

Educating Policy Students in Nuclear Forensics

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Introduction:

The subject of nuclear forensics has only attracted significant public attention in the 21st century although its origins arguably date from the first nuclear weapons program almost seventy years ago.

Currently nuclear forensics is receiving a significant amount of attention and funding in the international community. Many states are either developing or expanding their own efforts in nuclear forensics or looking at how they might participate in multinational nuclear forensics efforts and programs. The International Atomic Energy Agency's (IAEA's) efforts in encouraging states to establish libraries of their nuclear material holdings are raising consciousness of nuclear forensics issues in decision making bodies and regulatory agencies. Accompanying this activity has been awareness training targeting the potential users of the nuclear forensics process: decision makers, the scientific community, and diplomatic, security and law enforcement communities.

In addition, educational institutions, government laboratories, and professional societies have developed academic courses, professional short programs, summer institutes, etc., many of which provide students with scholarships and hands-on experience in various fields such as transuranic elements, radiochemistry, radiation detection, etc.

However, the majority of these programs focus almost exclusively on the science aspects of nuclear forensics. To date there has been little effort to develop curricula on nuclear forensics that provide a policy overview of the subject or consider legal aspects of the field.

For example, Lawrence Livermore National Laboratory (LLNL) which has a long history in nuclear forensics, is running a "Nuclear Forensics Summer Institute Program" this summer in which 8-10 students will receive world class training in the field.¹ The program's selection criteria for students are as follows:

¹ https://www-pls.llnl.gov/?url=jobs_and_internships-internships-nuclear_forensics_sip

We select graduate students who are majoring in physics, chemistry, geology and geochemistry, nuclear engineering, chemical engineering and environmental sciences that have an interest in nuclear science and would like to do hands-on research under the guidance of a staff scientist.²

Similarly, degree programs and coursework in nuclear forensics tend to originate in chemistry, nuclear engineering, and sometimes physics faculties. Available teaching materials, discussed further below, are extremely limited, and those that do exist focus primarily on the technical aspects of nuclear forensics.

Where can international relations majors, nonproliferation studies majors, or anyone whose training is non-technical go to find appropriate education for policy makers in nuclear forensics?

Based on the author's experience in teaching nuclear forensics and other technical topics to non-technical students in a master's degree program, this paper will focus on providing education for future policy and decision makers. It will consider why such education is needed and discuss what subjects should be covered. An underlying but extremely necessary discussion will address the issues of how to communicate scientific information to a non-science student and the challenges of presenting nuclear forensics materials to a non-technical group of students.

Finally, a proposed exemplar curriculum will be presented.

Discussion:

A. Why is teaching non-technical (i.e. policy) students about nuclear forensics important?

Why is the teaching of nuclear forensics to policy students important? Perhaps the answer should be obvious. However, the fact that teaching nuclear forensics to policy students is apparently only being done in a few locations may indicate that it is not considered important either by the academic community or by the students themselves.

Simply put, policy students evolve to become diplomats, politicians, and decision-makers who will ultimately influence the development of nuclear forensics primarily through the selective allocation of resources. It is important therefore that they develop an understanding of the topic at a level of detail that allows them to understand whatever scientific arguments are being made and to intelligently make policy decisions relating to nuclear forensics.

Who are policy students? Is it sufficient to address simply undergraduate and graduate students, or is the description of the educational need broader? The author would argue that a broad definition is preferable. Although the author currently teaches in a graduate

² Id.

program the discussion in this paper is equally applicable to the education of undergraduates and to the education of postgraduates, i.e., professionals in all levels including diplomats, members of regulatory bodies, etc. who do not possess a technical education that allows them to self-educate in the area of nuclear forensics.

So what are the typical characteristics of a "policy" student? Perhaps the most defining characteristic is that most of them come from non-technical educational backgrounds. As an undergraduate they may have studied international relations, political science, government, etc. A few policy graduate students may have technical undergraduate backgrounds. The author's course in Nuclear Forensics is an elective in the Nonproliferation and Terrorism masters program at the Monterey Institute of International Studies. The students' backgrounds in this course to date have been approximately two thirds non-technical students. The one third of students with technical backgrounds is higher than the general student population in this masters program.

What this means in practical terms is that teaching nuclear forensics to policy students involves the teaching of the relevant science concepts. For many of the policy students a course in nuclear forensics may be the first time they have taken any type of science course since high school. Terms such as "isotope," "fission," etc. may need to be explained. Their fundamental knowledge of science may be extremely basic or essentially nonexistent. This should by no means be taken to imply that the policy students are not intelligent. However, to some extent a course in nuclear forensics, or for that matter any course in science given to policy students, must be thought of as a language course. In fact, one of the author's stated goals for the course is the students' acquisition of a vocabulary with which to speak effectively to nuclear forensics professionals.

Unfortunately our current educational method in graduate school is still mainly lecture format. A dozen students may be listening to the lecturer and perhaps only half understand what he or she is saying. In many non-technical classes statements made by a lecturer that are not understood by the students would immediately be challenged. The author's impression is that tragically this is less likely to occur when the lecture has a scientific theme. Many students feel intimidated because they may assume that they are the only one in the class who does not comprehend what is being said. This adds to the general reluctance that students may have to pose questions which they feel will disclose what they may consider to be an embarrassing lack of scientific knowledge. Sometimes the lack of understanding by a student only becomes clear when they can't perform on an examination. How to address this challenge of a communication barrier between a science background instructor and a policy student is, in the author's opinion, one of the greatest challenges in teaching to non-technical students. It is tempting for the instructor to periodically ask the students in class, "Do you understand?" or pose some question of that nature. Many of us have seen this in practice, or may have experienced it as a student. Although it demonstrates a concern by the instructor, it rarely breaks through the barrier of reluctance students may have to admit that they truly are confused.

Another challenge that becomes apparent when teaching a mixture of technical and non-technical students in a technical subject such as nuclear forensics is the students' concern

about how they will be graded. Since the subject matter is technical, the non-technical students may be reluctant to even take the course for fear that they may suffer in grading with respect to the more technically competent students. The instructor must be sensitive to the realistic concerns of non-technical students that they may not be able to compete effectively with students who have a technical background. The course syllabus should clearly indicate that the focus of the course is on the policy issues of the subject and that assistance will be provided for learning the basic science concepts.

Although it is relatively easy to express some of these concerns or challenges, overcoming them is not easy in practice. One-on-one interactions with the students (which may be extremely difficult in a large class, but is achievable generally in a seminar session) may be necessary in order to allow the students to reach a comfort level where they can learn the material. As will be discussed later, some of these problems are compounded by the lack of a suitable text to use with policy students.

In summary, teaching nuclear forensics to policy students who are essentially non-technical is an important task that is not currently being fully addressed by either the science or the policy communities. There are a number of challenges in teaching nuclear forensics to non-technical students. Some of these may be overcome by adopting teaching methods that are appropriate for the students. It is not an easy task, but it is a task which is essential for the long-term viability of nuclear forensics programs on a national and international basis since the students will be future decision-makers who will deal with the future direction of nuclear forensics programs.

B. What should policy students be taught about nuclear forensics and at what level should they be taught?

Should policy students studying nuclear forensics cover the same subject matter that science students studying nuclear forensics cover? In a four credit seminar style course at the Monterey Institute, the author's description of the course is as follows in the course syllabus:

Nuclear forensics deals with the science related to the determination of the origins of nuclear materials such as uranium and plutonium and to the policy considerations, such as attribution, which result from determinations that can be made. In addition to science and policy considerations the course will cover the current international efforts in nuclear forensics and survey the performance of conventional forensics in the presence of radioactive material and related issues such as radioactive crime scene management and expert testimony on nuclear forensics issues. (NPTG 8656 Spring 2014)³

³ Note that there are a number of definitions of nuclear forensics. One of particular note is a statement in a press release by the U. S. Department of Energy's National Nuclear Security Agency (NNSA) "Nuclear forensics is the popular term for the scientific characterization and analysis of nuclear or other radiological materials, which can provide critical information on the place of origin and process history of nuclear materials. This information can help national authorities determine how and where control of material was lost and, when combined with law enforcement and intelligence information, can facilitate the prosecution of smuggling cases." <http://www.nti.org/gsn/article/nnsa-iaea-offer-nuclear-forensics-training/>

The course objectives are as follows:

Students successfully completing this course will be able to:

- Demonstrate an understanding of the basic concepts of nuclear forensics science.
- Demonstrate an understanding of the potential applications of nuclear forensics in the determination of the origin of nuclear and other radioactive materials,
- Demonstrate an understanding of the terms and definitions that are used in the field of nuclear forensics.
- Demonstrate a fundamental understanding of the international efforts to cooperate in nuclear forensics analysis.
- Demonstrate an understanding of the legal requirements for the introduction of evidence resulting from nuclear forensics analysis.
- Demonstrate an understanding of the policy implications of attribution.

By contrast, a four-day training course offered by the Radiochemistry Society⁴ described the topics covered as follows:

Key Topics You'll Learn About

- Fundamental Principles of Trans-Uranium Elements
- Fundamental Principles of Fission Products
- Fundamental Principles of Rapid Screening Measurements
- Fundamental Principles of Non- Destructive Assay
- Fundamental Principles of Neutron Activation Analysis
- Fundamental Principles of Alpha Spectrometry
- Fundamental Principles of Gamma Spectrometry
- Fundamental Principles of Neutron Counting
- Fundamental Principles of Portal Counting
- Fundamental Principles of Liquid Scintillation Counting
- Fundamental Principles of Gas Flow Proportional Counting
- Best Methods and Strategies for Separation Chemistry
- Making Reliable & High Quality Measurements in Nuclear Forensic
- Fundamental Principles of Contamination Control
- Fundamental Principles of Reporting of Results
- Fundamental Principles of External Communication

The difference in focus is obvious. Policy students need to have an understanding of what the Radiochemistry Society considers to be key topics, but they need to have that understanding at an overview level. Non-technical policy students will not understand initially what a gamma ray is or what types of detectors can detect various types of

⁴ Available at: http://www.radiochemistry.org/courses/rc_forensic.html

radiation. It is important for them to understand the differences, but far more important to understand why those differences can be critical. They do not need us to understand the details of how a portal monitor works, but they should have some understanding of how portal monitors are used and that portal monitors may have differences in sensitivity and different detection capabilities (i.e., that some may be able to detect neutrons in addition to gamma radiation).

Attached as Appendix 1 to this paper are the syllabus topics of the 16-week course on nuclear forensics taught at Monterey Institute by the author. In teaching these courses an educational concept known as "flipping the classroom" is employed to some extent. This involves the creation of short videos that further explain various topics that students found difficult to understand. Other videos provide guidance to the students on how to read and interpret some of the course materials. Educational freeware such as the iPad app "Explain Everything"⁵ and simple video capture software available on any computer are typically used to produce these videos. The Monterey Institute uses Moodle as course management software, but the file size of the videos makes the use of Dropbox preferable for distributing videos to the students. Typically the PowerPoint presentations used in class are made available on Moodle shortly after the lectures are completed.

The emphasis in teaching in the author's course is on concepts, definitions, and the organizational structure of how things fit together. In other words, where do pre-and post-detonation nuclear forensics fit into a national program? What are the differences between two conceptual types of nuclear forensics, i.e., determination or attribution with regard to nuclear or other radioactive material and performing conventional forensics in a radioactive environment or on radioactive or radioactively contaminated materials? In addition, the development of the concept of states' nuclear materials libraries and their importance are significant subjects for policy students to understand. The libraries, and the IAEA's efforts in the field can give rise to significant policy issues and discussions.

Policy students are capable of understanding the importance of radiochemical separations, mass spectrometry, and a number of concepts that are important in nuclear forensics, but their understanding is at the overview level. For example, they can learn the necessity of using radiochemical separations in order to look for trace elements in radioactive samples, but they will not intuitively grasp the differences in orders of magnitude. Scientific notation will have little to no meaning to them without explanation. They are quite capable of understanding these concepts, but an instructor must be aware that they need to be educated in principles such as scientific notation and cannot assume that they have learned these somewhere in their background.

In addition to the scientific concepts of nuclear forensics the author's program in nuclear forensics places some emphasis on the legal aspects associated with expert testimony on nuclear forensics in a court of law. Policy students are interested in these concepts and how they play out. It can be a "hook" for students who are otherwise not interested in some aspects of nuclear forensics. On the other hand, it has been the author's experience

⁵ See <http://www.newschooldtechnology.org/2013/02/explain-everything/>. The free app is available from iTunes App Store.

that U.S. students, much less international students, have little understanding of the American legal system and in the differences between federal and state courts and the differing standards that might apply in these courts.

Finally, international efforts of cooperation in nuclear forensics (and conversely the lack of cooperation) are of great interest to policy students. Whenever possible efforts by international organizations such as the IAEA, EURATOM, INTERPOL, EUROPOL, and the United Nations Interregional Crime and Justice Research Institute (UNICRI) are discussed in the class as are efforts by the FBI, Department of Homeland Security, Department of Defense, etc. on the US domestic scene are discussed. The Nuclear Forensics International Technical Working Group (ITWG) and the efforts of professional societies such as the American Physical Society and the American Association for the Advancement of Science are also topics of discussion, particularly when, as discussed in the following section, those organizations have made policy recommendations on nuclear forensics.

In summary, policy students need to be taught the basic elements of nuclear forensics from an overview perspective. They need to understand the language of nuclear forensics in order to be able to communicate effectively on the topic and they need to understand the legal and organizational frameworks that exist on a national and international basis.

It is worth considering whether or not a "one size fits all" course is the best for policy students. At the Monterey Institute full semester courses can be either in a lecture format or a seminar format. The author's nuclear forensics course has been taught in a seminar format which allows the students to pursue their individual interests to some extent through their choice of a paper topic to satisfy the requirements of the seminar. This allows each student to find and explore a nuclear forensics topic that they find interesting. Although some may initially struggle with the topic selection, it appears that each student discovers a topic in which they are truly interested. Often, for example, international students explore their country's efforts in some aspect of nuclear forensics. The author gives students a free range of topic choice so long as it connects to the basic nuclear forensics subject.

C. What materials are available to teach policy students?

Anyone establishing a course for policy students in nuclear forensics is faced with a dilemma of what materials to use. *Nuclear Forensic Analysis* by Kenton J. Moody, Ian D. Hutcheon, and Patrick M. Grant (Moody see Figure 1 below) is virtually the only published book on the subject.

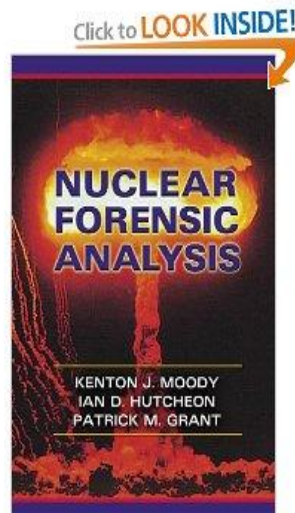


Figure 1. Cover of Moody, et. al.⁶

However, Moody is not a textbook--at least in its current edition.⁷ The author uses it as a text, but it is certainly above most policy students' ability to read without significant guidance, i.e. the students need to be told what areas to ignore as to technically difficult and which to focus on. An additional difficulty with the Moody book is that like all scientific texts it is expensive, a fact that leads to an unfortunate preference by some students to use the reference copies available in our library instead of buying a copy for their professional library.⁸ Certain chapters of Moody, particularly the case studies in the later part of the book are particularly good for use with the policy students as concrete demonstrations of the power and utility of nuclear forensics.

In addition to Moody, the IAEA's Nuclear Security Series publication on nuclear forensics, Nuclear Forensics Support⁹ (see Figure 2 below) is a useful reference.

⁶ <http://ecx.images-amazon.com/images/I/51JGfJ9wQiL._BO2,204,203,200_PIsitb-sticker-arrow-click,TopRight,35,-76_AA300_SH20_OU01_.jpg>

⁷ Note that in 2013 when students attempted to purchase the Moody book through Amazon they were advised that a new edition would be forthcoming. To the author's knowledge that has not happened yet and the warning has been removed from Amazon. CRC Press indicates that a Second Edition will be published in November 2014 (See www.crcpress.com/product/isbn/9781439880616). Hopefully the newer addition of Moody will retain its scientific merit while transitioning to more of a textbook format.

⁸ It should be noted that Amazon offers Kindle versions of Moody and also may offer semester rental options. These options vary from time to time and may offer better affordability for the students.

⁹ Available for download as a .pdf document at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1241_web.pdf

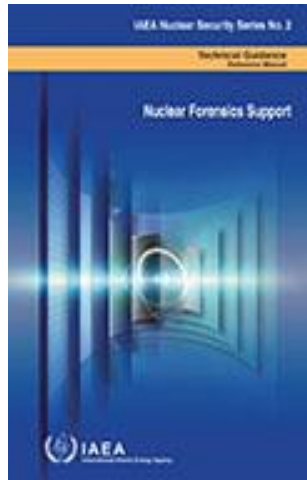


Figure 2. Cover of Nuclear Forensics Support--IAEA Nuclear Security Series No. 2

Although the Nuclear Security Series publication is in revision it is still useful as a reference and it can also be quite useful in explaining to students the operations of the IAEA in general and specifically with regard to nuclear forensics.

In addition to these more book or book-like publications, a nuclear forensics course for policy students must of necessity use materials available from the Internet including articles of topical interest. The author has found several national laboratory publications as well as professional society publications to be of utility in his nuclear forensics course.¹⁰

It should also be noted that the IAEA has developed a Master's degree level program in nuclear security that is set out in Nuclear Security Series No. 12.¹¹ One of the elective courses is NS19, "Nuclear forensics and attributions." The International Nuclear Security Education Network (INSEN)¹² has undertaken through its subcommittees to develop course materials in support of the IAEA's program, but to date there is no product available that supports NS19.

In summary, there does not appear to be a text which will be usable in the foreseeable future for policy students. INSEN or a private publisher may develop development a suitable text, but it appears that for the foreseeable future the teaching of nuclear

¹⁰ In particular, "Nuclear Forensics Role, State of the Art, and Program Needs," by a Joint Working Group of the American Physical Society and the American Association for the Advancement of Science available at: <http://www.aaas.org/report/nuclear-forensics-role-state-art-program-needs> is a useful publication. This has been presented to policy students late in the course in order to demonstrate to them their mastery of the concepts discussed in the study.

¹¹ "Educational Programme in Nuclear Security" available for download as a .pdf at: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1439_web.pdf

¹² See the report of INSEN's August 2013 meeting available at: <http://www-ns.iaea.org/downloads/security/annual-iinsens-meeting-2013-chairman-report.pdf>

forensics to policy students will need to rely on Moody (the original version or its second edition edition), much as the author has done in the nuclear forensics course taught at the Monterey Institute.

D. What should to be done to improve the situation?

An obvious way of improving the ability to teach policy students about nuclear forensics would be to develop a text which targets various levels of background in science.

However, a text focused totally on students with a non-technical background might not be a viable commercial option. Integration of the underlying fundamental science background with policy and legal aspects of nuclear forensics could be developed into a viable text that would be useful at the undergraduate and graduate level for students with a non-technical background and for a broader non-technical audience. If creatively written, such a text would also be suitable for students with a technical background who want to learn something about the technical aspects of nuclear forensics but are not interested in delving into detailed technical issues. In addition to an overview of the subject matter, a student with a technical background should find such a text provides a gateway to learning something about the legal and policy aspects of nuclear forensics.

Development of such a text would be a useful contribution to the long-term health of nuclear forensics and therefore to the long-term health and sustainability of the global nuclear security regime.

Appendix 1: Syllabus Topics from MIIS course NPTG 8656 Spring 2014

Week 1 Topic: Course Introduction and Overview—What is Nuclear Forensics?

Week 2 Topic: Nuclear Explosive Devices

Week 3 Topic: Scientific Basis for Nuclear Forensics

Week 4 Topic: Scientific Basis for Nuclear Forensics (continued)

Week 5 Topic: Chronometry

Week 6 Topic: Analysis Techniques

Week 7 Topic: Analysis Techniques (continued). Begin selection of paper topics for class presentation and final paper

Week 8 Topic: **Spring Break no class**

Week 9 Topic: Analysis Techniques (continued) **and** Case Studies

Week 10 Topic: **Midterm Examination**

Week 11 Topic: Case Studies

a) Assigned Reading: Moody Chapters 20 to 25

Week 12 Topic: Nuclear Forensics on the International Scene (possible guest speaker)

Week 13-16 Discussion of students' paper topics, each student presents their paper, plus outside speakers. There is no final examination. Student papers are ~20 pages in length and presentations are 20-30 minutes in length.