcher as Instrument

In most natural science research the instrument is – not the researcher. Even if one affectionately refers to her mass spectrometer as "Major Mass Spec", the instrument is still an instrument, programmed to report what nature (or the electrical surge) tells it. In social science research, especially the qualitative variety, the researcher is the instrument. (Maxwell, 2005) Humans are biased instruments. Therefore, not only must questions be phrased as correctly as possible, but the researcher brings to the interpretation of the answers not the reproducible facts of science, but the perspective of human insight with its idiosyncrasies and biases. A social science researcher must explore her innermost being (or at least her educational background) while interpreting the findings of her research. Thus it is necessary to delve into the researcher's bias before finalizing the overview of this study.

I was formally educated (BS and MS) in the natural sciences, chemistry to be specific, organic chemistry to be more specific. I got my on-the-job training in education in various high school and university science classrooms. I cut my writing teeth on Strunk and White (1959). I'm not sure that sentence works, but my writing is accompanied by gnashing of teeth: sometimes mine, at times those of my readers. These background facts may indicate who I am as an instrument.

Forty years of using science to teach young people to think has taught me many things. Those most pertinent to this research and also most pertinent to bridging the gap between social science and natural science research are:

- Every student is different.
- Every class is different.
- Every year brings new science.
- Every year brings new ways of looking at and learning science.
- Every year brings new ways of looking at and teaching students.
- Every year I learn more from my students than they learn from me.

Natural scientists and quantitative (positivist) social scientists study a mechanistic world (Gall, Gall, and Borg, 2003). Qualitative scientists study persons; they study a social reality that is authentic, fuzzy, and difficult to explain in numerically precise ways.

C. P. Snow (1969) dealt with a similar conundrum forty years ago in his famous lecture, *The Two Cultures*, the two cultures being the natural scientists and the "men of letters". John Brockman (1995) refined Snow's thoughts by positing the emergence of *The Third Culture,* suggesting that certain scientists have usurped the position of the literati in defining who and what we are. This dissertation research has tapped a Fourth Culture, or perhaps a subculture: that of natural scientists who interpret scientific phenomena to non-scientists. These non-scientists may or may not be the intellectual leaders in their own non-scientific fields, but in an increasingly scientific society, they need the guidance and understanding of science in their professional lives.

The meaning of many words committed to paper will be changed before the ink is dry. Many words are committed only to fleeting electrical pulses, and the people to whom the words are addressed are changing even as they read. The Fourth Culture, (not to be confused with the Fourth Estate, although the two do have similarities), the persons who can explain Science to the masses are, of necessity, those who were educated in the natural sciences; those who understand both the constancy of the rules of the natural world and the constancy of change in human institutions and human beings and who are, whether they admit it or not, a part of the natural world.

It is the bias of the researcher to believe that the natural science in this treatise will be judged acceptable or not acceptable with evidence from on-going scientific investigation. However, the product will, by the very nature of the endeavor, change continuously, possibly before, but definitely after publication. The product is, after all, to be delivered to human beings who are themselves changing rapidly and who demand that their curricula change likewise.

Having said that, let us return to the issue of the credibility and currency of the most important persons involved in this study: those who volunteered to answer questionnaires. Gall, Gall, and Borg label as "'really terrible sampling' those methods that depend entirely on respondents to volunteer in order to be included in the sample" (p. 183). I plead guilty as charged. Interestingly, Gall, Gall, and Borg report that volunteers are "better educated" and "tend to be more intelligent" than nonvolunteers (p. 183). My bias causes me to think that highly intelligent and better educated volunteers are exactly who I want.

My bias led me to believe that scientists, specifically forensic scientists, would be the cohort needed to decide whether there is a need for forensic chemical science education in the universities. I chose to ask for help with questionnaires mostly Kansas Bureau of Investigation (KBI) scientists, a few retired investigators, and a crime scene investigator and coroner from the Shawnee County Coroner's office. In all cases I personally knew a gatekeeper. In the KBI this was crucial, as the KBI firewall is all but impenetrable. The results of the Needs Assessment questionnaire are recorded elsewhere in this dissertation. However, allow me to reiterate that over 60% of those offered the Needs Assessment questionnaires responded, and 75% of those felt there was a definite need for forensic chemical science education in the universities. Numbers always look like they're true, and these quantitative data – and the qualitative data within the bodies of the questionnaires – convinced me that my research was built on a firm foundation.

I used my experience of at least ten years of teaching forensic science and the contacts I have made during that time with others in the forensic science area to find gatekeepers to the university professor cohort I needed for the First Field Test. At least five years ago, when this research was just a glimmer in my eye, I had a chance to discuss it with Todd Zdorkowski of the Midwest Forensics Resource Center within Ames Laboratory, Iowa State University. He agreed at that time that the project had merit, and he pledged to give me any help I needed. When the time came, he sent email to forty Midwest university educators of forensic science programs asking them to help me with my dissertation project.

Lawrence J. Kaplan is nationally known for his pioneering work in forensic science. I've had several contacts with Dr. Kaplan over the years, and he graciously agreed to share my need for information with thirteen university educators in his Forensic Science Workshop in the summer of 2007.

From these fifty-three university educators, I received eight completed questionnaires and an analysis of the product from six professors. (Five professors provided both questionnaire and product analysis.) Quantitatively, not impressive, but my bias says the quality was there. I base that on the fact that, of the eight professors who responded, five have been at some time an expert witness. Expert witnessing combines the qualities of understanding the science and being able to convey the science to a jury in a way that mostly science-illiterate juries can understand. Since this is what I am proposing to do with the product of this dissertation – conveying the science to university students in a way they can understand - I felt that these people were exactly the ones I needed.

For the Second Field Test, I turned to students in my own Introductory Forensic Chemistry course in the spring semester of 2008: I became my own gatekeeper. Out of forty-seven students, eight responded. Not a great response, quantitatively, but, in addition to Gall, Gall, and Borg (2003) citing studies indicating that volunteers are "better educated" and "tend to be more intelligent" than nonvolunteers (p. 183), my proclivity of being always honest and open with my students has convinced me over the years that my students are, in general, honest and open with me. Call me biased: honest trumps every time.

Anonymity

Krathwohl states that “anonymity refers to researchers’ not knowing the identity of subjects or at least not being able to link data with specific subjects” (p. 215). Krathwohl also states that (researchers) “must gather data in such a way that anonymity is ensured from the outset” (p.215), but admits that “(the) ultimate responsibility for respecting privacy rests with the researcher” (p.216). Insofar as was possible and necessary, while still obtaining the necessary data, I guarded the anonymity of my subjects.

For the needs assessment I first sent a hard-copy letter to the forensic scientists. The letter explained the purpose of the study, the arrival of a questionnaire (see Appendix A) via electronic mail, and instructed them as to what action to take when the questionnaire arrived – to accept the questionnaire, answer the questions within the body of the questionnaire and return it to me, or to delete the email if they chose not to be involved. When the questionnaires were returned, I color coded the answers to the questions: preliminary comments, pink; first priority, orange; second priority, yellow; third priority, green; and final comments, blue. I then analyzed from the color coding containing no names.

In addition to allowing these subjects to easily opt out of the study, I am, by choice, keeping their identities anonymous from anyone except myself. The value of identities could speak only to their validity as subjects, and I prefer to assume that because of their vocation as forensic scientists, their validity is unquestionable.

For the First Field Test I sent a hard-copy letter to the professors of forensic science whose names were provided by Todd Zdorkowski of the Midwest Forensics Resource Center. The letter (see Appendix I) explained the purpose of the study and the arrival of the email questionnaire. Later I offered the course outline to participants of Lawrence Kaplan’s forensic summer workshop. The analysis of the questionnaires was similar to the analysis of the questionnaires from the forensic scientists. The course analysis was accomplished by typing methods and other suggestions from the professors on sheets of paper and working on the sheets of paper alone, keeping the professors totally anonymous to myself at that time. Therefore, the professors were unknown to me at the time I was analyzing their data.

For the Second Field Test I send a hard-copy letter (see Appendix J) to each student who volunteered to critique the course. They received a questionnaire which I analyzed after removing each name. They also received a copy of the course which I analyzed as I did the course sent to the professors. Therefore, the students were unknown to me at the time I was analyzing their input.

I chose to guard the anonymity of the forensic scientists and the students. However, the names and institutions of the professors can be found in Appendix B-3.

Conclusions and Implications

The Product, Introductory Forensic Chemistry: On the Cutting Edge, a course prototype for a one-semester course for the general education of university undergraduates, was developed by the fall of 2008. As with most research, more questions have been generated than have been answered. For example, extensions from the product course might include:

- Could a course similar to the general education course product (Introductory Forensic Chemistry: On the Cutting Edge) be developed for forensic science majors? The progression of the units (Unit I: Physical Properties, Unit II: Spectroscopy, Unit III: Chromatography, and Unit IV: Drugs and DNA) covers the most common analytical techniques and would easily lend itself to a forensic chemistry course taught on a deeper (higher) level.
- Is there a need for development of creative delivery methods that would effectively convey the contributions of the practicing forensic scientists to university students? One of the forensic scientists who participated in the Needs Assessment of this research stated that only forensic scientists should be teaching forensic science because only practicing forensic scientists understand their work. However, most practicing forensic scientists are not educators. Some forensic scientists feel comfortable speaking directly to university students; some don't. However, practicing

forensic scientists understand forensic science in ways that university professors cannot, and innovative methods need to be developed to include in the forensic science education of university students the expertise of the forensic scientists without interfering in the day-to-day work of these experts.

- Could an on-line version of this course be developed for forensic chemical science general education students? Certainly, on-line forensic chemistry could be of value to those in the criminal justice, crime scene investigation and criminal law fields. These persons need insight into forensic laboratory analysis, but do not need to understand the rigor of the scientific procedures which can be learned, at present, only in a scientific laboratory.
- Could inquiry laboratories be developed for middle school, high school, university general education and university forensic science majors to deliver significant learning of the concepts contained in Introductory Forensic Chemistry: On the Cutting Edge? Forensic science laboratories featuring inquiry methods could be developed for all levels of learning. Development of inquiry method laboratories is more difficult, and in order to be done well, requires a team: perhaps a team of persons similar to those who participated in this present study.
- Could forensic laboratory experiments be designed for middle school and high school students to coordinate with state and *National Science Education Standards* (*SES*)? Since a good deal of the learning involved with the course, Introductory Forensic Chemistry: On the Cutting Edge, is not so much forensic chemistry as simply chemistry, it already aligns with concepts recommended to be learned by both the state (Kansas) and *National Science Education Standards* (*SES*).

A Final Thought

If I'd known it was going to be this much fun, I'd have done it twice!

References

Abbas, A. O., Goldsby, K. A, & Gilmer, P. J. (2002) In Taylor, P.C., Gilmer, P.J., & Tobin, K. (Eds.), *Transforming Undergraduate Science Teaching*. (pp. 183-199). New York: Peter Lang Publishers.

About forensics in the classroom. *Court TV.com*. Retreived October 21, 2003 from **http://www.courttv.com/forensics_curriculum/about.html**.

Adams, K. A. (1983). Needs sensing: The yeast for r & d organizations. *Educational Evaluation and Policy Analysis, 5*(1), 55-60.

Alalou, A. (1999). Using student expectations and perceived needs to rethink pedagogy and curriculum: A case study. *Foreign Language Annals, 32*(1), 27-44.

Altschuld, J. W. & Witkin, B. R. (2000), *From Needs Assessment to Action: Transforming Needs Into Solution Strategies.* Thousand Oaks, CA: Sage Publications, Inc.

Anderson, R. C., Shirey, L. L., Wilson, P. T. & Fielding, L. G. (1987) Interestingness of children's reading material. In Snow, R. E. & Farr. M. J. (Eds.), *Aptitude, Learning, and Instruction, Vol. 3: Conative and Affective Process Analyses*. (pp. 287-299). Hillsdale, N. J.: Lawrence Erlbaum and Associates, Publishers.

Askell-Williams, H. & Lawson, M. J. (2002). Mapping students' perceptions of interesting class lessons. *Social psychology of Education, (5)*, 127-147.

Ausbrooks, C. Y. B. (2002). Taking the instructional pulse: A model for instructional needs assessment and formative classroom evaluation. *Catalyst Change, 31*(2), 13-20.

Beckwith, H. (1997). *Selling the Invisible: A Field Guide to Modern Marketing*. New York: Warner Books.

Bell, S. (2006). *Forensic Chemistry*. Upper Saddle River, NJ: Pearson Prentice Hall

Bernstein, M. R.(1955). Relationship between interest and reading comprehension. *Journal of Educational Research, 49*, 283-288.

Bredo, E. (2000) Reconsidering Social Constructivism: The Relevance of George Herbert Mead's Interactionism. In Phillips, D. C. (Ed), *Constructivism in Education: Opinions and Second Opinions on Controversial Issues.* (pp. 127-160). Chicago: The National Society for the Study of Education.

Brockman, J. (1995). *The Third Culture.* New York, NY: Simon & Schuster.

Brophy, J. (2004). *Motivating students to learn,* 2nd ed. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Carson, J. (2005). Objectivism and Education: A Response to David Elkind's 'The Problem with Constructivism. *The Educational Forum, 69*(3), 232-238.

Catalog. (2005 – 2006) Unnamed university.

Cavallo, A. M. L., Rozman, M., Blickenstaff, J. & Walker, N. (2003). Learning, reasoning, motivation, and epistemological beliefs. *Journal of College Science Teaching, 33*(3), 18-23.

Chance, P. (1992). The rewards of learning. *Phi Delta Kappan, (74),* 200-207.

Chance, P. (1993). Sticking up for rewards. *Phi Delta Kappan, (75),* 787-790.

Cobb, P. (1994). Constructivism in Mathematics and Science Education. *Educational Researcher, 23* (7), 4.

Colgan, C. Teaching forensics, then and now. *School Board News, 22*(3), 59-61.

Collins, K. (2003, October) NSTA/Court TV offer free forensic science curricula. *NSTA WebNews Digest*. Retrieved October 21, 2003 from wysiwyg://36/http://www.nsta.org/main/ne…ories/nsta_story.php?news_story_ID=48693.

The Committee of Ten: Main Report (1892). Retreived October 27, 2005, from http://tmg.floonet.net/books/commoften/mainrpt. html

Costner, H. (Ed.) (1989). *New Perspectives on Liberal Education.* Seattle and London: University of Washington Press.

Creswell, J. W. (1998). *Qualitative Inquiry and Research Design: Choosing Among Five Traditions*. Thousand Oaks, CA: SAGE Publications.

Dick, W., Carey, L. & Carey, J. O. (2001). *The Systematic Design of Instruction*, 5th ed. New York: Addison-Wesley.

Dick, W. (1995). Instructional design and creativity: A response to the critics. *Educational Technology, 35*(4), 5-11.

Dick, W. (1995a). Response to Gordon Rowland on "Instructional design and creativity". *Educational Technology, 35*(5), 23-24.

Dick, W. (1997). Better instructional design theory: Process improvement or reengineering? *Educational Technology, 37*(5), 47-50.

Dillman, D. A. (2007). *Mail and Internet Surveys: The Tailored Design Methods*, 2nd ed. Hoboken, NJ: John Wiley & Sons, Inc.

Driver, R., H. Asoko, J. Leach, E. Mortimer, P. Scott. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Elkind, D. (2004). The Problem with Constructivism *The Educational Forum, 68*(4), 306-312.

Ernest, P. (1995). The One and the Many. In Steffe, L. P. & Gale, J. (Eds.), *Constructivism in Education.* (pp. 459-486). Hillsdale, N.J.: Lawrence Erlbaum Associates, Publishers.

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational Research: An Introduction 7th ed*. Boston, MA: Allyn and Bacon.

Gall, J. P., Gall, M. D., & Borg, W. R. (1999). *Applying Educational Research: A Practical Guide, 4th ed.* New York, NY: Addison Wesley Longman, Inc.

Garner, R., Alexander, P. A., Gillingham, M. G., Kulikowich, J. M., & Brown, R. (1991). Interest and learning from text. *American Educational Research Journal, 28*(3), 643-659.

Garner, R., Gillingham, M. G. & White C. S. (1989). Effects of "seductive details" on macroprocessing and microprocessing in adults and children. *Cognition and Instruction, 6*(1), 41-57.

Guinn, V. P. (1979). JFK Assassination: Bullet Analyses. *Analytical Chemistry, 51*, 484A.

Guralnik, D. B. (Ed.) (1984). *Webster's New World Dictionary of the American Language.* New York: Simon & Schuster.

Harwood, W. S. (2004). A new model for inquiry: Is the scientific method dead? *Journal of College Science Teaching, 33*, 29-33.

Herrington, J. & Standen, P. (2000). Moving from an instructivist to a constructivist multimedia learning environment. *Journal of Educational Multimedia and Hypermedia, 9*(3), 195-205.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, (60)*4, 549-571.

Hollis, W. G., Jr. (1996). *Jurassic Park* as a teaching tool in the chemistry classroom. *Journal of Chemical Education, 73*(1), 61-62.

Iran-Nejad, A. (1987). Cognitive and affective causes of interest and liking. *Journal of Educational Psychology, (79)*2, 120-130.

Jackson, A.R.W. & Jackson, J. M. (2004). *Forensic Science*. Essex, England: Pearson Education Limited.

Johll, M. (2006). *Investigating Chemistry.* New York, NY: W. H. Freeman.

Jones, S. (1995) in Brockman, J. (1995). *The Third Culture.* New York, NY: Simon & Schuster, pp. 24-25.

Keller, J. M. (1987). The systematic process of motivational design. *Performance & Instruction,* Nov/Dec, 1-8.

Kimball, B. A. (1986). *Orators & Philosophers: A History of the Idea of Liberal Education.* New York: Teachers College Press.

King, C. and Fricker, B. (2002). Multimodal Curriculum Delivery in Distance Education. *Journal of Distance Education, 17*(2), 102-111.

Kintsch, W. (1980). Learning from text, levels of comprehension, or: Why anyone would read a story anyway. *Poetics (9)*, 87-98.

Kohn, A. (1993). Rewards versus learning: A response to Paul Chance. *Phi Delta Kappan, (75)*, 783-787.

Krathwohl, D. R. (1998). *Methods of Educational & Social Science Research, 2nd ed.* New York, NY: Addison Wesley Longman, Inc.

Lebow, D. (1993). Constructivist values for instructional systems design: five principles toward a new mindset. *Educational Technology Research and Development, 41*(3), 4-16.

LeMaine, A. (2004, July 25). The CSI effect: More students looking at forensics thanks to series' popularity. *The Topeka Capital-Journal*, p. unknown.

Lepper, M. R. (1988). Motivational considerations in the study of instruction. *Cognition and Instruction 5*(4), 298-309.

Lepper, M. R. and Cordova, D. I. (1992). A desire to be taught: Instructional consequences of intrinsic motivation. *Motivation and emotion, 16*(3), 187-208.

Lin, Y., McKeachie, W. J. & Kim, Y. C. (2003). College student intrinsic and/or extrinsic motivation and learning. *Learning and individual differences, (13),* 251-258.

Lovlie, L & Standish, P. (2002). Introduction: *Bildung* and the idea of a liberal education. *Journal of Philosophy of Education, 36*(3), 317-340.

Matthews, M. R. (2000). Appraising Constructivism in Science and Mathematics Education. In Phillips, D. C. (Ed.), *Constructivism in Education: Opinions and Second Opinions on Controversial Issues.* (pp. 161-192). Chicago, Ill: National Society for the Study of Education.

Maxwell, Joseph A. (2005). *Qualitative Research Design: An Interactive Approach, 2nd ed.* Thousand Oaks, Calif: Sage Publications

Malhotra, N. K. (1993). *Marketing research: An applied orientation*. Englewood Cliffs, NJ: Prentice-Hall.

Mayo, K. (2004). Show me the education. *Evidence Technology Magazine, 2*(4), p. 3.

McCarty, L. P. & T. A. Schwandt. (2000). Seductive illusions: von Glasersfeld and Gergen on epistemology and education. In *Constructivism in Education*. (pp. 41-86). Chicago, ILL: National Society for the Study of Education.

McGrath, E. J. (Ed.) (1948). *Science in General Education.* Dubuque, IA: Wm. C. Brown Company.

Meloan, C. E., R. E. James & R. Saferstein. (1998). *Lab Manual: Criminalistics: An Introduction to Forensic Science*, 6th ed. Upper Saddle River, NJ: Prentice Hall.

Miller, A. & Hom, H. L., Jr. (1990). Influence of extrinsic and ego incentive value on persistence after failure and continuing motivation. *Journal of Educational Psychology, 82*(3), 539-545.

Minsky, M. (1995). In Brockman, J. (1995). *The Third Culture.* New York, NY: Simon & Schuster, pp 177 – 178.

Mitchell, J. V., Jr. (1992). Interrelationships and predictive efficacy for indices of intrinsic, extrinsic, and self-assessed motivation for learning. *Journal of Research and Development in Education, 25*(3), 149-155.

Mitchell, M. (1993). Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology, 85*(3), 424-436.

National Association of Scholars. (1996). *The dissolution of general education: 1914-1993.* Princeton, NJ.

National Research Council. Bransford, J. D., Brown, A. L., & Cocking, R. R.(Eds.) (2002). *How people learn: Brain, mind, experience, and school.* Washington, D.C.: National Academy Press.

National Research Council. (1999). *The National Science Education Standards.* Washington, D.C.: National Academy Press.

National Science Teachers Association. (2003, March). Forensic Science. *NSTA Science Class enewsletter.* Retreived March 3, 2003, from **file:///Macintosh%20HD/private/tmp/501/Temporary%20Items/QM**

Nelson, L. H. (1993). Epistemological communities. In L. Alcoff & E. Potter (Eds.), *Feminist epistemologies* (pp. 121-159). New York: Routledge.

Newby, T. J. & Alter, P. A. (1989). Task motivation: Learner selection of intrinisic versus extrinsic orientations. *Educational Technology Research and Development, 37*(2), 77-89.

News from the Field. (2004, July-August) NIJ releases special report on forensic-science education and training. *Evidence Technology Magazine,* 2(4), 5.

Nussbaum, M. (2004). Liberal education & global community. *Liberal Education, Winter,* 42-47.

Office of Institutional Research. (2006). *Enrollment Report.* Washburn University, Topeka, KS.

Office of the Attorney General, State of California, Department of Justice. Retreived 07/22/2008 from http://www.ag.ca.gov/publications/index.htm.

Ornstein, A. C. and D. U. Levine. (1993). *Foundations of Education, 5th ed.* Boston: Houghton.

Parker, R. B. (2005). *Cold Service.* New York: G. P. Putnam's Sons.

Perkins, S. (2004, October 16). What's wrong with this picture? Educating via analyses of science in movies and TV. *Science News. 166*(16), 250-252.

Phillips, D.C. (1995). The Good, the Bad, and the Ugly: The Many Faces of Constructivism. *Educational Researcher. 24*(7), 5-12.

Pond, W. K. (2002). Distributed Education in the 21st Century: Implications for Quality Assurance. *Online Journal of Distance Learning Administration. V*(II).

Richardson, V. (2003). Constructivist pedagogy. *Teachers College Record, 105*(9), 1623-1640.

Rossett, A. (1982). A typology for generating needs assessments. *Journal of Instructional Development 6*(1). 28-33.

Rowland, G. (1995). Instructional design and creativity: A response to the criticized. *Educational Technology 35*(5), 17-22.

Saferstein, R. (2007). *Criminalistics: An Introduction to Forensic Science.* Upper Saddle River, N.J.: Pearson Prentice Hall.

Sale, R. (1989). A mind lively and at ease. In Costner, H. (Ed.), *New Perspectives on Liberal Education.* (pp. 3-24). Seattle and London: University of Washington Press.

Schiefele, U. (1991). Interest, learning, and motivation. *Educational Psychologist, 26*(3&4), 299-323.

Schraw, G., Bruning, R., and Swoboda, C. (1995). Sources of situational interest. *Journal of Reading Behavior, 27*(1), 1 – 17.

Schraw, G. & Lehman, S. (2001). Situational interest: A review of the literature and directions for future research. *Educational Psychology Review, 13*(1), 23 –52.

Schwab, J. J. (1978). Education and the Structure of the Disciplines. In Westbury, I. & Wilkof, N. J. (Eds.), *Science, Curriculum, and Liberal Education: Selected Essays*. (pp. 229-272). Chicago: The University of Chicago Press.

Schwab, J. J. (1978). Science and Civil Discourse: The Uses of Diversity. In Westbury, I. & Wilkof, N. J. (Eds.), *Science, Curriculum, and Liberal Education: Selected Essays*. (pp. 133-148). Chicago: The University of Chicago Press.

Schwab, J. J. (1978). The Practical: Translation into Curriculum. In Westbury, I. & Wilkof, N. J. (Eds.), *Science, Curriculum, and Liberal Education: Selected Essays*. (pp. 133-148). Chicago: The University of Chicago Press.

Snow, C. P. (1959). *The Two Cultures.* Cambridge: Cambridge University Press.

Spunt, T. M. (1999). *Guide to Customer Surveys: Sample Questionnaires and Detailed Guidelines for Creating Effective Surveys.* New York: The Customer Service Group.

Staver, J. R. (1998). Constructivism: Sound theory for explicating the practice of science and science teaching. *Journal of Research in Science Teaching,(35)*5, 501-520.

Stone, E. (2004). Liberal Arts: Vocation vs. Vocational. *The Chronicle of Higher Education* Nov. 12. 5.

Strunk, W. & E. B. White (1959) *The Elements of Style*. New York, NY: Macmillan Publishing Co. Inc.

Taylor, J. S. (1998). *Poetic Knowledge: The Recovery of Education.* Albany, NY: State University of New York Press.

Taylor, P.C., Gilmer, P.J. & Tobin, K. (2002). Introducing Transformations.
In Taylor, P.C., Gilmer, P.J. & Tobin, K. *Transforming Undergraduate Science Teaching.* (pp. ix-xxiv). New York: Peter Lang Publishers.

Technical Working Group for Education and Training in Forensic Science, Education and Training in Forensic Science: *A Guide for Forensic Science Laboratories, Educational Institutions, and Students.* Retrieved January 30, 2009, from www.aafs.org/pdf/NIJReport.pdf.

Thompson, B. R. & Thornton, H. J. (2002). The transition from extrinsic to intrinsic motivation in the college classroom: a first year experience. *Education 122*(4), 785-792.

Tyler, R. W. (1949). *Basic Principles of Curriculum and Instruction.* Chicago and London: The University of Chicago Press.

Von Glasersfeld, E. (1984). An Introduction to Radical Constructivism. In Watzlawick, P. (Ed.), *The Invented Reality: How Do We Know What We Believe We Know?* (pp.). New York: W.W. Norton and Co.

Westbury, I. & Wilkof, N. J. (1978). Introduction. In Westbury, I. & Wilkof, N. J. (Eds.), *Science, Curriculum, and Liberal Education: Selected Essays.* (pp. 1-40). Chicago: The University of Chicago Press.

Willis, J. (1995). A recursive, reflective instructional design model based on constructivist-interpretivist theory. *Educational Technology 35*(6), 5-23.

Willis, J. (1998). Alternative instructional design paradigms: What's worth discussing and what isn't. *Educational Technology 38*(3), 5-16.

Willis, J. (2000). The maturing of constructivist instructional design: Some basic principles that can guide practice. *Educational Technology 40*(1), 5-16.

Willis, J. & Wright, K. E. (2000). A general set of procedures for constructivist instructional design: the new r2d2 model. *Educational Technology 40*(2), 5-20.

Wilson, M., Retreived January 28, 2009 from http://www.wcu.edu/8625.asp

Yost, W. (2003, November 6). Courses in forensic science enliven high school curricula. *Sacramento Bee.* Retreived December 5, 2003 from wyg://98http://www.sacbee.com/conte…ion/v-print/story/7735722p-8675164c.html

Appendix A - Questionnaire to forensic science professionals in the field

<u>Section one: Demographics</u>

Name:
Position:
Business Address:
Number of years experience in current field:

<u>Section two: A need for more understanding of forensic chemical science?</u>

Is there a need for persons outside the forensics area (jurors, lawyers, those working in the criminal justice field) to have a better understanding of forensic chemical science? Yes or No.

If no, why not?

If yes, specifically what topics of forensic chemical science should be understood by these lay people?

Please prioritize, if possible, the topics listed above.

Which of the above topics involve, in your opinion, understanding of chemical concepts – even to a minor amount?

Why, in your opinion, is this need for understanding of forensic science concepts not being met?

Thank you for your time.

Appendix B - Analysis of Comments from forensic science professionals

Questionnaire from forensic science professionals in the field

30 sent; 20 returned 67%

<u>Section two: A need for more understanding of forensic chemical science?</u>

Is there a need for persons outside the forensics area (jurors, lawyers, those working in the criminal justice field) to have a better understanding of forensic chemical science? Yes or No. **15 Yes; 4 No; 1 Both 75% Yes**

Preliminary Comments:

There is a need for forensic science, but not for more understanding of forensic chemical science.

An understanding of the chemistry is not as important as an understanding of what departments of the law enforcement community to and how they come to their conclusions. In general, most people outside the criminal justice field get their info from TV, and that is giving them false information.

There is a need for people to have plain common sense.

Better all round knowledge to help understand findings presented in court.

The "CSI effect" is the one thing that comes to mind that would be beneficial for non-forensic scientist to understand. Understanding what techniques are available and how practical some things are would help forensic science.

There are huge misunderstandings about what forensic testing can really do, what it should do, how long it takes the testing to be complete and how expensive excessive and unnecessary testing can be. **Unfortunately, many schools throughout the country are adding to the problem by starting forensic science programs in which instructors with no practical forensic science experience teach about forensic science.**

They should understand the limits of forensics.

I think that lawyers would benefit from a better understanding of forensic chemical science in the sense that this would allow them to make better use of the expert witness.

Separating the CSI concept of forensic science from the reality of it would be helpful with respect to the jurors.

Basic information should be available for jurors, lawyers and others in need of the material in form of a pamphlet or tapes.

Topics to discuss would be the “real CSI”; understanding the roles of Forensic Scientists.

I believe that there is a need for persons outside the forensics area to have a better understanding and a true understanding of forensic science. Todays jurors can not, or do not, separate fact from fiction. TV always shows a positive conclusion. Many times there is no evidence left at a crime scene. Not one lab could conduct the examinations as shown on television. Todays lay person should have a general knowledge of a forensic lab’s ability to assist in solving crimes.

This is not a major issue for the courts, lack of time and resources.

The need for understanding of forensic science concepts is not being met because of :
1) a lack of funds
2) a lack of personnel
3) ignorance of the need

The majority of the programs out there are not being instructed by forensic scientists with experience. Working in the field creates an appreciation and understanding for how science and math works together to create the field of forensic science. Having a degree in chemistry or biology alone does not make a person able to adequately teach forensics.

Another problem: we are letting the TV do the teaching.

Television misrepresents the field; TV programs plant seed of misunderstanding in the minds of viewers.

Insufficient funding of all forensic sciences, so attraction of a high quality work force in sufficient numbers is not possible.

Any training should not only inform, but address misconceptions and be weighted on practicality.

Most consider chemistry a complicated and technical thing. Some “old school” thinkers would just as soon the general public not understand the process and not “out-think” the attorneys. Jurors should not think ahead of facts being presented.

Just understanding the procedure is what is most important.

Most forensic science topics contain science, to varying degrees.

The field of forensic science is ever changing/advancing; not everyone has access to or background in science/forensics; people get their knowledge of forensic science from misleading sources (TV shows).
I don't feel that current jury pools are terrible in their understanding of science, but there is room for improvement.

I don't know how big the problem truly is. We hear news stories of juries doing strange things – seemingly from a lack of knowledge, and occasionally we run across attorneys that could use a little more background. I don't know how widespread the problem has become.

I think that television shows like CSI and Law and Order provide incorrect information to people. Although those not in the law enforcement field feel they understand forensic science they really have received incorrect information. These shows reach more people than any demonstration, program, or training course law enforcement can provide.

Appendix C - Questionnaire to instructors of general education natural science courses

<u>Section one: Demographics</u>

Name:
Have you ever worked as a forensic scientist or as an expert witness? If so, please describe your work in these areas.
Position at the present time:
Institution address:
Number of years experience in current field:
General education courses taught, please indicate current and past

Section two: Concepts in a course of forensic chemical science

1. What subject areas should be covered in a course dealing with forensic chemical science and offered to general education students, ie non-science majors such as pre- law students, criminal justice majors, and, of course, potential jurors. Please include in your listing both areas of chemistry and also appropriate applications of the science to forensic problems.

2. What delivery methods do you find to be most effective with your students? Delivery methods may include, but are not restricted to:

lecture
recitation
textbook
laboratory work
on-line work
student-researched papers or presentations

3. For each method mentioned in #2 above, what makes this method work for you and your students.

4. What delivery methods (see #2 above) do you find **are not** effective with your students? Again delivery methods may include, but are not restricted to the list in #2 above.

Introductory Forensic Chemistry: On the Cutting Edge

A one-semester course designed for the general education of university undergraduates

Unit I – Physical Properties of Materials
Emphasis on Glass and Soil

Laboratory: Inquiry into analysis of glass fragments (see next page)

Guest Speaker: Practicing or retired forensic scientist discussing:

1. Science: its basics and limitations (what can and cannot be analyzed; it can't be analyzed if it's not there)
2. How the "CSI" effect in jurors can be counteracted
3. Common sense applied to forensic analyses

(See Appendix 4 for additional topics for discussion by forensic scientist.)

Topics Covered

A. Crime scene investigation
   1. Measurement – accuracy and precision
   2. Scientific method applied to investigation

B. Mathematics (good for recitation)
   1. Metric / metric conversions
   2. Metric / English conversions
   3. Significant digits

C. Physical properties of materials
   1. Intensive – forensic value (advantage / disadvantage)
      a. Temperature
      b. Density (calculations good for recitation)
      c. Refractive index
      d. Gross appearance
      e. pH

   2. Extensive – forensic value (advantage / disadvantage)
      a. Weight / mass
      b. Volume

   3. Glass fractures

Introductory Forensic Chemistry Laboratory Exercise I
Inquiry into Crime Scene Glass Analysis
(To be done after discussion of density in lecture, group work: 2 – 3 students)

Set the stage:

Your task, if you accept it, is to analyze the four samples of glass given to you: one questioned sample (from the crime scene) and three known samples (from three different suspects). In order to analyze these samples, you will have access to the following equipment and supplies:

Goggles
Nitrile gloves
Magnifying glass
Ruler
Electronic balance
Graduated cylinder
Deionized, distilled, or tap water

You may ask for any other item you want / need, and if it is available, your lab instructor will get it for you or explain why you may not use it. **However:** density analysis is required.

Your laboratory report:

1) Describe everything you do and the results of your experimentation. When using measurements, record to the precision of the instrument / equipment you are using. When doing calculations, show all work, and report the answer(s) to the correct number of significant digits.
2) You are to determine, if possible, whether any of the known samples can be eliminated as being different from the questioned sample. If you think a known sample might be the same as the questioned sample, discuss / list (in detail and specifically) all the similarities you found.
3) Discuss your testimony as an expert witness, ie what you will suggest that the prosecuting attorney ask and what you can testify to in regards to your analysis in the lab. **Be specific and concise. Testify to only what you did and saw with your own eyes. Remember that elimination of suspects is more reliable with class evidence than is identification.**

Unit II – General Inorganic Analysis by Spectroscopy

Laboratory: Choice of two or, if time allows, both. (See following pages.)

1. Bullet Fragment Analysis by Atomic Absorption Spectrophotometry
   This laboratory exercise is a nice example of the analysis of the bullet fragments in the Kennedy assassination case. The results are designed to be similar, although the analysis techniques are different. This laboratory experiment can lead into two areas of discussion: 1) Why was Neutron Activation Analysis used on the real bullet fragments? And 2) What led to the decision of the FBI to stop using this method for bullet fragment analysis?
2. Inquiry into glass fragments

Guest Speaker: Practicing or retired forensic scientist discussing:

1. How forensic scientists and police together complete the investigation
2. How long analyses take
3. Logic of results, margin of error, and the value of qualitative analysis
4. Role of the expert witness

(See Appendix 4 for additional topics for discussion by forensic scientist.)

Topics Covered

A. Mathematics concepts (good for recitation)
   1. Percentage
   2. Parts per million (ppm)
   3. Parts per billion (ppb)
   4. Interconversion of above

B. Atomic Structure (good for recitation)
   1. Electron energy levels and sublevels
   2. Electron configuration and dot diagrams
   3. Isotopes

C. Nuclear decay reactions and neutron activation analysis (good for recitation)

D. Basic spectroscopy
   1. Qualitative / quantitative analyses
   2. Basic spectroscopy
      a. Inductively coupled plasma - Optical Emission Spectrophotometry (ICP-OES)
      b. Atomic absorption spectroscopy (AAS)
      c. X-ray analyses
         i. X-ray diffraction (XRD)
         ii. X-ray fluorescence or microfluorescence (XRF)

Simulated Analysis of Trace Amounts of Silver in Bullet Fragments

loosely patterned after V.P. Guinn's neutron activation analysis of trace silver amounts (Guinn, 1979) in the bullet fragments from the John F. Kennedy assassination

Analysis of silver by flame atomic absorption spectroscopy

Introduction

Over the past thirty-seven years, much controversy has arisen concerning the assassination of John F. Kennedy. (Lifton) Complete lifetimes have been spent analyzing evidence and predicting convincing scenarios different from that outlined the Warren Commission report. (Menninger)

Prior to the analysis of the actual bullet fragments from the assassination, Guinn "analyzed a number of samples of WCC/MC 6.5-mm bullet lead, from all four of the production lots made by WCC." (Guinn, p 486A) This study showed that bullet lots were heterogeneous, especially in the trace amounts of silver and antimony, but individual bullets were particularly homogeneous in regards to these elements. Therefore, an analysis of the trace amounts of silver or antimony should give a good indication of the total number of bullets from which the six "fragments" came.

Silver is our trace metal of choice, as it is detected at low ppm levels on our instrument.

Procedure

After the instrument has warmed up, a calibration curve will be calculated using a blank and three standards of 2.0 ppm Ag, 6.0 ppm Ag, and 12.0 ppm Ag. Four unknowns, W1 through W4, will be analyzed. (The bullet fragments to be analyzed have already been dissolved in acid in order to facilitate the time in lab.) The number of bullets represented by the four samples (fragments) will be determined.

A. Calibration curve determination:
   1. With the tubing in the blank press the appropriate button to analyze.
   2. Record the absorbance value and the standard deviation on your data sheet.
   3. Place the tubing into the deionized (DI) water to rinse.
   4. Place the plastic tubing into the low standard (2.0 ppm Ag).
   5. Press the appropriate button to analyze.
   6. Place the tubing into the DI water to rinse.
   7. Repeat #4,5, and 6 with the mid standard (6.0 ppm Ag) and the high standard (12.0 ppm Ag).
   8. Record standard concentrations and all absorbance readings on your data sheet.

B. Analyzing samples: Analyze samples by placing the plastic tubing into each sample container and pressing the appropriate button to analyze. Rinse between samples as before with DI water.

DATA SHEET

Solution	**Concentration**	**Absorbance**
Blank		
Low Standard		
Mid Standard		
High Standard		
W1		
W2		
W3		
W4		

C. Graph the calibration curve using the data from the blank and the three standards using Microsoft Excel. If the linear regression line misses any points by a large amount, see Ms. Salem.

D. Using the mean ppm (mg/L) values and standard deviations for the bullet fragment solutions, determine how many bullets are represented by the four solutions.

NOTE: I use [Ag] unknown values close to the values in Guinn (1979) so the students not only get a learning experience, but feel that they are recreating a piece of history.

Bibliography

Guinn, V.P. "JFK Assassination: Bullet Analyses", Analytical Chemistry, 51 (1979), 484A. Copyright 1979, American Chemical Society.

Lifton, David S. Best Evidence. New York: Macmillan, 1980.

Menninger, Bonar. Mortal Error: The Shot That Killed JFK. New York: St. Martin's Press, 1992.

Introductory Forensic Chemistry Laboratory Exercise I

Inquiry into Crime Scene Soil Analysis

Group work: 2 – 3 students

(To be done after discussion/demonstration of heat-activated emission of elements)

Set the stage:

Your task, if you accept it, is to analyze the four samples of soil given to you: one questioned sample (from the crime scene) and three known samples (from three different suspects). In order to analyze these samples, you will have access to the following equipment and supplies:

Goggles
Nitrile gloves
Magnifying glass
Ruler
Electronic balance
Nichrome wire
Solution of hydrochloric acid
Bunsen burner
Spot plates
Cobalt glass

You may ask for any other item you want / need, and if it is available, your lab instructor will get it for you or explain why you may not use it. **However:** Emission analysis is required.

Your laboratory report:

1) Describe everything you do and the results of your experimentation. When using measurements, record to the precision of the instrument / equipment you are using. When doing calculations, show all work, and report the answer(s) to the correct number of significant digits.
2) You are to determine, if possible, whether any of the known samples can be eliminated as being different from the questioned sample. If you think a known sample might be the same as the questioned sample, discuss / list (in detail and specifically) all the similarities you found.
3) Discuss your testimony as an expert witness, ie what you will suggest that the prosecuting attorney ask and what you can testify to in regards to your analysis in the lab. **Be specific and concise. Testify to only what you did and saw with your own eyes. Remember that elimination of suspects is more reliable with class evidence than is identification.**

Unit III – Organic Analysis Emphasizing Chromatography

Laboratory: Thin Layer Chromatography of Inks (See next page.)

Guest Speaker: Practicing or retired coroner or medical examiner discussing

1. Determination of time of death
2. Chemistry of the human body

(See Appendix 4 for additional topics for discussion by forensic scientist.)

Topics Covered:

A. Organic compounds
   1. Lewis electron dot structures
   2. Molecular mass
   3. Molecular shapes
   4. Polar and nonpolar bonds

B. Oxidation/Combustion Reactions
   1. Balancing chemical equations
   2. Covalent bond energy

C. Introduction to chromatography and mass spectrometry

Analysis of Ink by Thin Layer Chromatography

Modified with permission from: Meloan, Clifton E., Richard E. James, and Richard Saferstein.
Lab Manual: Criminalistics: An Introduction to Forensic Science, 6th ed.
Upper Saddle River, NJ: Prentice Hall, 1998.

The thin layer technique is based on the fact that silica gel contains a thin film of water, called a **stationary phase**. A mixture of the compounds to be separated is placed in a small spot at one end of the gel-covered plate, and an organic solvent (**mobile phase**) is passed over the spot and across the paper. Since each compound present has a different size, shape, and distribution of electrical field, each compound will dissolve in the water and organic solvent to a different extent.

The net result is that if two compounds are started at the same place and solvent passed over them, one compound will move along the paper faster than the other. After a period of time the flow of the mobile phase is stopped. The plate is dried and then sprayed with a reagent that will produce colored spots, if the compounds are not colored. The materials used in our experiment - inks - are already colored, so the latter step is not required.

Some years ago the color in inks was made of a single component substance. Therefore, when this ink was chromatographed, only one colored spot was evident. Inks manufactured in more recent times are more often multi-component materials, with the ink color due to a mixture of dyes. These inks, then show a variety of colored spots when chromatographic separation is performed.

In this analysis we determine which type of ink pen was used to write a certain document.

CRIME SCENE

A document has been submitted to the document examination section of a forensic laboratory with the following explanation and request:

A ransom note was left at the scene of the kidnapping of Jack E. Lapping, beloved Labrador retriever of the Prince and Princess of Wellington. The note was hand-written in blue ink. After investigation, proper search warrants were issued, and pens were seized from four suspects. Using thin layer chromatography, you are to determine which pen might possibly have written the ransom note. Your plate will be given to you spotted with ink from the ransom note.

Preparation for chromatographing the ink samples involves the determination of a proper developing solvent. This will be done during the course of the laboratory.

EQUIPMENT

600 or 800 mL beakers
150 mm watch glasses
Silica gel thin layer plates
pencils

REAGENTS

Deionized water
Ethanol (denatured)
Hydrochloric acid, 0.1 M
Methanol
Water-methanol, 50:50 (v/v)
Water-ethanol, 50:50 (v/v)

METHOD

1. Make up a developing chamber for one of the reagents above. (Each solvent system will be chosen by one or two groups in order for all of us to determine which system works best.) Pour a small amount of your reagent (should be below the pencil line on the chromatography plate) into a 600 mL beaker and cover with a watch glass. This will allow the solvent to saturate the atmosphere inside the beaker before you are ready to start the chromatogram.

2. Spot the four suspect pens on the **pencil** line on which the crime scene ink is spotted. Spot and dry once. Try to make each spot as small as possible. Try not to get fingerprints on the paper.

3. Lower the paper into the solvent, with the pencil line toward the bottom of the beaker, but do not immerse the spots. Replace the watch glass, dome side up. Let the solvent come up the plate over the spots by capillary action.

4. While the chromatogram is developing, observe the developing chromatograms of your classmates, and note differences and similarities.

5. Allow the solvent to rise up the plate until it reaches a point approximately 4 cm from the top of the paper or until the rise slows perceptibly.

6. Remove the plate, mark the solvent front and allow the strip to dry on a clean sheet of paper.

7. Look at the chromatograms of your classmates to determine which solvent system gave the best separation

8. Determine, if you can, which pen most likely wrote the ransom note. If, from your experiment, you cannot determine a decided difference, use a different solvent system and try again, if time allows.

DATA SHEET

1. What solvent did you use?

2. Which component was most soluble in this solvent? How can you tell?

3. Is the order of colors on the papers the same in every case of solvent used? Explain.

4. What is the maximum number of different colors that you see on a chromatogram? What are these colors?

5. In your opinion, which pen wrote the ransom note? Why?

6. Attach plate(s) here.

Unit IV - Analysis of Drugs and DNA

Laboratory: Paper DNA analysis: "A Case of Abduction – Mitochondrial DNA Identity Testing" by William H. Humphries and Diane L. Baker, copy write 2002, Flinn Scientific, Inc.

Guest Speaker: Practicing or recently retired forensic scientist discussing:

1. How DNA is analyzed
2. Statistics applied to DNA analysis
3. Expense of analyses and salaries (Discuss necessary vs. unnecessary analyses and analysts)

(See Appendix 4 for additional topics for discussion by forensic scientist.)

Topics Covered

A. Drugs
   1. Formulas, structures, and molecular weight calculations
   2. Analysis of gas chromatograms and mass spectra

B. DNA
   1. Structure
   2. Function
   3. Forensic applications
      a) PCR using STR
      b) RFLP
      c) Statistical analysis

APPENDICES

These learning techniques can all be used with the same class, or different techniques can be used as time and student interest/abilities allow.

APPENDIX 1 - ONE PAPER

The paper will analyze one episode from the first six seasons of the original CSI (available in DVD format). Each person will have his/her own episode to work with, ie, two people **cannot** use the same episode, and first come, first served.

The author will choose 10 instances in the episode where forensic science was used and will analyze each. To analyze means to discuss in appropriate detail and explain – in writing – whether collection, processing, and/or analysis was correct or incorrect and document each instance with at least one reference. (If using internet references, please choose .gov, .org, or .edu) Use APA style when reporting references at the end of the paper.

The papers will be posted (anonymously or not – by author's choice) on a web site where all of us can view them.

APPENDIX 2 – STUDENT PRESENTATIONS

Each group of 2 or 3 students will choose a topic from the list below. The rubric by which these presentations are to be graded is on the next page.

Forensic entomology
Forensic odontology
Forensic anthropology
Fingerprinting
Questioned documents
Blood spatter reconstruction
Chemical development of blood patterns
Hair and fiber analysis
Impression evidence
Forensic computer science
Forensic engineering
It's the Law: Frye and Daubert

PRESENTATION RUBRIC

Areas	**Excellent** 10 points	**Good** 8 points	**Fair** 6 points	**Minimal Effort** 0 points
Content	Information presented with introduction, body, conclusion and much supporting data	Information presented in logical order with some supporting data	Information presented in logical order	Irrelevant material and few details
Answers to Questions ***Indicates depth of research***	Indicate in-depth knowledge	Indicate some knowledge	Shows understanding only of topics covered in speech	Major lack of understanding of topic
Visual Aid ***Power Point***	Very creative: enhances presentation – does not dominate it	Too wordy – too few pictures and diagrams but relatively creative	Disorganized, little relation to topic, shows little creativity	No visual aid
Style	Equal participation of all group members; outstanding eye contact, posture, enthusiasm and appearance; voices loud enough and at correct pace	Good eye contact, posture and appearance; voice clear and loud enough to be heard by all	Eye contact and appearance are acceptable; need more group practice	No eye contact; voice low and indistinct; does not flow; non-participation by some members
Printed Outline and Bibliography (APA style) Provide to instructor before presentation ***(PPT) printout*** (email to class and instructor 2 days before) presentation)	Well-defined introduction, body and summary or conclusion 10 solid references	Ill-defined outline parts or PP printout; or emailed late 8 solid references	Incomplete outline 6 solid references	No outline 5 or fewer references

APPENDIX 3 – ON-LINE DISCUSSIONS

The instructor may choose to use any or all of these discussion topics – or choose a topic that arises naturally in class. The grading rubric for on-line discussions is on the following page.

1. Discuss the proper collection and packaging of three common types of physical evidence. Speculate on why collection and packaging are as they are for these types of evidence. (Must be types of evidence not chosen by anyone else ie the early student gets the choice.) Reply to at least one post.

2. Outline the forensic use of one of the following instruments or analytical techniques listed below. Find an actual case study in which one of these instruments was used to analyze evidence that was crucial to solving the case. (Atomic absorption spectrophotometry, Inductively Coupled Plasma (ICP), ICP-Mass Spectrometry (ICP-MS), Laser Ablation-ICP (LA-ICP), LA-ICP-MS, Neutron Activation Analysis (NAA), X-ray diffraction, X-ray fluorescence, X-ray microfluorescence). (Must be a case different from all other postings, ie: post early!) Reply to at least one post.

11. Discuss a case wherein fibers, paint and/or arson debris was crucial to solving the case. (Must be a case different from all other postings, ie: post early!) Reply to at least one post.

12. Discuss a case wherein analysis of drugs and/or DNA was crucial to solving the case. (Must be a case different from all other postings, ie: post early!) Reply to at least one post.

13. Who should be included in the national DNA database: convicted felons, those arrested for felonies, all people arrested for any felony or misdemeanor, those over the age of eighteen, all babies at birth. Support your opinion. Reply to at least one post.

14. What is the most important tool/test forensic scientists have? Support your opinion. Reply to at least one post.

15. Would it be ethical to legislate implantation of an RFID-tag in every individual's tooth for easier identification after terrorist acts or natural disasters? Support your opinion. Reply to at least one post.

16. How far are we as taxpayers willing to go to foot the bill to fund the different training or technology that may be necessary to get more accurate findings, faster processing, more databases, etc. Support your opinion. Reply to at least one post.

17. Which is more important: personal freedom or personal safety? Support your opinion. Reply to at least one post.

DISCUSSION BOARD POSTINGS WILL BE GRADED BY USE OF THE RUBRIC BELOW. Each posting must include at least one acceptable reference* in APA style.

Points Assigned	5 points	4 points	2 - 3 points	0 - 1 point
Quality of Information	Information clearly relates to the main topic **and adds new concepts and/or information.** It includes **several** supporting details and/or examples.	Information clearly relates to the main topic. It **provides at least 1 supporting detail or example.**	Information relates to the main topic. No details and/or examples are given.	Information has little or nothing to do with the main topic or simply restates the main concept.
Critical Thinking	Enhances the critical thinking process consistently through **reflection and difference**, thereby **questioning self and others.**	Critical thinking and **reflection** is demonstrated in discussion **by the individual only**.	Responds to questions but does not engage in reflection.	Does not respond to questions and problems posed by the facilitator.
Participation	**Encourages and facilitates interaction** among members of the online community.	Responds to other members of the online community.	Rarely interacts or responds to other members of the online community.	Responds to the discussion facilitator only.
Professional Language	Both professional vocabulary and writing style are used **consistently** throughout the discussion.	Both professional vocabulary and writing style are used **frequently** throughout the discussion.	Both professional vocabulary and writing style are used **occasionally** throughout the discussion.	Professional vocabulary and writing style are not used.
*Reference(s)	All references are from scholarly journals	Scholarly journals, professional trade journals or .edu or .gov	.edu or .gov only	.com only

Adapted (thanks) from Anna Page, Instructor, Life Science at Johnson County Community College.

REPLIES WILL BE GRADED on a 10 - point scale: 5 points for **adding new information** to the discussion, and 5 points for a reference from a scholarly journal, professional trade journal, .edu or .gov.

APPENDIX 4 – ADDITIONAL TOPICS FOR DISCUSSION BY FORENSIC SCIENTISTS

Management and organization of the forensic laboratory
Quality assurance and quality control in the laboratory
Ethics
Tests available in a modern forensic laboratory, dependence on funds available
How can lawyers make better use of expert witnesses
Sample preparation for drugs and DNA
Sample preservation from the crime scene
Physical inspection (by police) of drugs confiscated by them
Microscopy of vegetation
Identification of prescription pills (IR/Raman)/confirmation by GC/MS
Qualitative testing for drugs, blood and semen
Chemical/physical properties of latent fingerprints that allow us to visualize them

Appendix E - Questionnaire to university/community college students

<u>Section one: Demographics</u> (Your name will be kept confidential and deleted from this email before analysis.)

Year in college/university:
Major:

<u>Section two: How do you learn science concepts and applications?</u>

1. What general education science courses (Title and Area, ie biology, chemistry, physics, physical science, astronomy, etc) have you taken at the university/community college level (include the present introductory forensic chemistry course)?

2. What science concepts, (ie cell structure, atom structure, mechanics, etc) have you learned in those courses (include the present introductory forensic chemistry course)?

3. For each concept listed in #2, discuss how the concept was taught (lecture, recitation, textbook reading, laboratory work, on-line work, student-researched papers or presentations, individual work, group work, etc.)

Which learning method works best for you for each specific concept learned?

4. How do you learn best from courses outside the sciences? Please be specific about how these methods could be used in general education science courses.

5. What topics did you expect to learn about in a general education forensic chemical science course? Please be specific and also state why each topic would be important to you personally.

6. Did this present introductory forensic chemistry course fulfill your expectations? Why or why not?

Thank you for your time.

Initial here _____ if you would like to receive information concerning the outcome of this research.

Appendix F - Form of Consent

Second Field Test

Form of Consent – Research Involving Human Subjects
Kansas State University, Manhattan, Kansas

ORIENTATION

You have volunteered to take part in a research study that focuses on the research and development of a course for a one-semester course designed for the general education of university undergraduates in introductory forensic chemistry. Your input has been requested due to your expertise as a university undergraduate.

The primary purpose of the second field test of this course is to provide feedback for improvement and revision. Respondents can expect to spend no more than five hours reacting and responding to components of the course and the associated on-line questionnaire.

For organizational purposes, the field test asks for your demographic information, but all data reported in the study will be confidential, and the subject's name will not be linked with results. Questionnaires will be archived with dissertation artifacts for a minimum of five years.

CONSENT

My participation in this study is purely voluntary; I understand that my refusal to participate will involve no penalty or loss of benefits to which I am othersiwe entitled and that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

If I have questions about the rationale or method of the study, I understand that I may contact:
Roberta Sue Salem, Chemistry Department, Washburn University, Topeka, KS 66621; 785-670-2271; or sue.salem@washburn.edu

If I have questions about the rights of subjects in this study or about the manner in which the study is conducted, I may contact the Chairman of the Committee on Research Involving Human Subjects, 1 Fairchild Hall, Kansas State University, Manhattan, KS 66506, at 785-532-3224

______________________________ ______________
Signature Date

Appendix G - Professors Participating in the Research and Their Institutions

Professor Number Designation	Professor Name	Institution
1	Murphy Brasuel	Colorado College
2	Charles Cornett	Univ. of Wisconsin-Platteville
3	Pat Tille	Univ. of Sioux Falls
4	Patrick Jones	Purdue
5	Jim McGill	SE Missouri State Univ.
6	Alan H. Colen	Kansas City Kansas Comm College
7	Jay A. Siegel	Indiana University
8	Grace Zoorob	Vanderbilt University
9	Corinne Deibel	Earlham College

Appendix H - First Field Test Course

Introductory Forensic Chemistry:

A one-semester course designed for general education of university undergraduates

UNIT I

Physical Properties

of

Glass and Soil

Unit I – Physical Properties of Glass and Soil

Lab: Analysis of glass fragments

Guest speaker or Video: Analysis of glass and/or soil by forensic scientist(s)

A. Conversions
    1. Metric / metric conversions
    2. Metric / English conversions
B. Physical properties of glass and/or soil
    1. Temperature
    2. Weight / mass
    3. Volume
    4. Density
    5. Refractive index
    6. Gross appearance
    7. pH of soil
    8. Glass fractures

Introductory Forensic Chemistry Hands-on
Determination of Density of Glass

A. **Equipment and Supplies**
    1. Electronic balance
    2. Graduated cylinder (10 mL or 25 mL)
    3. Deionized, distilled, or tap water
    4. Glass shards
    5. Nitrile gloves

B. **Calculating the Density of Glass:**
    1. You will be given glass (Questioned) from a crime scene and glass samples (Known) retrieved from three suspects.
    2. Obtain a graduated cylinder and fill to approximately half its volume with water.
    3. Record the volume to the nearest 0.01 mL
    4. Weigh one or more pieces of Questioned glass totaling 3 to 6 grams to the highest readability of your balance.
    5. Carefully place (do not splash) the glass pieces into the graduated cylinder.
    6. Record the new volume.
    7. Determine the volume change (V_{end} - V_{start}), which is the volume of the glass (V_{glass}). Use this volume to calculate the density of the Questioned glass. Calculate the density by dividing the mass by the volume.
    8. Repeat #2 - #7 for samples from your suspects (Known glass samples).

Suggested data table set-up:

Sample	Mass of glass	Volume of H_2O	Volume of H_2O and glass	Volume of glass	Density of glass

C. Questions / Conclusions

1. Are there one or more suspects who can be linked to the crime scene? Explain.
2. Can you, in your persona as expert witness, tell with relative certainty that glass from all suspects or none **may have** come from the Crime Scene?
3. What other tests or observations could be used (with the equipment available in this laboratory) to distinguish between these samples? Which of these additional observations did you use?

4. What could be done to increase the precision of your densities? What could be done to make them more accurate?

Unit II

General Inorganic Analysis

by

Spectroscopy

Unit II - General Inorganic Analysis by Spectroscopy

Lab: Bullet Fragment Analysis by Atomic Absorption
Required for Forensic Chemical Science majors
Extra Credit for nonmajors
Guest speaker or Video: analysis by spectroscopy by forensic scientist

A. Math concepts
1. Percentage
2. Parts per million / parts per billion
3. Conversions

B. Atomic structure
1. Electron configuration
2. Lewis electron dot diagrams

C. Radioactive decay reactions and neutron activation analysis

D. Basic spectroscopy
1. Emission spectroscopy, ICP and LA-ICP-MS
2. Atomic absorption spectroscopy, AA or AAS
3. X-ray analyses: diffraction and fluorescence/microfluorescence

Simulated Analysis of Trace Amounts of Silver in Bullet Fragments

loosely patterned after V.P. Guinn's neutron activation analysis of trace silver amounts (Guinn, 1979) in the bullet fragments from the John F. Kennedy assassination

Analysis of silver by flame atomic absorption spectroscopy

Introduction

Over the past thirty-seven years, much controversy has arisen concerning the assassination of John F. Kennedy. (Lifton) Complete lifetimes have been spent analyzing evidence and predicting convincing scenarios different from that outlined the Warren Commission report. (Menninger)

Prior to the analysis of the actual bullet fragments from the assassination, Guinn "analyzed a number of samples of WCC/MC 6.5-mm bullet lead, from all four of the production lots made by WCC." (Guinn, p 486A) This study showed that bullet lots were heterogeneous, especially in the trace amounts of silver and antimony, but individual bullets were particularly homogeneous in regards to these elements. Therefore, an analysis of the trace amounts of silver or antimony should give a good indication of the total number of bullets from which the six "fragments" came.

Silver is our trace metal of choice, as it is detected at low ppm levels on our instrument.

Procedure

After the instrument has warmed up, a calibration curve will be calculated using a blank and three standards of 2.0 ppm Ag, 6.0 ppm Ag, and 12.0 ppm Ag. Four unknowns, W1 through W4, will be analyzed. The number of bullets represented by the four samples (fragments) will be determined.

A. Calibration curve determination:
   1. With the tubing in the blank press the appropriate button to analyze.
   2. Record the absorbance value and the standard deviation on your data sheet.
   3. Place the tubing into the deionized (DI) water to rinse.
   4. Place the plastic tubing into the low standard (2.0 ppm Ag).
   5. Press the appropriate button to analyze.
   6. Place the tubing into the DI water to rinse.
   7. Repeat #4,5, and 6 with the mid standard (6.0 ppm Ag) and the high standard (12.0 ppm Ag).
   8. Record standard concentrations and all absorbance readings on your data sheet.

B. Analyzing samples: Analyze samples by placing the plastic tubing into each sample container and pressing the appropriate button to analyze. Rinse between samples as before with DI water.

DATA SHEET

Solution	Concentration	Absorbance
Blank		
Low Standard		
Mid Standard		
High Standard		
W1		
W2		
W3		
W4		

C. Graph the calibration curve using the data from the blank and the three standards using Microsoft Excel. If the linear regression line misses any points by a large amount, see Ms. Salem.

D. Using the mean ppm (mg/L) values and standard deviations for the bullet fragment solutions, determine how many bullets are represented by the four solutions.

NOTE: I use [Ag] unknown values close to the values in Guinn (1979) so the students not only get a learning experience, but feel that they are recreating a piece of history.

Bibliography

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Lifton, David S. Best Evidence. New York: Macmillan, 1980.

Menninger, Bonar. Mortal Error: The Shot That Killed JFK. New York: St. Martin's Press, 1992.

Unit III

Organic Analysis

Emphasizing

Chromatography

Unit III - Organic Analysis emphasizing Chromatography

Lab: Paper Chromatography of Ink

Guest speaker or Video: Analysis of drugs, arson, and/or toxicology by a forensic scientist

A. Organic compounds:
    1. Lewis electron dot structures
    2. Molecular mass
    3. Molecular shapes
B. Oxidation/Combustion Reactions - Balancing chemical equations
C. Covalent bond energy
D. Introduction to Chromatography and Mass Spectrometry

Analysis of Ink by Paper Chromatography

modified from: Meloan, Clifton E., Richard E. James, and Richard Saferstein. Lab Manual: Criminalistics: An Introduction to Forensic Science, 6th ed. Upper Saddle River, NJ: Prentice Hall, 1998.

Paper chromatography was developed in the early 1940's in England. The technique is based on the fact that paper contains a thin film of water around the cellulose fibers of the paper, called a **stationary phase**. A mixture of the compounds to be separated is placed in a small spot at one end of a strip of paper, and an organic solvent (**mobile phase**) is passed over the spot and across the paper. Since each compound present has a different size, shape, and distribution of electrical field, each compound will dissolve in the water and organic solvent to a different extent.

The net result is that if two compounds are started at the same place and solvent passed over them, one compound will move along the paper faster than the other. After a period of time the flow of the mobile phase is stopped. The paper is dried and then sprayed with a reagent that will produce colored spots, if the compounds are not colored. The materials used in our experiment - inks - are already colored, so the latter step is not required.

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In this analysis we determine which type of ink pen was used to write a certain document.

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Preparation for chromatographing the ink samples involves the determination of a proper developing solvent. This will be done during the course of the laboratory.

EQUIPMENT

600 or 800 mL beakers
150 mm watch glasses
Filter paper, Whatman No. 1
pencils

REAGENTS
Deionized water
Ethanol (denatured)
Hydrochloric acid, 0.1 M
Methanol
Water-methanol, 50:50 (v/v)
Water-ethanol, 50:50 (v/v)

METHOD

1. Make up a developing chamber for one of the reagents above. Pour a small amount of the reagent (should be below the pencil line on the chromatography paper) into a 600 mL beaker and cover with a watch glass. This will allow the solvent to saturate the atmosphere inside the beaker before you are ready to start the chromatogram.

2. Spot the four suspect pens on the **pencil** line on which the crime scene ink is spotted. Spot and dry once. Try to make each spot as small as possible. Try not to get fingerprints on the paper.

3. Fold the paper in half length-wise, and lower the paper into the solvent, with the pencil line toward the bottom of the beaker, but do not immerse the spots. Replace the watch glass, dome side up. Let the solvent come up the paper over the spots by capillary action.

4. While the chromatogram is developing, observe the developing chromatograms of your classmates, and note differences and similarities.

5. Allow the solvent to rise up the paper until it reaches a point approximately 4 cm from the top of the paper or until the rise slows perceptibly.

6. Remove the paper, mark the solvent front and allow the strip to dry on a clean sheet of paper.

7. Look at the chromatograms of your classmates to determine which solvent system gave the best separation

8. Determine, if you can, which pen most likely wrote the ransom note. If, from your experiment, you cannot determine a decided difference, use a different solvent system and try again, if time allows.

DATA SHEET

1. What solvent did you use?

2. Which solvent gave the best separation of the components in the ink?

3. Which component was most soluble in this solvent? How can you tell?

4. Is the order of colors on the papers the same in every case of solvent used? Explain.

5. What is the maximum number of different colors that you see on a chromatogram? What are these colors?

6. In your opinion, which pen wrote the ransom note? Why?

7. Attach chromatogram(s) here.

Unit IV

Analysis

of

Drugs and DNA

Unit IV. Analysis of Drugs and DNA

Lab: Paper DNA analysis: A Case of Abduction – Mitochondrial DNA Identity Testing, Flinn Scientific Inc.

Guest speaker or video: DNA analysis by forensic scientist

A. Drugs
   1. Formulas, structures, and molecular weight calculations
   18. Analysis of gas chromatograms and mass spectra
B. DNA
   1. Structure
   2. Function
   3. Forensic applications
      ii. PCR using STR
      iii. RFLP
      iv. Statistical analysis

Appendix

These learning techniques have been used from time to time, but not all in the same class.

ONE PAPER

The paper will analyze one episode from the first six seasons of the original CSI (available in DVD format). Each person will have his/her own episode to work with, ie, two people **cannot** use the same episode, and first come, first served.

The author will choose 10 instances in the episode where forensic science was used and will analyze each. To analyze means to discuss in appropriate detail and explain – in writing – whether collection, processing, and/or analysis was correct or incorrect and document each instance with at least one reference.

The papers will be posted (anonymously or not – by author's choice on a web site where all of us can view them.

DISCUSSIONS – IN CLASS – OR ON-LINE DISCUSSION BOARD

1. Who should be included in the national DNA database: convicted felons, those arrested for felonies, all people arrested for any felony or misdemeanor, those over the age of eighteen, all babies at birth. Support your opinion.
2. What is the most important tool/test forensic scientists have? Support your opinion.
3. Would it be ethical to legislate implantation of an RFID-tag in every individual's tooth for easier identification after terrorist acts or natural disasters? Support your opinion.
4. How far are we as taxpayers willing to go to foot the bill to fund the different training or technology that may be necessary to get more accurate findings, faster processing, more databases, etc. Support your opinion.
5. Which is more important: personal freedom or personal safety? Support your opinion.

Appendix I - Letter to Professors

June 21, 2007

Dear Dr. … :

My thanks to Todd Zdorkowski for introducing us. He suggested you as someone who might be interested in helping develop a university course to teach the **real** forensic science to laypeople. As a part of the requirements for my PhD from Kansas State University, I am currently developing a forensic science course (with emphasis on chemistry) for university students of various majors to take as a general education credit.

If you choose to be involved in this endeavor, do nothing, and I will send, in about a week, a questionnaire for you to fill out. This will take approximately 30 – 45 minutes of your time. The questionnaire will ask about forensic science topics you consider to be important for the average juror, lawyer, person-on-the-street.

If you prefer not to be involved with this project, simply delete the e-mail when it comes. If you would like to suggest someone other than yourself – or in addition to yourself - who might be interested in this project, feel free to send that person's contact information to me.

Thank you for your time.

Sincerely,

Sue Salem
Forensic Chemical Science Coordinator
Chemistry Department
Washburn University
Topeka, Ks 66621
785 670-2271
Sue.salem@washburn.edu

Appendix J - Letter to Students of Introductory Forensic Chemistry

March 23, 2008

Dear student of Introductory Forensic Chemistry Spring 2008:

You have volunteered to critique this new forensic chemistry course and are therefore seen as someone who would be interested in helping develop a university course to teach the **real** forensic science to laypeople. As a part of the requirements for my PhD from Kansas State University, I am currently developing a forensic science course (with emphasis on chemistry) for university students of various majors to take as a general education credit.

As you have chosen to be involved in this endeavor, do nothing, and I will send, this week, a questionnaire, embedded in email, for you to fill out. Fill out the questionnaire within an email reply, and send it back to me by reply. This will take approximately 30 – 45 minutes of your time. The questionnaire will ask about science and non-science university courses you have taken, and what learning techniques are successful for you.

You will also receive a copy of a new introductory forensic science course. Please look through this course and make notes directly on it whenever you find something good – or something that needs to be changed. Please be specific.

We have agreed that both the reply to the questionnaire and the critique of the course should be returned, with the consent form, by _________________.

Thank you for your time.

Sincerely,

Sue Salem

Forensic Chemical Science Coordinator

Chemistry Department Washburn University

Topeka, Ks 66621

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