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Dual Use Issues in the Life Sciences: Challenges and Opportunities for Education in an Emerging Area of Scientific Responsibility

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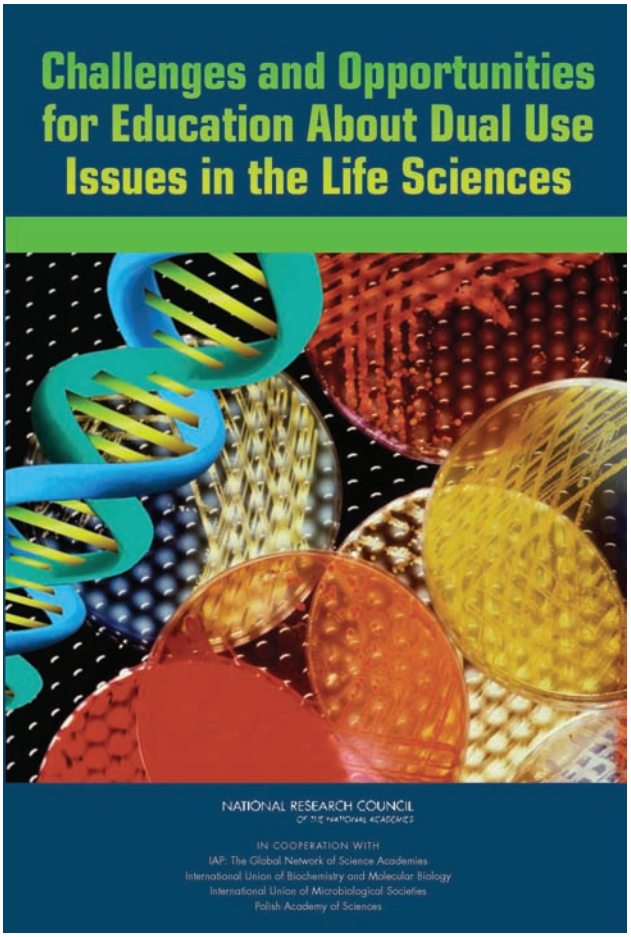
INTRODUCTION

The life sciences offer tremendous promise in meeting complex interdisciplinary challenges in areas such as food, health, energy, and the environment in the coming century. As a recent National Research Council (NRC) report notes,

> Years of research have generated detailed information about the components of the complex systems that characterize life—genes, cells, organisms, ecosystems—and this knowledge has begun to fuse into greater understanding of how all those components work together as systems. . . . The life sciences have reached a point where a new level of inquiry is possible, a level that builds on the strengths of the traditional research establishment but provides a framework to draw on those strengths and focus them on large questions whose answers would provide many practical benefits. (NRC, 2009a, pp. 12–13)

In parallel with the excitement generated by the rapid pace and global nature of developments in the life sciences, concerns have grown that these advances have the potential to yield knowledge, tools, and techniques that could be misused for biological weapons or bioterrorism. This is the so-called dual use dilemma—the possibility that advances in the life sciences intended for legitimate and beneficent purposes might also be used for malevolent ends (NRC, 2004, p. 1). Examples of research with dual use potential that have stimulated controversy include reconstruction of the 1918 pandemic influenza virus (Gibbs *et al.*, 2001) and the genetic engineering of plants such as tobacco to produce



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toxin proteins for vaccination (Wang *et al.*, 2001).[1] The 2001 mailing of letters containing lethal anthrax, which the Federal Bureau of Investigation (FBI) has concluded was perpetrated by a U.S. scientist, represents a widely known example of actual misuse of biological materials (FBI, 2008).

Thus an understanding that scientists have responsibilities to uphold standards of ethics and integrity in the conduct of their work, and a recognition that scientific developments exist within a social context, needs to be embedded into the education of current and future biologists. As the third edition of *On Being a Scientist*, the National Academies' introduction to responsible conduct of research, notes,

> The standards of science extend beyond responsibilities that are internal to the scientific community. Researchers also have a responsibility to reflect on how their work and the knowledge they are generating might be used in the broader society. (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2009, p. 48)

There have been increasing calls to incorporate discussions about the potential security implications of scientific developments into the education of students and practitioners at multiple educational levels (American Association for the Advancement of Science, 2008; Federation of American Societies in Experimental Biology, 2009; NRC, 2009b). However, many scientists and educators themselves currently lack awareness of this topic,[2] of how or why they might wish to incorporate it into their courses, and of why their input is critical to ongoing policy discussions. A committee of the NRC's Board on Life Sciences recently sought to address these issues to call attention to the range of materials that exist and to recommend steps to integrate this topic into a variety of educational forums.

WHAT ARE THE CHALLENGES AND OPPORTUNITIES POSED BY "DUAL USE" IN THE LIFE SCIENCES?

The prohibition on the use of biological weapons and emphasis on the peaceful uses of biological knowledge are embedded in the Biological and Toxin Weapons Convention[3] as well as in several other international agreements. The biological sciences pose special security challenges. The availability of biological materials in nature, including dangerous pathogens, and the ability of these materials to replicate, means that there are no technical "chokepoints" where restricting access to materials poses a formidable barrier to acquisition. The broad array of life sciences research that might be of concern covers many fields and types of research institutions. Commercial research and applications are equally diverse, so monitoring potentially relevant activities is a formidable task. And the rapid pace of scientific advances makes it difficult to keep abreast of potentially new or unanticipated risks and then to craft legal or regulatory measures that can stay current and relevant without unduly hampering scientific research. As a result, there is widespread recognition that efforts to minimize the potential misuse of the biological sciences, while ensuring the continued advancement of knowledge for beneficial purposes, must draw on the education and active engagement of the scientific community.[4]

As recognized by the recent NRC (2011) report, one essential way in which the community can contribute to this engagement is through the formulation and adoption of effective educational materials. In addition to advancing a tradition of scientists' self-governance and self-regulation when challenged to address the potential implications of research developments,[5] education about dual use issues provides good opportunities to engage students in conversations about the intersection of science and society. The topic is flexible, encompassing examples drawn from multiple areas of biology and from collaborating disciplines such as engineering and mathematics. It highlights the global nature of scientific research and can be adapted to the needs of multiple educational settings and multiple groups, from undergraduate students to faculty.

AN INTERNATIONAL CONVERSATION ABOUT EDUCATION ON DUAL USE ISSUES

The U.S. Department of State asked the IAP: The Global Network of Science Academies[6] to organize a workshop about ways to educate life scientists on dual use issues. Because research in the biological sciences is a global enterprise, there was a recognition that these discussions about education also must be international in scope. The group was challenged to survey the baseline of educational materials available, identify gaps, and consider opportunities to fill those gaps. The U.S. NRC convened a committee of experts to help organize the workshop and develop a consensus report, based both on insights offered at the workshop and additional data and research. Two other international scientific organizations, the International Union of Biochemistry and Molecular Biology and the International Union of Microbiological Societies, served as coconveners. Hosted by the Polish Academy of Sciences in November 2009, more than 60 participants from almost 30 countries attended the workshop, including life scientists, bioethics and biosecurity practitioners, and experts in

[1] Additional information and examples are available in the booklet *Understanding Biosecurity: Protecting against the Misuse of Science in Today's World*, from the NRC's Board on Life Sciences. Free copies of the booklet are available at http://dels.nas.edu/Materials/Booklets/Biosecurity1.

[2] For an overview of biosecurity issues, see *Understanding Biosecurity* at http://dels.nas.edu/Materials/Booklets/Biosecurity1.

[3] The text of the convention is available at www.unog.ch/bwc.

[4] This view is embedded, for example, in the U.S. National Strategy for Countering Biological Threats, which notes that "Life scientists are best positioned to develop, document, and reinforce norms regarding the beneficial intent of their contribution to the global community as well as those activities that are fundamentally intolerable. Although other communities can make meaningful contributions, only the concerted and deliberate effort of distinguished and respected life scientists to develop, document, and ultimately promulgate such norms will enable them to be fully endorsed by their peers and colleagues" (National Security Council, 2009, p. 8).

[5] A well-known example is the 1975 Asilomar Conference, convened following the development of gene-splicing techniques and the ability to manipulate and recombine DNA from different organisms. This was followed in 1976 by the National Institutes of Health–issued *Guidelines for Research Involving rDNA Molecules*.

[6] Formerly the InterAcademy Panel on International Issues; additional information may be found at www.interacademies.net.

the design and implementation of educational methods and materials.

The committee drew on commissioned papers, other background materials, and the discussions at the workshop to fulfill its charge. Two important themes arose from the workshop: First, to engage the life sciences community, these security issues would best be approached in the context of responsible conduct of research, that is, within the wide array of issues that the community addresses to fulfill its responsibilities to society. Second, education about dual use issues would benefit from the insights of the "science of learning," the growing body of research about how individuals learn at various stages of their lives and careers and the most effective methods for teaching them (e.g., NRC, 2000; Eshel, 2007).

CURRENT EDUCATIONAL MATERIALS, GAPS, AND POTENTIAL REMEDIES

The Baseline

To date, there has been a very limited introduction of education about dual use issues either as stand-alone courses or as components of other courses. However, in recent years such education has begun to increase in many parts of the world, primarily from the work of interested, committed individuals or specific projects;[7] there are a few cases of government support and encouragement. Most education about dual use issues occurs as part of general education about responsible conduct of research in basic life sciences courses or as part of training in biosafety or bioethics. A number of helpful and stimulating online resources are available, including case studies, video clips with involved scientists, and a role-playing game. For example, a discussion about the possible uses and misuses of RNA interference regulation with Greg Hannon (Cold Spring Harbor Laboratory) is sure to provoke discussion among today's students (see Box 1).

Educational Materials and Methods Needed

Given the diversity of fields, interests, and experiences across the life sciences, making dual use issues relevant to all students is a challenge. Further, it is important to reach out to other disciplines that are becoming an increasingly important part of life sciences research—physical sciences, mathematics, and engineering. The committee found that tailoring educational materials to suit the needs of these different groups could help reach wider audiences. Channels through which life scientists already receive exposure to issues of responsible conduct, like biosafety, bioethics, and research ethics, offer the greatest opportunity to reach the largest and most diverse range of students and professionals, the committee found. To reach students in different parts of the world, a critical need, more materials are needed in languages other than English. Providing such materials for students in their native languages will be particularly important in undergraduate settings or when training technical personnel. In addition to online resources, educational CDs or DVDs are needed for geographical areas that lack sustained Internet access or the capacity to take advantage of Web-based materials. Providing widespread access to materials that could be adapted for specific contexts or applications using open access repositories or resource centers would help implement and sustain education on dual use issues.

Box 1. Examples of Online Educational Resources

Case Studies in Dual-Use Biological Research, Federation of American Scientists (USA), www.fas.org/biosecurity/education/dualuse. The FAS project currently includes eight online modules focused primarily on case studies that exemplify potential questions about dual use issues that a researcher might encounter. The first module provides a brief introduction to dual use issues, including a history of bioweapons and efforts to control them. The other modules concentrate on real-life examples, including links to original scientific papers and videos of scientists discussing their research. Additional references and resources are included at the end of the modules. One of the case studies has been translated into French, another into Chinese, and a third is being translated into Russian. Although the modules are designed to be used as stand-alone resources, plans are being made to develop materials that make it easy for teachers to integrate the modules into existing courses.

The Life Sciences, Biosecurity and Dual Use Research: Dual Use Role Playing Simulation, University of Exeter (UK), University of Bradford (UK), and University of Texas at Dallas (USA), http://projects.exeter.ac.uk/codesofconduct/BiosecuritySeminar/Education/index.htm. This site provides resources and discussion questions that can be used for group activities with an instructor or leader. For example, the role-playing simulation provides an introductory PowerPoint lecture, information on 16 roles, and instructor notes. The exercise covers issues in research publication, funding, and oversight and discussion of relevant policy documents.

Educational Module Resource, Bradford Disarmament Research Centre (UK), National Defense Medical College (Japan), and Landau Network Centro Volta (Italy), www.dual-usebioethics.net. This site is primarily for teachers and will assist them in learning about dual use topics and provide materials for developing lesson plans to train scientists. The EMR is a major component of an ambitious education effort by researchers from the United Kingdom, Italy, and Japan. Much of the activity is carried out by the Bradford Disarmament Research Centre of the University of Bradford, which developed the EMR in cooperation with the Defense Medical College of Japan and the Landau Network Centro Volta. The EMR provides 21 sets of PowerPoint slides with links to associated briefing papers on major themes such as "The Threat of Biological Warfare (BW) and Biological Terrorism (BT) and the International Prohibition Regime," "The Dual-Use Dilemma and the Responsibilities of Life Scientists," "National Implementation of the BTWC," and "Building an Effective Web of Prevention to Ensure Benign Development." The material is available in English, Japanese, and Russian and is being translated into other languages. The slide sets are intended to provide resources that can be used for anything from a short module focused on a single topic to a complete course that could extend over a number of weeks. As the project website notes: "We would like to emphasize that the educational module resource is not a Teaching Module, rather it is a 'Module Resource.' Conscious that there is no one-size-fits-all approach, our educational module resource is designed to be 'modified and tailored to fit the requirements of different local educational contexts'" (www.dual-usebioethics.net) (accessed 20 June 2010).

[7] For example, the Bradford Disarmament Research Centre (see Box 1) is the center of a network of international partners to support the expansion of education about dual use issues.

Rather than developing additional websites for such materials, the development, dissemination, maintenance, and updating of such materials might be undertaken as an addition to the biological sections of the National Science Digital Library through the oversight of BioSciEdNet (BEN),[8] or by finding ways to link existing sites to BEN since a number of them are international and aimed at constituencies beyond education (such as training programs for biosafety professionals).

Furthermore, it will be important to develop methods that allow the life science and educational communities to review and edit educational materials, much like an appropriately monitored Wikipedia model, to ensure the materials remain accurate and up-to-date. The ability to share lessons learned and best practices as experience increases will be a key factor for success. Teaching strategies need to focus on clear learning objectives, emphasizing active learning, while allowing for local adaptation and application. To encourage expanded implementation by helping faculty develop the skills, abilities, and knowledge needed to teach dual use issues effectively, the best "train-the-trainer" programs explicitly seek to create a network among faculty to support and sustain each other.[6]

In addition to the specific barriers posed by a lack of awareness of and engagement in dual use issues among life scientists, there are a number of obstacles to *any* effort to implement new content or teaching methods that must also be addressed. These include competition for space in crowded curricula, pressures on students to focus on their research, and in some cases a general lack of support for teaching. Thus, rather than trying to cram yet more content into courses, educators need to consider carefully how various types of content can be integrated to improve learning (e.g., Labov and Huddleston, 2008), contributing to the broad range of learning goals for a course (e.g., Handelsman *et al.*, 2007).

THE COMMITTEE'S RECOMMENDATIONS

On the basis of the findings and conclusions described briefly above, the committee proposed the following specific actions to improve education on dual use issues:

- Develop an international open access repository of materials that can be adapted for the local context.
- Design methods for commenting on and vetting of materials (such as an appropriately monitored Wikipedia model) so that they can be improved by faculty, instructors, and experts in science education.
- Develop a range of methods to assess outcomes and, where possible, impact. These should include qualitative approaches as well as quantitative measures of learning outcomes.

NEXT STEPS AND HOW *CBE-LSE* READERS CAN CONTRIBUTE

There is a need to develop engaging, interactive materials suited to specific educational settings as well as to provide faculty with the resources and peer networks to support teaching and learning about dual use issues in the life sciences. *CBE-LSE* readers are encouraged to browse the materials described in Box 1 and to consider whether a discussion on dual use is a topic that should be integrated into education on scientific ethics and responsibility for undergraduate and graduate students, postdocs, and others. The NRC is working toward developing a faculty institute using dual use as an example of a topic that can be taught through interactive and outcomes-focused educational methods. The planned institute, which will have its first pilot in the Middle East in 2011, will be modeled on the Summer Institute on Undergraduate Education in Biology (Pfund *et al.*, 2009). It is hoped that it may serve as a model for future education initiatives in many parts of the world.

[8]The National Science Digital Library is accessible at http://nsdl.org. BEN is available at http://biosciednet.net/portal.

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