Reflections on Teaching the Manhattan Project

— BY B. CAMERON REED

The Legacy of Manhattan

In 1999, the *Newseum* of Washington, D.C. released the results of a survey of journalists and the public as to the top 100 stories of the twentieth century. Number one on the list for both groups was the atomic bombings of Hiroshima and Nagasaki and the end of World War II.[1] Journalists ranked the *Trinity* test in New Mexico as number 48, and the Manhattan Project itself as number 64. Nuclear weapons were arguably *the* single most important factor on the geopolitical stage for the last half of the twentieth century, and they will remain enormously influential for years to come. In the decades since the Manhattan Project, FAS and the organizations that gave rise to it have sought to provide the scientific community, legislators, and the public at large with reliable information on nuclear issues to help guide the development of national policies.

For most members of the public, however, nuclear physics comes to their attention only when the news seems dire: What are the Iranians and North Koreans doing? How concerned should I be about the disaster at Fukushima? What is reactor-grade plutonium and should I worry about who has access to it? Lack of basic knowledge in the area of anything "nuclear" contributes to public apprehension and impedes the development and implementation of broadly supported policies. The need for public education on nuclear issues is as pressing now as it has ever been.

For several years now I have taught a general-education course on the history of the Manhattan Project and its legacy to liberal-arts students at Alma College in an effort to address, in a very modest way, the lack of knowledge in this area. In this article I describe Alma College, the course and the student population it attracts, and offer some reflections on what I have learned about offering such a course and how it has evolved after what is now some half-dozen offerings.

Alma College

Alma College is a strictly undergraduate liberal-arts school of about 1,300 students located in central Michigan. In addition to choosing a major, every student must complete a requisite number of credits in the humanities, social sciences, and natural sciences. These general-education courses comprise about one-third of a student's overall credit requirements. Within the natural sciences is a physical-science requirement, with courses such as astronomy, geology, and general chemistry being popular choices. Alma operates on a "4-4-1" schedule: two traditional four-month terms (Fall and Winter), followed by a one-month Spring term. The latter is the time frame during which my course, "The Making of the Atomic Bomb," is usually offered. Spring term begins in late April and runs to just before Memorial Day. During this time students take one course intensively, often meeting five days a week for 3-4 hours; every student is required to complete two Spring terms within a four-year degree. Class size is typically 15-20 students. The rationale for this short small-class semester is to provide an opportunity for the College to offer courses that would not otherwise conveniently fit into a regular term. While many courses involve a field work or travel component, students with local jobs or who are on a sports team prefer on-campus classes, particularly ones that carry general-education credit and have no or minimal prerequisites. There is no formal prerequisite for my class, but students are encouraged to have at least taken if not placed beyond our basic algebra course. The course even attracts the occasional physics major. Indeed, how many college physics majors emerge from their curricula with much better ideas of the details of nuclear weapons than what they did from high school?

Teaching the Manhattan Project

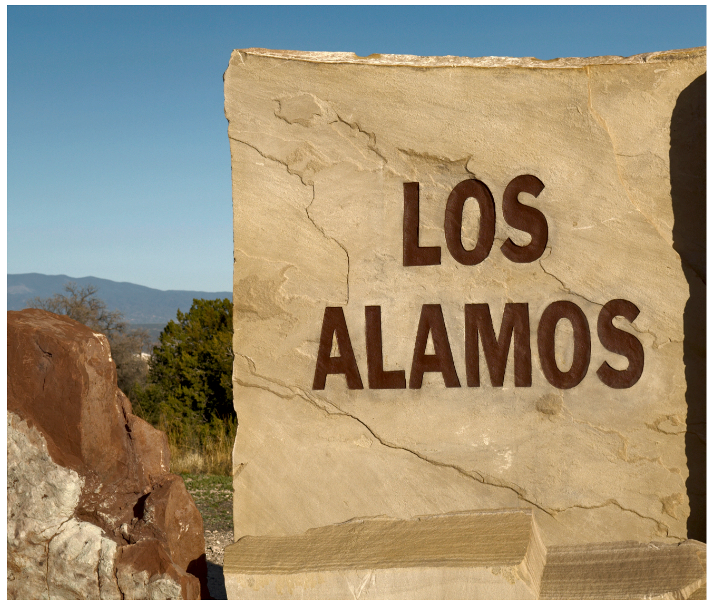
The development of my class represented a convenient marriage of two factors: I wanted to be able to offer a general-interest class for non-science students, and for many years I have been publishing on the history and physics of the Manhattan Project. By 2002 I felt that I had acquired enough command of the topic to offer a course on it. I have now taught the course a total of six times during Spring terms plus a spin-off "First-Year Seminar" course which was offered in a regular Fall semester (2009) and is scheduled again for Fall 2011.

Since the very first offering I have begun with a survey that asks fundamental questions such as:

- Which country first developed nuclear weapons?
- In what year and during which war were they first used?
- On what cities were they dropped?
- What other countries subsequently developed nuclear weapons?
- What "explosive elements" do the weapons utilize?
- Name one person prominently associated with the Manhattan Project.

The war, country of development, and target cities are usually quite well known, but knowledge of other nuclear powers and identifying a leading personality tend to be extremely weak: most students think that nuclear proliferation is much broader than it is in reality, and Einstein frequently comes to the fore as the "father" of nuclear weapons. I always have my work cut out for me.

The text for the course is Richard Rhodes' masterful *The Making of the Atomic Bomb*. Our Spring term runs to about 19 instructional days, which corresponds to about one chapter per day. Students are expected to read a chapter the evening before each day's class. Lectures then consist of me explaining the material with the aid of numerous Power-Point slides, occasional videos, sample calculations involving reactions and isotopes, examining some classic original papers, and performing some simple demonstrations with equipment such as a Geiger counter and radioactive sources or a cathode ray tube to illustrate the idea of bending ion streams with a magnetic field. Students are often astonished to see that household smoke detectors, bananas, Trinitite, and old Fiestaware are mildly radioactive. Because the Manhattan Project is such a plethora of names, places, and concepts, students soon become hopelessly saturated if it is all presented in a traditional lecture style, so the videos, demonstrations, and photos of and anecdotes about the lives of the people involved are vital for breaking up the routine. I tweak the course every year in an effort to find an appropriate balance of hard-core and lighter content, and I suspect that I will never find the perfect one.



In the first incarnation of the class I stuck closely to the one-chapter-per-day prescription, but this proved somewhat awkward. Rhodes devotes considerable space to tangential issues which are relevant to setting the historical stage but are not directly germane to the science of nuclear weapons. We have a lot to cover in three and a half weeks, and deleting such material from the required reading has freed up time to go into more detail on the underlying science and current events. For example, in the most recent offering of the course (Spring 2011) I spent some time discussing radiation units and looking at maps of Fukushima fallout patterns.

The course content goes mostly in chronological order. The first half of the material takes us to 1939. We begin with the discovery of X-rays, radioactivity, and the electron as the opening acts of modern physics, then move on to the work of the Curies, Rutherford, and Bohr, artificial transmutation, the discovery of the neutron, artificial radioactivity, the work of Enrico Fermi, the tangled story of the discovery and interpretation of fission, the Szilard/Einstein/FDR letter, and the opening of World War II in Europe.

The second half of the course begins with the establishment of the Manhattan District and proceeds to a discussion of what was accomplished at Oak Ridge, Hanford, and Los Alamos; the *Trinity* test and the Hiroshima and Nagasaki missions then follow. As time permits in the last couple of days we look briefly at some selected topics such as the effects of nuclear weapons, the staggering number of postwar tests conducted by America and the Soviet Union, current deployment statistics (always a surprise), the concept of fusion weapons, and nonproliferation and arms-control treaties.

Weekly tests cover material at a qualitative level via multiple-choice and short-answer questions, while occasional homework assignments require students to balance reactions, predict the result of a decay process, compute the energy release in a reaction, or estimate a critical mass given a simplified formula. When I do the course during a regular semester the additional time allows me to add an extra reading/writing component: each student is randomly assigned a different book to read and on which they must prepare a report, with one cycle of submit-revise-resubmit. In most cases these are biographical or popular-level synoptic works; one cannot get into great technical depth with such a class.

Overall, my goal is for students to emerge from the course with fundamentally correct understandings of the history and basic science of nuclear weapons. I try to help them appreciate that nuclear weapons were in no sense pre-ordained and that even many of the leading physicists of the time scoffed at the idea of harnessing nuclear energy, *viz.* Ernest Rutherford's "moonshine" comment. I tell them that I consider the course a success if they can explain to a friend how the first nuclear weapons were developed, the essentials of how they function, what problems were overcome in making them, how a reactor differs from a weapon, how implosion creates a more efficient device, and why a subcritical mass of U-235 sitting on a desk would be perfectly safe. But I also want them to know something of the people involved: of Lise Meitner's flight from Germany just months before the discovery of fission, of Enrico Fermi and Hans Bethe, among others, making their way to America, of Oppenheimer's brilliant, eclectic, and tragic life. I want them to know that science and engineering are carried out and historic decisions made by real people.

LESSONS AND REFLECTIONS; STUDENT OPINIONS

With the Manhattan Project now a two-generation-old memory, a realization that hits me afresh every time I offer my course is that many of today's young people have only the vaguest notions of the course of World War II and the ferocity it had reached by the summer of 1945. Equally new for many of them is learning of the McCarthyist hysteria that swept America in the 1950s and the almost insane growth in the number of nuclear weapons since that time. As befits a liberal-arts environment, it is important that I teach some related history and sociology in addition to some physics.

Probably the most gratifying result for me is to see that many students are *very* interested in learning about nuclear history and issues. Many express a desire to do further reading on their own, so I learned early on to always devote some time to giving them some pointers on where to look for credible sources. These include the FAS site, the Los Alamos history site, the Washington and Lee University *Alsos Digital Library for Nuclear Issues* site, and some annotated bibliographies and a book that I have prepared.[2] Given that an online search on "Manhattan Project" or "Nuclear weapons" returns millions of hits, having good starting points is essential.

Mine will always be a small-scale contribution to public nuclear education. Alma is a small college; since 2002 about 120 students have taken the course. In 2007 I began taking an end-of-course survey, asking students to imagine themselves as President Truman in the summer of 1945 but with the benefit of some understanding of the functioning and effects of nuclear weapons. They are asked to choose, anonymously and with comments if they desire, one of six statements that most closely matches their own thoughts.

Paraphrased, these are:

- The use of nuclear weapons against Japan without prior warning was entirely justified.
- The use of the first bomb without prior warning was justified, but you would have allowed more time to elapse before the second (and any subsequent) ones were used, and a warning should have been issued.
- Even if you would have had personal moral reservations about using nuclear weapons, Hiroshima and Nagasaki were essentially foregone conclusions in view of the ferocity of the war, the looming post-war geopolitical situation with Russia, and the tremendous resources that had been devoted to the Manhattan Project. (I think of this as the "default" option.)
- Nuclear weapons should have been used only after the Japanese had been given a clear demonstration of their power, followed by a warning that they would be used unless Japan surrendered.
- Because the development of nuclear weapons could probably not have been kept secret for long, you would have supported their development but vetoed their use except as a last resort in case America faced an invasion or the imminent threat of nuclear attack by another country.
- Nuclear weapons are a moral abomination in any conceivable circumstance. You would have foresworn their development entirely even if it was known that other countries were working to develop and produce them.

Responses from 65 students have been collected so far; the results are shown in the figure. I never disclose individual-class or cumulative results to a current group of students, and the distribution of responses has remained fairly consistent over the years. Before distributing the survey I do show the class some casualty statistics from the Pacific island-hopping campaigns of 1945 to give a sense of the scale of the war; we also look briefly at the planned Olympic and Coronet invasions of Japan that were scheduled for late 1945 and early 1946. The results of the survey do not surprise me: Alma students are from smaller towns and tend to be conservative; they have likely had little exposure to revisionist history. It would be interesting to try the survey with another population at a larger, urban institution.

In an order roughly corresponding to the above options, here are some selected student comments (paraphrased and grammatically tidied):

" ... the anticipated casualties from an invasion made it so the bombs saved lives."

"... the bomb saved a lot of American lives and sped up the end of WW II."

"I do not believe that Japan was clearly headed for defeat ... America's position in the post-war world was determined by the vast destruction ..."

" ... after the drop on Hiroshima we should have given Japan the opportunity to reevaluate whether defending their honor would be worth further nuclear warfare."

"The use of the bombs was inevitable with all the resources and money that had been put into the Manhattan Project ... however, their power is horrifying, absolutely nothing about them is child's play."

" ... scientists all over the world knew of the potential for atomic weapons ... the creation of atomic bombs was inevitable ... but the use of these weapons without warning on a nation that did not also possess them was a very poor decision ..."

"After the debut of nuclear weapons there has not been a major war in Europe or between major powers in over 60 years."

"Attacking civilians is never sound military strategy. We are in the midst of a war on 'terror' – the use of nuclear weapons on a city is nothing but more efficient terrorism."

" ... these are weapons of genocide ... these weapons acknowledge, and even endorse, the loss of innocent life ..."

" ... the use of nuclear weapons against Japan was not a proportional response [but] as much as I would like to choose option 4 or 5, I really believe there was not much choice, or a more efficient way to end the war."

"I really feel that a weapon of such destruction should be used only as a last resort."

I know of a few faculty around the country who are teaching similar classes, and would encourage development of analogous courses at other institutions. Depending on the expertise of individual faculty, courses could take a variety of implementations and could develop into ideal vehicles for interdisciplinary offerings. We will never run out of customers.

The history and physics of the Manhattan Project is a virtually open-ended vehicle for teaching our students some physics, history, political science, and sociology. I see it as supporting, in a small way, the efforts of organizations like the FAS in their ongoing efforts to bring light to the debates on nuclear issues. ■

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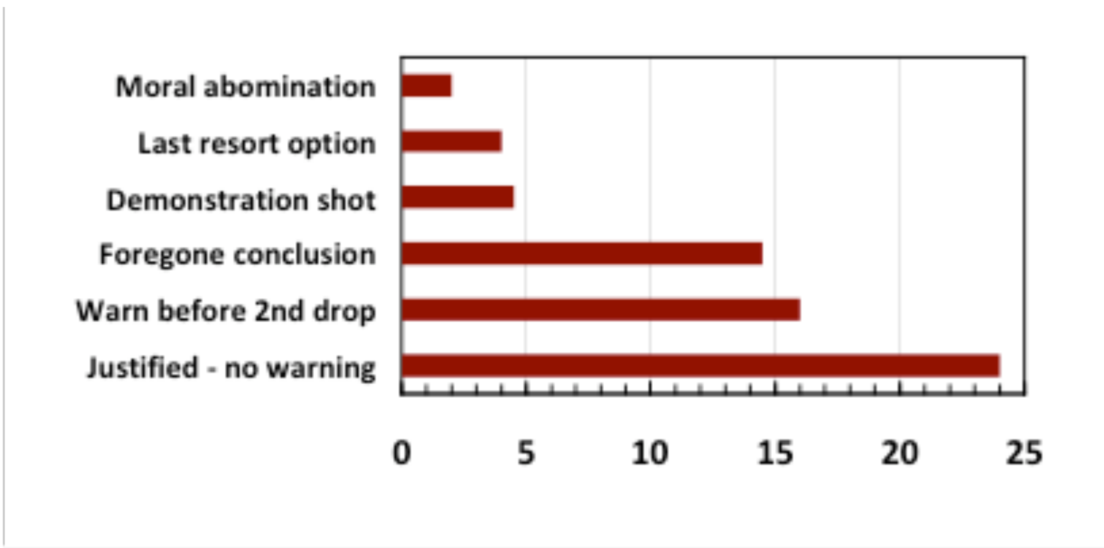

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[1]. http://www.newseum.org/century/

[2] Reed, B. C. Resource Letter MP-1: The Manhattan Project and related nuclear research." American Journal of Physics **73**, 805-811 (2005); "Resource Letter MP-2: The Manhattan Project and related nuclear research." American Journal of Physics **79**(2), 151-163 (2011); See also B. C. Reed, *The Physics of the Manhattan Project* (Springer-Verlag, Heidelberg, 2010).